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Teaching ‘out of field’ in STEM subjects in Australia: Evidence from PISA 2015¹

Chandra Shah², Paul Richardson³ and Helen Watt⁴

Abstract: Science, technology, engineering and mathematics (STEM) education is a critical part of a modern education system. Motivating students to learn STEM subjects is however a challenge. Teachers have a critical role in motivating students but to do this effectively they need to have appropriate subject matter knowledge. Data from PISA 2015 show a substantial proportion of teachers in Australian schools are teaching STEM subjects ‘out-of-field’, which is that they do not have the qualifications to teach these subjects. This paper examines the effects of individual teacher characteristics and school context on of out-of-field teaching in STEM subjects. In particular, it examines the role of school autonomy and staff shortage in this. The results show these two variables have a strong association with out-of-field teaching, however, other factors either mediate or confound their effects. A full understanding of the results requires knowing the role of school funding and school budgets in out-of-field teaching. While we do not have direct measures of these in the data, we can infer their likely roles through the effects of other factors, such as school sector and education level of parents of students in the school, in the model.

JEL classification: C25, I22, I24, J23, J24

Key words: out-of-field teaching, teacher supply and demand, multi-level logit model

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Introduction

Science, technology, engineering and mathematics (STEM) education is a critical part of a modern education system (Marginson et al. 2013). The skills, knowledge and understanding that come from learning and enjoying these subjects at school prepare young people for further study, and for life and jobs in an increasingly technology-rich world that depends on science and technology for solutions to its many and varied problems.

Motivating students to learn STEM subjects is however a challenge. Apart from parents, teachers generally have a significant influence on a young person's personal and intellectual development. This influence becomes even more significant in STEM subjects, subjects that parents often claim to find difficult and which tend to be less positively represented in youth culture than other subjects (The Royal Society 2007). The role, quality and deployment of STEM teachers in schools thus becomes critical for ensuring all young students gain a sound understanding of the basic underlying scientific principles. Many countries, including Australia, have continuing concerns about whether sufficient numbers of well-qualified STEM teachers are coming through the system to meet future demand (Ingersoll & Perda 2010; The Royal Society 2007; Smith 2017; Productivity Commission 2012; OECD 2012, 2014; Office of the Chief Scientist 2014; Audit Office of New South Wales 2019; Queensland Audit Office 2013).

While there is almost universal belief that the quality of teachers matters for positive student outcomes, there is less consensus on which aspects of teacher quality matter most or even what a useful definition of teacher quality might be (Goe 2007). According to The Royal Society (2007):

“Classroom teachers need a wealth of professional and personal attributes, knowledge and skills to do their jobs well, and to work within their wider team. Enthusiasm for their subject, the ability to explain concepts and the creativity to make them relevant need to be backed up with skills in communication, class management and resource management as well as delivered within the context of a relationship with each and every one of their pupils. A good teacher has the ability to move their pupils forward in life by passing on their own knowledge, skills and passion for learning. An excellent teacher - one that is credited with inspiring life-changing decisions and is remembered forever - has an extra dimension of dynamism, dedication and imagination that make for the most stimulating lessons and effective engagement of young people.”

Teacher quality is multi-faceted. It includes teacher qualifications, experience and professional development, as well as personality characteristics such as teachers' career motivations and self-efficacy. Goe (2007) differentiates between *teacher* quality and *teaching* quality. Teacher quality includes teacher qualifications and other characteristics outlined above and provides indicators of who might be successful in the classroom (inputs). Teaching quality, on the other hand, is about what teachers *do* or *practice* in the classroom (process). Inputs influence process but both have the potential to influence teacher effectiveness, the value teachers add through their teaching to the learning outcomes of students.

One aspect of teacher quality that is concerning relates to teachers' subject matter knowledge, which is largely, though not exclusively, acquired in pre-service tertiary study usually lasting a minimum of two years. Seidel & Shavelson (2007) review of teacher effectiveness shows in-depth understanding of the content and the nature of the subject domain is pedagogically important for teachers if they are to create an environment in which students are able to engage in domain-specific learning activities. Teachers without the domain-specific expertise, especially in upper high school mathematics and

science, will find the task challenging even if they have high efficacy in their pedagogical skills acquired from teaching in another subject domain. In the literature, the term used to describe the teaching of subjects for which a teacher does not have subject-specific qualifications is 'out-of-field teaching'. An example of this is when a trained teacher teaches mathematics when they are qualified to teach only science. Clotfelter, Ladd & Vigdor (2010) show significant positive effect of subject-specific credentials, particularly in mathematics and English, on student achievement.

Despite the obvious theoretical justification and the existence of some empirical evidence pointing to the ill effects of out-of-field teaching on student learning, the practice of out-of-field teaching is significant across many countries. The most extensive documentation of the problem relates to the practice in the United States (Ingersoll & Gruber 1996; Ingersoll 1999, 2002, 2003, 2004, 2005, 2019; Seastrom et al. 2004; Morton et al. 2008; Hill & Gruber 2011; Hill, Stearns & Owens 2015; Nixon, Luft & Ross 2017). McConney & Price (2009), Weldon et al. (2014) and Weldon (2016) provide indications of the extent of the practice in Australia and Zhou (2014) provides a cross-country perspective.

While quite a few studies document the extent of out-of-field teaching in different countries, not many explore the institutional, school and teacher factors associated with the practice. The exceptions are Ingersoll (1999,2004) and Zhou (2014). A common, and often repeated, explanation given for out-field teaching is inadequate quality and quantity of teachers, but the evidence showing this link seems to be weak. Ingersoll (2004) proposes that school organisational practices best explain out-field-teaching in the United States and provides some evidence for this effect.

This study uses data for Australia from the 2015 Programme for International Student Assessment (PISA) survey to investigate out-of-field-teaching practices in STEM subjects in secondary schools. PISA 2015 was special in the sense that for the first time in its history it included a nationally representative survey of teachers and principals in the participating schools. A common identifier allows the linking of data at the school level from the three surveys. This allows the creation of a rich dataset to investigate teacher-level and school context factors associated with out-of-field teaching at Year 10 in Australia for the first time. As out-of-field teaching is generally more common at junior levels and less at senior levels, the data for Year 10 provide reasonable representation of the average across all levels.

This report shows staff shortages are associated with increased risk of out-of-field teaching but increase in school autonomy is associated with decreased risk. However, there are a number of factors that confound and mediate these relationships, making the pathways linking the various factors to out-of-field teaching complex. The study identifies several risk factors for out-of-field teaching and calculates the associated predicted probabilities. Some of these factors are the number of subjects a teacher teaches, the number of subjects a teacher is qualified to teach, age, employment contract, professional development and experience in terms of the number of schools a teacher has worked in, school location, state or territory where the school is and school size.

Structure of the paper

In the next section, we summarise the previous literature on out-of-field teaching. The third section contains a description of the PISA 2015 data. The fourth section describes the model for estimating the probability of teaching out-of-field for a teacher teaching STEM subjects. In the fifth section we present and discuss the results. The final section contains the conclusion.

Literature review on out-of-field teaching

International research

United States

Most international research on out-of-field teaching emanates from the United States and goes back several decades (National Commission on Teacher Education and Professional Standards 1965; Gardner 1983; Robinson 1985; Council for Basic Education 1986; Brodbelt 1990). The research has been stimulated by concerns about equality in education, which has been a challenge for education policy for a long time, and still continues to be in the United States as well as in many other countries (e.g. see Coleman et al. (1966); Kozol (1991); Teese et al. (2007)). Research shows that students in most need, those from poor, minority and disadvantaged backgrounds, are often taught by the least qualified teachers and this has consequently resulted in poorer educational outcomes for these students (e.g. see Darling-Hammond (1987); California Commission on the Teaching Profession (1985)). Precisely because of this, access to qualified teachers and quality teaching has been central in the debate over equality of educational opportunity for all (Ingersoll & Gruber 1996).

In 2001, the U.S Congress passed the *No child left behind Act*. The Act included specific incentives for states to eliminate out-of-field teaching by requiring ‘highly qualified’ teachers in all core academic classes and by asking district and state leaders to attest that low-income and minority students are not taught disproportionately by out of-field teachers (The Education Trust & with analysis by Ingersoll 2008). Nowadays almost all teachers in public schools in the United States have to have certification in the subject they wish to teach. Certification generally requires a teacher to have a major or minor in the subject they wish to teach at a bachelor’s or higher degree level. The degree can be an academic or an education degree. The certification standards are however state-based and tend to vary widely and often change (Tryneski 1997; Kaye 2016). According to Ravitch (2003) less than 40% of teachers have a major in any academic field.

There are varying views on how to define out-of-field teaching empirically. Often the measure selected for empirical work depends on the type of data that is available. Ingersoll (1999) uses a minimalist concept and defines it as when a teacher lacks either a major or a minor (in both academic and education degrees) in the subject they are teaching.

Seastrom et al. (2004) with access to data from the *Schools and Staffing Survey (SASS)*⁵, a national survey of elementary and secondary teachers in the United States conducted by the National Centre for Education Statistics (NCES), defines out-of-field teaching in the context of:

1. a teacher’s main teaching assignment (M1)
2. each subject a teacher teaches (M2)
3. the proportion of classes taught out-of-field (M3)
4. the proportion of students taught by out-of-field teachers (M4).

⁵ The frequency of the survey is irregular, with data missing for a number of years since the inception of the survey in the mid-1980s. In 2012, the National Centre for Education Statistics redesigned the survey calling it the National Teacher and Principal Survey.

M1 is the most narrowly defined a teacher’s only main teaching assignment is accounted. In terms of the magnitude of the estimate of out-of-field teaching, using M2 will generally yield the largest estimate and using M1 the smallest. Using M3 and M4 will yield estimates that are in between these two.

Notwithstanding the difficulties due to breaks in data collections and changes in the survey questionnaire over time, table 1 provides a summary of out-of-field teaching in the United States from 1987-88 to 2011-12. The break in the series in 2003-04 is a result of the change in definition of out-of-field teaching. Prior to this period, teachers are out-of-field teaching if assigned to teach subjects for which they had neither a minor nor a major. From 2003-04, they are out-of-field teaching if assigned to teach subjects for which they did not have a major. This is the most likely reason for the sharp increase in the out-of-field teaching rates from 2003-04. The table also illustrates an aggregation problem in science. A teacher with a major or minor in biology who is assigned to a chemistry class is teaching out-of-field in the physical sciences, and yet the same teacher is actually teaching in-field in science. Thus, out-of-field teaching rates will generally be lower in science than in any of its sub-domains. Overall, about 20% of teachers are teaching out-of-field in mathematics, 33% in the life sciences and 50% in the physical sciences. Despite the passing of the *No Child Left Behind Act* of 2001, the rates of out-of-field teaching in mathematics and science do not seem to be improving.

Table 1 Out-of-field teaching in high school grades (9-12) in the United States, 1987-88 to 2011-12

	Mathematics	Science		
		All	Biology/life science	Physical science
<hr/> % teachers out-of-field by subject taught (M2) <hr/>				
1987-88	28.0	18.1	30.8	51.8
1990-91	28.3	15.5	32.8	53.0
1993-94	27.7	17.0	30.0	52.1
1999-00	28.0	20.1	36.8	51.3
<hr/> % of classes taught out-of-field (M3) <hr/>				
1987-88	18.2	13.0	26.9	47.2
1990-91	20.0	10.8	30.6	47.4
1993-94	20.2	11.6	25.0	46.2
1999-00	20.5	15.0	33.0	46.0
2003-04	25.5	16.3	22.6	49.7
2007-08	29.6	18.3	27.1	56.8
2011-12	32.0	22.4	29.0	58.3
<hr/> % of students taught out-of-field (M4) <hr/>				
1987-88	15.6	12.6	25.8	47.0
1990-91	18.0	9.0	28.6	46.4
1993-94	18.1	9.9	24.0	45.1
1999-00	18.1	13.6	31.3	45.9
2003-04	23.7	14.7	21.5	49.6
2007-08	27.4	17.2	24.9	56.7
2011-12	29.8	21.2	28.3	58.2

Note: The definition of out-of-field teaching for 1987-88 to 1999-00 is teaching without a major or minor in the subject and for 2003-04 to 2011-12 it is teaching without a major in the subject. The change in the definition probably accounts for a significant part of the increase in the rates. Furthermore, there was also a change in the design of the SASS in 2003-04. The data relate to public schools, both traditional and charter.

Source: Seastrom et al. (2004); Morton et al. (2008); Hill & Gruber (2011); Hill, Stearns & Owens (2015).

Using data, also from SASS, Ingersoll (1999) shows the out-of-field teaching rates in mathematics and science are much higher among teachers:

- with less than five years of experience
- in schools with high proportions of students from high poverty families
- in small schools
- in private schools
- teaching low-track classes.

These results suggest the assignment of teachers to classes could be a factor exacerbating inequality in education that already exists because of a range of other socio-economic factors.

While many reports have documented the extent of out-of-field teaching, Ingersoll (2004) is one of the first to actually investigate the reasons behind the prevalence of this practice. He proposes two perspectives to explain out-of-field teaching. The first, which he labels the deficit perspective, suggests that the source of the problem of out-of-field teaching is inadequate quality and quantity of teachers. In other words, it is because of poor training of teachers (teacher training programmes lack rigour, breadth and depth) and a shortage of teachers (because of increasing student enrolments and the ageing teacher workforce). In the first instance, the suggested remedy is to improve the training system, and in the second instance, it is to increase recruitment of new teachers. As most teachers already have at least a bachelor's degree and have full certification, Ingersoll dismisses the 'inadequately trained teachers' hypothesis. The second perspective, which Ingersoll labels the organisational perspective, suggests out-of-field teaching reflects the organisation of schools and the employment and utilisation of teachers once on the job. A full understanding of the problem of out-of-field teaching thus requires investigating the management practices of schools, especially in relation to teachers.

Ingersoll's empirical analysis shows a lack of support for the deficit hypothesis. The results from multiple regression⁶ show schools with recruitment difficulties were just as likely to assign teachers to out-of-field classes as schools without recruitment difficulties. Thus, recruiting large numbers of new teachers or mandating additional teacher training will not solve the problem of underqualified teaching if schools continue to assign large numbers of teachers to out-of-field teaching.

To test the organisational hypothesis, Ingersoll adds a number of organisational variables to the regression model that already includes variables about school context and teacher recruitment and vacancies. The results show significantly less out-of-field teaching in schools with policies requiring new hires to have a major or a minor in the fields they are to teach. They also show significantly more out-of-field teaching in schools that cover vacancies with less than fully qualified staff; assign teachers of another subject or grade level to teach the class; assign administrators or counsellors to teach the class; or use short-term or long-term substitutes. These results are however unsurprising because almost by definition schools adopting these strategies will have such outcomes. The analysis also shows significantly less out-of-field teaching in schools in which teachers have high ratings for the school leadership. Increasing the average class size leads to significantly less out-of-field teaching. The average class size has a significant negative effect on out-of-field teaching, but there must be structural and regulatory factors limiting the extent to which this strategy is practically applicable for reducing out-of-field teaching.

⁶ Ingersoll estimates a two-level mixed effects multiple regression model with the percentage of a teacher's daily classes taught out-of-field as the dependent variable. The two levels are teachers and schools but the model does not include any teacher-level variables. As the response variable takes the values between zero and one and also because there is a district-level explanatory variable, an alternative specification could be a three-level fractional response model.

As Hoxby (2004) rightly points out, Ingersoll's study is at best suggestive or exploratory, particularly in relation to the effects of the school context and organisational variables, and to infer causality from the analysis is fraught with difficulties. For example, it is unclear what aspects of principals' behaviour relate to how they assign teachers to classes and whether teachers' attitudes towards principals are a cause or an effect of this. Teachers may highly rate principals who avoid assigning teachers to out-of-field classes but may poorly rate principals who due to circumstances beyond their control cannot avoid assigning teachers to out-of-field classes.

Hoxby's review of Ingersoll's paper also identifies possible bias in the results due to omitted variables. For example, the result for school location, a contextual, exogenous variable, suggests rural schools have significantly less out-of-field teaching than urban schools. This is counterintuitive because one would think schools in sparsely populated areas would find it hardest to ensure in-field teaching of all their classes. Similarly, the results suggest large districts have more out-of-field teaching, which is again counterintuitive because large districts theoretically have more flexibility to reallocate teachers to meet subject area demands.

Hoxby (2004) proposes measurement error in teachers' areas of skills and knowledge as a possible alternative explanation of out-of-field teaching. She suggests that it is possible that teachers have the skills and knowledge to teach a particular subject but lack formal qualifications. While this may explain out-of-field teaching in lower grades, it is not a convincing explanation in higher grades where subject knowledge is more critical. She also conjectures that perhaps out-of-field teaching occurs because it is not harmful for student outcomes. We discuss this further later in this section.

In summary, Ingersoll's study and Hoxby's review of it illustrate the difficulties in inferring causality when using observational data. A lack of evidence supporting the deficit hypothesis in explaining out-of-field teaching is an important finding. The evidence supporting the organisational hypothesis is however at best suggestive. Some of the counterintuitive results, probably due to omitted variables, demand further discussion.

Teaching and Learning International Survey (TALIS) data, 2008

Zhou (2014) uses data from the 2008 *Teaching and Learning International Survey* (TALIS) to analyse out-of-field teaching in mathematics and science at the lower secondary level in public schools across 15 countries.⁷ The United States is not in the sample, which is unfortunate because it means we cannot validate the results discussed in the previous section.⁸ Zhou adopts the school-level measure of out-of-field teaching: the percentage of mathematics and science teachers teaching out-of-field in the school. Zhou finds the average rate of out-of-field teaching of 10.3% across all countries—from 2% in Hungary to 15.7% in Brazil.⁹ While these estimates vary significantly across countries, they are substantially lower than for the United States reported above.¹⁰ The TALIS teacher sample, however, has a narrower scope, and excludes substitute, emergency, and occasional teachers, who are generally more likely to be out-of-field teaching.

⁷ In his original study, Zhou uses data for 21 countries (Zhou 2012).

⁸ The 2003 TIMSS data show out-of-field teaching in mathematics in the United States was 29.7%, in Australia 26.4%, in Japan 12.1% and in 12 other high-achieving countries 11.1% (Akiba & LeTendre 2009).

⁹ A shortcoming of this study is that the analysis is not by subject. Other studies, discussed earlier, show large differences in out-of-field teaching rates between mathematics and science, and one of the main problems drawing comparisons between these two fields is the aggregation problem in science.

¹⁰ Zhou suggests measurement error as a possible explanation for the large differences in the rates, and cites the misinterpretation of the question relating to teachers' formal education and training as a possible cause.

Zhou also rules out inadequate training of teachers as a source of out-of-field teaching, as most teachers are qualified to at least the bachelor level, and finds little evidence to support the deficit perspective in explaining out-of-field teaching. He finds some support for the organisational perspective in the terms of school autonomy in hiring teachers. Schools with higher levels of autonomy had significantly less out-of-field teaching. The effect however becomes small and insignificant in a model that includes country fixed effects, which means country fixed effects are important confounding factors. From this one could conclude that school autonomy is correlated with the unobserved characteristics of the country, and that the influence of school autonomy is mediated through the country fixed effects.¹¹ Zhou also reports strong associations between out-of-field teaching and a number of school context variables. In contrast to Ingersoll, he finds rural schools have significantly more out-of-field teaching than urban schools. Out-of-field teaching also increases with the proportion of teachers on temporary contracts in the school.

Australian research

A few studies have investigated the problem of out-of-field teaching in Australia. Weldon et al. (2014) defines out-of-field teaching as when a teacher teaches a subject for which they have less than a second year of tertiary study, either in an academic or education degree. Using data on secondary school teachers from the 2013 *Staff in Australia's Schools* (SiAS), a national survey of teachers, they estimate out-of-teaching rates of 19.6% for mathematics, 8.5% for biology, 9.1% for chemistry, 20.5% for physics and 17.2% for general science.¹² Out-of-field teaching rates are higher for teachers in grades 7-10 (26%) than for teachers in grades 11-12 (15%). Also, out-of-field teaching rates are higher among teachers with less than five years of teaching experience and among those teaching in rural and regional areas (Weldon 2016). Furthermore, they vary by sector and jurisdiction. McKenzie et al. (2014), using data from the same survey, report 60% of principals having staff shortages. Of these, a third nominated assigning teachers to out-of-field classes as a strategy to deal with the problem (39.1% in government schools, 35.7% in Catholic schools and 15.2% in independent schools). Other major strategies principals use includes recruiting teachers not fully qualified in the subject area of need (24.4% in government schools, 14.3% in Catholic schools and 7.6% in independent schools) and recruiting retired teachers on short-term contracts (30.2% in government schools, 11.9% in Catholic schools and 6.3% in independent schools).

McConney & Price (2009) use data from a survey of teachers in Western Australia to estimate out-of-field teaching rates.¹³ They estimate an out-of-field teaching rate of 29% among secondary school teachers in Western Australia, with disproportionately higher numbers in the independent and Catholic school sectors than in the government sector. Schools in non-metropolitan areas of the state also have higher rates of out-of-field teaching.¹⁴ Given the small sample size and high non-response, these estimates lack reliability.

Qualitative studies can be useful in understanding the problems of out-of-field teaching at the individual teacher or school level. For example, they can provide clues about the effect of out-of-field teaching on

¹¹ Country fixed effects account for all across-country variation and, therefore, what remains is the within-country variation. This means that the identification of the estimated school autonomy in hiring teachers comes from the differences in the outcomes between schools in the same country who have different levels of autonomy in this respect.

¹² With a response rate of less than a third, one needs to exercise caution when interpreting the estimates based on these data.

¹³ Out-of-field teaching occurs when a teacher teaches a subject for which they do not have a major or minor in their tertiary degree qualification. Altogether 535 teachers responded to the survey, which represents a response rate of less than a quarter for the survey. Of these only 198 are secondary school teachers.

¹⁴ Altogether 535 teachers responded to the survey, which represents a response rate of less than a quarter for the survey. Of these only 198 are secondary school teachers.

teacher identity and their well-being as well as on the rest of the school community (du Plessis 2012; Hobbs 2013a, 2013b). Such data are often unavailable from large surveys. By their nature, however, these studies cannot provide information about the extent of out-of-field teaching in Australian schools; and they are limited in terms of generalisability of the results.

Prince & O'Connor (2018) assume out-of-field teaching in mathematics is because of a national shortage of mathematics teachers. They provide back of envelope calculations of the number of teachers required to reduce the number of out-of-field classes from one in every three, as estimated from the SiAS survey, to one in every six over five years. To reach this goal would require an additional 6000 new graduates and 2200 current teachers to retrain, and to reduce the ratio to one in every ten would require the same number of new graduates but an additional 1400 current teachers to retrain. These calculations assume an out-of-field teaching rate of 30%, a retirement rate of 5% and 18% of class hours devoted to mathematics.

Effect of out-of-field teaching on student outcomes

Out-of-field teaching is an aspect of teacher quality and, therefore, has the potential to affect teaching effectiveness. All other things equal, teachers with domain-specific expertise (qualifications) should be more effective than should teachers without such expertise. This will be more so in the upper high school grades than in the lower grades. Some aspects of out-of-field teaching can be more detrimental for learning outcomes than others. For example, the consequences of an English teacher taking a mathematics class could be more serious than a physics teacher taking the same class because there is more of an overlap in the specific subject domain knowledge required for teaching mathematics and physics than there is for teaching mathematics and English. Furthermore, while a specialist physics teacher may have sufficient mathematics knowledge to be able to teach mathematics at a junior level, it may be insufficient to teach at a senior level, without affecting effectiveness. Similarly, a teacher with a biology major may cope with junior secondary science but may find it difficult to teach senior chemistry or physics if asked to. While qualifications in the subject matter on their own do not guarantee qualified teachers, nor quality teaching, they are however necessary, especially for building further knowledge and skills through ongoing professional development activities¹⁵ (Ingersoll & Gruber 1996).

In an attempt to explain the high rates of out-of-field teaching in the United States, Hoxby (2004) and Skilbeck (2003) suggest that perhaps out-of-field teaching does not have an adverse effect on student outcomes. This may be true if the same students do not have out-of-field teachers over a prolonged period and in the same subject. The effect of an occasional out-of-field class could be counteracted and not result in significant adverse outcomes for students.

Hoxby argues that there is a lack of evidence, from carefully evaluated policy experiments, showing out-of-field teaching has, in fact, an adverse effect on student outcomes. Hoxby's proposition is clearly the antithesis of what theory predicts. While the empirical evidence in support of the theory is not strong yet, there is already evidence, especially in mathematics, which shows the positive effects of in-field teaching. Two main challenges for empirical work are lack of linked student-teacher-school longitudinal data and robust and valid instruments for measuring student outcomes.

¹⁵ Professional development is particularly important for STEM subjects because of the rapid change in technology and the associated generation of new knowledge in these subjects.

Following a review of the literature from the 1980s and early 1990s, Ingersoll & Gruber (1996) find moderate but consistent evidence that teacher subject knowledge and teaching skills are important predictors of both teaching quality and student outcomes. A review by Wayne & Youngs (2003) also finds evidence of positive learning outcomes but only for students in high schools taught by teachers with mathematics qualifications. Goe (2007) comes to a similar conclusion following a review of the post-2000 literature and Hill, Rowan & Ball (2005), Baumert et al. (2010) and Blömeke & Delaney (2012) provide further evidence for the positive effect of teacher quality on student achievements in mathematics. Clotfelter, Ladd & Vigdor (2010) provide the most robust evidence so far of the positive effect of subject-specific credentials, especially in mathematics and English, on student achievement in high schools in North Carolina.¹⁶ They show the observed uneven distribution of teacher credentials by the socioeconomic status and race of students contributing to the unequal access to high quality education for minority students and those with less well-educated parents, which in turn contributes to lower achievement among these groups.

¹⁶ They use longitudinal data to estimate a model that includes fixed effects to minimise the bias due to non-random distribution of students and classrooms in schools.

Data description

This study uses data from the 2015 Programme for International Student Assessment (PISA). PISA is a triennial international survey, managed by the OECD, to evaluate education systems by testing the skills and knowledge of 15-year-old students. In 2015, and for the first time, as part of the PISA survey, 19 countries distributed an optional questionnaire to teachers, whose main activity in schools is student instruction, and another to principals. Australia was one of 72 participating countries that administered the optional surveys. The data include a common school identifier, which allows the linking of data from the student and principal surveys to the data from the teacher survey.

The survey employs a two-stage stratified design, with the first stage involving the sampling of schools in which 15-year-old students enrol and the second stage the sampling of students within these schools. The teacher survey consists of separate random samples of science teachers (science, physics, physical science, chemistry, biology, human biology, environmental science, agriculture, horticulture, forestry) and non-science teachers from the respective eligible populations in each sampled school.¹⁷ The reason for the separate samples is that PISA 2015 had a particular focus on science teaching. These two groups of teachers are administered separate questionnaires. Although there are a number of common questions in the two questionnaires, the science teachers' questionnaire has specific questions relating to science teaching practice. Teachers eligible to take part in the survey include those who were currently teaching, had taught before, or will/could teach in the future at year 10 level, the modal grade for 15-year-old students. Potentially this represents a broad spectrum of teachers.

The teacher questionnaire has questions on teachers' background; initial education; professional development; teaching practices; and subjects they are teaching and qualified to teach. The principal survey has questions on school organisation, the quality of the school's human and material resources, decision-making processes, instructional practices, and school and classroom environment. Important questions in the principal survey in the context of this study relate to school autonomy and staff shortage. The student survey also provides contextual information about the school relating to its student population and that of students' parents.

PISA 2015 includes a number of variables derived from responses to multiple questions by students, teachers and principals. Three different kinds of derived variables are:

- simple questionnaire indices constructed through the arithmetical transformation or recoding of one or more items
- derived variables based on item response theory (IRT) scaling
- composite scores (OECD 2017).

Most derived variables are standardised to an OECD mean of zero and standard deviation of one. The analyses in this report include a number of these variables.

¹⁷ OECD (2017) provides full details of the sampling design for both the student and teacher surveys for PISA 2015, including the stratification variables. PISA also provides a set of student weights to account for sample design and non-response among schools and students. Weights to account for the sample design and non-response among teachers are however unavailable. Teacher weights used in this report are an adaptation of the student weights. In the calculation, we first sum the student weights for each school. Next, we uniformly distribute 35.1% of the total weight among science teachers in the school who responded to the survey and 64.9% among non-science teachers. These ratios reflect overall teacher responses to the survey and approximates the sampling design for selecting the two groups of teachers—generally, ten teachers of science and fifteen teachers of non-science subjects.

Definition of out-of-field teaching in STEM subjects

The survey does not contain a specific question to determine whether a teacher is teaching out-of-field or not, but from the following question it is possible to infer this:

Were any of the following [subjects] included in your teacher education or training programme or other professional qualification and do you teach them to Year 10 in the current school year?

The subjects are: reading, writing and literature [English]; mathematics; science¹⁸; technology¹⁹; social studies; modern foreign languages; ancient languages (e.g. Latin); arts; physical education; religion and/or ethics; and practical and vocational skills. Of these, mathematics, science and technology are STEM subjects. For each subject, a teacher responding to the survey provides answers to two questions: 1) are they currently teaching the subject at Year 10 level; and 2) are they qualified to teach the subject. Thus, we can define out-of-field teaching as when a teacher teaches a subject that was not part of their teacher education or training programme or other professional qualification. From the data, we can identify all subjects a teacher teaches at Year 10 level, whether they are being taught out-of-field or in-field, but not the number of classes they teach in each subject.

The survey does not differentiate science by its sub-domains. Science includes not only general science but also the sub-domains of physics, physical science, chemistry, biology, human biology, environmental science, agriculture, horticulture and forestry. This means we cannot identify between a teacher teaching, for example, physics from one teaching chemistry. As a result, out-of-field teaching in science will be underestimated. For example, a teacher with qualifications to teach only chemistry and biology but is teaching physics will not be counted as teaching out-of-field. Such aggregation bias may also affect technology and social studies²⁰.

STEM teachers

The Australian PISA 2015 student sample consists of 14 530 students in 758 schools and the school survey contains responses from 738 principals.²¹ The teacher sample has 16 234 teachers, but only 11 715 responded to the questionnaire, a response rate of 72.2%. Of these, 8898 teachers, in 732 schools, taught one or more subjects at Year 10 level in the year when the survey was conducted.

Table 2 shows that more than half of all teachers taught one subject only. Most teachers however taught no more than three subjects, although a small number of teachers indicate teaching quite a large number of subjects, which we assume is due to either measurement or coding error and, therefore, we discard observations for teachers who are teaching seven or more subjects.

¹⁸ Science includes science, physics, physical science, chemistry, biology, human biology, environmental science, agriculture, horticulture and forestry.

¹⁹ Technology is about orientation in technology, including information technology, computer studies, construction/surveying, electronics, graphics and design, keyboard skills, word processing, workshop technology and design technology.

²⁰ The PISA teacher questionnaire defines social studies to include community studies, contemporary studies, economics, environmental studies, geography, history, humanities, legal studies, studies of their own country, social sciences, ethical thinking and philosophy.

²¹ Before linking the data from the three surveys, we impute missing values for a certain number of relevant variables in each survey.

Table 2 Teachers by number of subjects taught

Number of subjects taught	Number of teachers			
	Unweighted		Weighted	
	n	%	n	%
1	4926	55.4	4964	55.5
2	2270	25.5	2315	25.9
3	897	10.1	852	9.5
4	412	4.6	406	4.5
5	205	2.3	204	2.3
6	94	1.1	100	1.1
7	45	0.5	43	0.5
8	31	0.3	41	0.5
9	12	0.1	14	0.2
10	5	0.1	6	0.1
11	1	0.0	1	0.0
Total	8898	100	8947	100

Source: PISA 2015.

Table 3 shows the total numbers of teachers teaching each subject and the proportion of that teaching the subject out-of-field. Of the 15 394 teacher-classes, 15.5% are taught out-of-field. This is comparable to 15% out-of-field teaching rate in years 11 and 12 that Weldon (2016) reports. Out-of-field teaching varies from 6.2% in the sciences to 63.4% in ancient languages. The low rates in science and social studies are because sub-domains of these subjects are unidentifiable in the data. The estimates for English, mathematics and modern languages are comparable to Weldon's estimates.

Table 3 Out-of-field teaching by subject

Subject	Number of teachers	% teaching out-of-field
English	2605	16.1
Mathematics	2204	20.5
Science	3011	6.2
Technology	1746	21.0
Social studies	1510	12.2
Modern languages	330	14.5
Ancient languages	22	63.4
Arts	1029	6.6
Physical education	1050	12.8
Religion/ethics	616	29.7
Vocational education	1271	26.4
Total ¹	15394	15.5

Note: Weighted estimates. Excludes teachers teaching seven or more subjects.

Teachers teaching multiple subjects are in multiple rows. Includes 319 teachers who did not provide information on the subjects they are qualified to teach.

Source: PISA 2015.

Table 4 shows teachers by the subject(s) they are currently teaching at Year 10 level and the subjects they are qualified to teach. In this table, all non-STEM subjects are in one group as are all non-STEM qualifications. For 163 (1.8%) teachers, no information is available about the subjects they were qualified to teach. Most teachers have qualifications in multiple fields, with only a minority qualified to

teach just one subject. Many teachers (67.7%) are qualified to teach a combination of both STEM and non-STEM subjects, with about 25.4% qualified to teach only STEM. Altogether:

- 37.5% are qualified to teach mathematics
- 46.6% are qualified to teach science
- 28.4% are qualified to teach technology
- 72.7% are qualified to teach non-STEM subjects.

About 59.5% of teachers are teaching at least one STEM subject—37.3% only STEM subjects and 22.2% a combination of STEM and non-STEM subjects. About half of all teachers teaching STEM teach only one STEM subject—16.6% only mathematics, 27.8% only science and 4.8% only technology. About 3.9% of teachers teaching STEM have only non-STEM qualifications and further 1.9% do not have any qualifications. On the other hand, 16.7% of those qualified in some STEM field are not teaching STEM subjects at Year 10 level but are instead teaching non-STEM subjects. However, almost all these teachers also have on-STEM qualifications. Table 5 shows, of the 997 such teachers, 37.9% are teaching English, 25.7% social studies and 29.3% physical education. Table 6 shows that a disproportionately small number of these teachers are in New South Wales.

Table 4 Teachers by subject(s) currently teaching and subject(s) qualified to teach

	Subject(s) qualified to teach																Total
	Mathematics	Science	Technology	Mathematics & science	Mathematics & technology	Science & technology	Mathematics, science & technology	Mathematics & non-STEM	Science & non-STEM	Technology & non-STEM	Maths, sci & non-STEM	Maths, tech & non-STEM	Sci, tech & non-STEM	Maths, sci, tech & non-STEM	Non-STEM	None	
Mathematics	234	25	1	192	34	4	34	118	23	0	68	39	3	62	21	14	872
Science	6	553	1	332	0	23	66	4	183	0	148	4	34	82	10	19	1464
Technology	3	2	84	2	10	6	9	3	2	68	3	9	6	23	14	9	254
Mathematics & science	3	42	1	210	0	1	24	1	22	13	62	1	4	45	6	13	449
Mathematics & technology	2	2	2	4	31	0	8	0	4	2	1	13	1	8	1	0	79
Science & technology	0	13	2	8	0	24	13	1	7	3	5	0	5	23	0	1	103
Mathematics, science & technology	0	4	0	7	0	7	33	1	0	0	6	1	0	14	4	3	80
Mathematics & non-STEM	3	1	0	3	0	0	2	51	10	8	29	7	2	26	26	13	181
Science & non-STEM	1	10	0	13	0	4	1	5	181	0	60	4	18	46	9	4	355
Technology & non-STEM	1	3	15	3	3	2	1	4	8	436	8	44	52	77	86	10	755
Mathematics, science & non-STEM	0	20	0	18	0	2	2	8	29	3	72	4	2	24	11	3	196
Mathematics, technology & non-STEM	0	1	0	3	1	0	1	10	0	23	0	35	4	21	9	2	112
Science, technology & non-STEM	0	0	0	1	0	5	2	1	10	0	8	3	55	38	4	2	129
Mathematics, science, technology & non-STEM	0	7	0	19	0	4	7	3	16	10	23	1	11	123	5	6	234
STEM	253	684	108	813	80	82	202	209	493	567	493	165	197	613	206	99	5264
Non-STEM (STEM qualified)	6	6	7	4	1	0	2	153	212	249	120	41	34	162	0	0	997
Non-STEM (non-STEM qualified)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2515	65	2579
Total	260	690	115	816	80	82	204	362	705	816	613	206	231	775	2721	163	8841

Note: Weighted estimates. Excludes teachers teaching seven or more subjects.

Source: PISA 2015.

Table 5 Teachers with STEM qualifications teaching only non-STEM subjects

Subject	Number of teachers	%
English	378	37.9
Social studies	256	25.7
Modern languages	63	6.3
Ancient languages	3	0.3
Arts	147	14.7
Physical education	292	29.3
Religion/ethics	99	9.9
Vocational education	146	14.7
Total ¹	997	

Note: Weighted estimates. Excludes teachers teaching seven or more subjects.

The percentages in the third column add to more than 100 because some teachers teach more than one subject and, therefore, are in multiple rows.

Source: PISA 2015.

Table 6 Teachers with STEM qualifications teaching only non-STEM subjects by state

Subject	Number of teachers	%
New South Wales	189	18.9
Victoria	271	27.2
Queensland	236	23.6
South Australia	94	9.4
Western Australia	135	13.5
Tasmania	39	3.9
Northern Territory	11	1.1
Australian Capital Territory	23	2.3
Total	997	100.0

Note: Weighted estimates. Excludes teachers teaching seven or more subjects.

Source: PISA 2015.

Teacher characteristics

The PISA 2015 data include demographic, educational and job information on teachers. It also includes teachers' self-assessment of their profession and their current job environment. Job satisfaction and satisfaction with teaching are derived variables. Their construction uses teachers' responses about their jobs and profession, on a four-point Likert scale, to a number of statements. The four statements for the first variable are:

- I enjoy working at this school.
- I would recommend my school as a good place to work.
- I am satisfied with my performance in this school.
- Overall, I am satisfied with my job.

For the second variable, the four statements are:

- The advantages of being a teacher clearly outweigh the disadvantages.
- If I could decide again, I would still choose to work as a teacher.

- I regret that I decided to become a teacher.
- I wonder whether it would have been better to choose another profession.

Table 7 compares the characteristics of in-field and out-of-field teachers by STEM subject. The data represent information on 5234 teachers, 2225 teaching mathematics, 3006 science and 1744 technology. As some teachers teach more than one subject, the total across subjects is larger than the actual number of teachers in the sample. For the two continuous variables, 'satisfaction with job' and 'satisfaction with teaching', the table includes their means and standard deviations. The specific categorisation of age and experience variables is to capture the treatment and experience of early career teachers.

The table shows, for example, in mathematics, 53.9% of out-of-field and 47.3% of in-field teachers are female. About 20% of teachers teaching out-of-field in mathematics teach no other subjects. The corresponding proportions in science and technology are 23.7% and 10.6%, respectively. Interestingly, a small proportion of teachers (97 teachers) are not qualified to teach any subject, let alone a STEM subject. The cause of this is most likely either missing values or coding errors and we will exclude these teachers' records from the analyses in the next section. Most teachers are however qualified to teach more than one subject, be it a STEM or non-STEM subject, although they are relatively fewer among those teaching out-of-field.

In-field and out-of-field teachers teaching mathematics and science are different in a number of characteristics. For example, relatively more out-of-field teachers are on temporary contracts and they have relatively less experience. In-field and out-of-field teachers teaching technology, on the other hand, have similar characteristics, except that a relatively smaller proportion of out-of-field teachers have completed more than three professional development activities.

Teachers teaching out-of-field in mathematics and technology are, on average, less satisfied with teaching as well as their current job than those teaching in-field. With respect to those teaching science, out-of-field teachers are less satisfied with teaching but more satisfied with their current job than in-field teachers, which is a little perplexing.

Table 7 Personal characteristics of in-field and out-of-field teachers by subject (%)

Characteristic	Subject								
	Mathematics			Science			Technology		
	In-field	Out-of-field	Total	In-field	Out-of-field	Total	In-field	Out-of-field	Total
Gender									
Female	47.3	53.9	48.7	53.0	50.7	52.8	50.7	49.6	50.4
Male	52.7	46.1	51.3	47.0	49.3	47.2	49.3	50.4	49.6
Age group (years)									
<30	14.8	20.4	16.0	16.9	18.3	16.9	14.9	11.6	14.2
30-49	46.8	56.7	48.9	50.6	58.1	51.1	53.4	52.8	53.2
>49	38.3	22.9	35.2	32.5	23.6	32.0	31.7	35.6	32.5
Qualification level									
Lower than bachelor	4.8	4.7	4.8	4.2	4.6	4.3	6.6	7.9	6.9
Bachelor	75.6	74.8	75.4	74.1	77.2	74.2	77.2	74.2	76.6
Higher than bachelor	19.6	20.5	19.8	21.7	18.2	21.5	16.1	17.9	16.5
Hours of work									
Full-time	85.1	85.7	85.2	87.4	89.6	87.5	85.4	86.4	85.6
Part-time	14.9	14.3	14.8	12.6	10.4	12.5	14.6	13.6	14.4
Employment contract									
Permanent	87.3	78.0	85.4	86.1	80.1	85.8	87.5	86.7	87.3
Temporary	12.7	22.0	14.6	13.9	19.9	14.2	12.5	13.3	12.7
Experience (years)									
1	2.9	3.9	3.1	3.9	6.1	4.0	2.6	0.5	2.2
2-5	15.4	20.8	16.5	18.1	22.0	18.4	15.6	14.8	15.4
>5	81.7	75.3	80.4	78.0	71.9	77.6	81.8	84.6	82.4
Exp. in current school (years)									
1	9.9	13.0	10.5	11.4	16.5	11.7	10.2	6.5	9.4
2-5	34.0	37.7	34.8	33.6	37.8	33.9	30.6	32.8	31.0
>5	56.1	49.2	54.7	55.0	45.7	54.4	59.3	60.6	59.5
Experience (no. of schools)									
1	14.4	12.3	14.0	15.7	16.7	15.8	14.1	10.5	13.3
2-5	60.2	64.9	61.2	61.5	67.1	61.8	60.7	65.4	61.6
>5	25.4	22.8	24.9	22.8	16.2	22.4	25.3	24.1	25.0
No. of subjects currently teaching									
1	44.6	20.0	39.6	50.3	23.7	48.6	15.6	10.6	14.6
2	28.1	33.0	29.1	27.3	32.4	27.6	33.9	25.2	32.0
>2	27.3	47.0	31.3	22.5	44.0	23.8	50.5	64.2	53.4
No. of subjects qualified to teach									
0	0.00	11.9	2.40	0.00	27.4	1.70	0.00	9.10	1.90
1	13.9	33.2	17.8	23.0	26.0	23.1	7.60	25.3	11.3
>1	86.1	54.9	79.7	77.0	46.7	75.2	92.4	65.6	86.8

Table 7 Continued

Characteristic	Mathematics			Science			Technology		
	In-field	Out-of-field	Total	In-field	Out-of-field	Total	In-field	Out-of-field	Total
Professional development ¹									
<=3 activities	44.7	45.7	44.9	36.9	40.7	37.1	31.3	38.2	32.7
>3 activities	55.3	54.3	55.1	63.1	59.3	62.9	68.7	61.8	67.3
Satisfaction with current job ²									
Average	0.068	-0.098	0.034	0.099	-0.022	0.092	0.062	0.070	0.063
Standard deviation	0.984	1.034	0.997	0.988	1.029	0.991	1.016	1.002	1.013
Satisfaction with profession ³									
Average	0.077	0.032	0.068	0.043	0.096	0.047	0.101	-0.029	0.074
Standard deviation	1.005	0.966	0.997	0.975	1.052	0.979	1.011	0.991	1.008

Note: Weighted estimates. Excludes teachers teaching more than seven subjects.

1 Professional development activities are: 1) qualification programme 2) participation in a network of teachers formed specifically for the professional development of teachers 3) individual or collaborative research on a topic of interest to the teacher professionally 4) mentoring and/or peer observation and coaching as part of a formal school arrangement 5) reading professional literature (e.g. journals) 6) engaging in informal dialogue with colleagues on how to improve own teaching.

2 Derived variable uses IRT scaling and responses to four items: 1) I enjoy working at this school 2) I would recommend my school as a good place to work 3) I am satisfied with my performance in this school 4) All in all, I am satisfied with my job.

3 Derived variable uses IRT scaling and responses to four items: 1) the advantages of being a teacher clearly outweigh the disadvantages 2) if I could decide again, I would still choose to work as a teacher 3) I regret that I decided to become a teacher 4) I wonder whether it would have been better to choose another profession.

Source: PISA 2015.

School context

Information about the school context is from two sources, the principals' survey and the students' survey. The school context variables are averages over all students in the survey from the same school. We use the unique school identifier to link these data to the unit record data for teachers. All teachers from the same school will have the same value for all school context variables. The index of economic, social and cultural status (ESCS) is derived using principal component analysis of three items from the students' survey:

- parental education
- parental occupation
- home possessions.

Staff shortage is scaled using item response theory and schools' responses to items on the availability of staff (both teaching and assisting²²) and their qualifications. It measures whether staff shortage hinders provision of instruction to students in the school. A large value for it indicates the school is experiencing a serious staff shortage.

²² As teachers comprise most of the staff in any school, the inclusion of non-teaching staff in the derivation of the staff shortage variable is unlikely to make a material difference.

School autonomy is a simple composite index and uses principals' responses to the following questions for its construction:

- hiring and firing of teachers
- setting staff salaries
- formulating and deciding budget allocation
- courses, textbooks and assessment
- student admission and discipline.

The larger its value, the more autonomy the school has. The variable is an indicator of school organisational practices.

Sector of school is an important context variable because it is a proxy for the total funding available to schools, which has a significant influence on a school's capacity to compete in the segments of teachers' labour market experiencing shortages. The variable is highly correlated with a number of other variables. Table 8 shows the average scores, calculated over teachers in the sample, for a selected number of school indicators by sector of school.²³ It shows very clearly that teachers in government schools teach the most disadvantaged students, in terms of ESCS, and those in independent schools teach the most advantaged students. The average student ability, in terms of the three PISA scores, is also least in government schools and highest in independent schools. Government schools have the least autonomy and report the highest staff shortages, but the converse is true for independent schools.

Table 8 Selected context characteristics of schools where teachers work by sector of school, average

Variable	Sector of school			All
	Government	Catholic	Independent	
Index of economic, social and cultural status of students (ESCS)	0.029	0.409	0.634	0.230
School autonomy	0.626	0.770	0.895	0.710
Staff shortage	-0.062	-0.522	-0.897	-0.324
PISA reading score	479	513	542	498
PISA mathematics score	473	500	529	490
PISA science score	487	517	549	505

Note: Weighted estimates. Excludes teachers teaching seven or more subjects.

Source: PISA 2015.

Table 9 shows that almost all teachers in schools where less than 25% of students' parents have higher education qualifications are in the government sector (94.1%), which is disproportionately higher than the total number of teachers in the sector (58.3%). Similarly, a disproportionately high number of teachers in schools where more than 75% of students' parents have higher education qualifications work in the independent sector, 48.5% compared to overall 18.8% in the sector.

²³ In effect these are weighted averages with the weights depending on the number of teachers from each school.

Table 9 Teachers in government, Catholic and independent schools by proportion of students' parents with higher education qualifications in the school (%)

Students' parents with higher education qualifications in school	Sector of school			All
	Government	Catholic	Independent	
<25%	972	48	13	1033
25-75%	1881	974	618	3473
>75%	198	176	353	728
All	3052	1199	983	5234

Note: Weighted estimates. Excludes teachers teaching seven or more subjects.

Source: PISA 2015.

Table 10 compares the school context characteristics of in-field and out-of-field teachers by STEM subject. While these characteristics vary between schools with in-field and out-of-field teachers in mathematics and science, the corresponding differences are very much smaller with respect to teaching technology.

Among teachers teaching mathematics and science, a larger proportion of out-of-field teachers are in government schools and in smaller schools than are in-field teachers. The student ability (PISA reading, mathematics and science), ESCS and school autonomy indicators are, on average, lower in schools where teachers teach out-of-field than in schools where they teach in-field, but the staff shortage indicator is higher. The proportion of in-field teachers who are in schools that have highly educated parents (more than 75% with higher education qualifications) is higher than the proportion of out-of-field teachers.

Table 10 School-level characteristics of in-field and out-of-field teachers by subject (%)

Characteristic	Mathematics			Science			Technology		
	In-field	Out-of-field	Total	In-field	Out-of-field	Total	In-field	Out-of-field	Total
Sector									
Government	59.6	66.3	61.0	57.6	68.6	58.3	60.5	65.2	61.5
Catholic	21.5	22.3	21.6	23.0	24.0	23.1	23.4	18.1	22.3
Independent	18.9	11.4	17.4	19.3	7.5	18.6	16.1	16.7	16.2
Location									
Metropolitan	72.8	66.7	71.6	74.0	63.6	73.4	71.1	71.9	71.3
Provincial	25.9	30.6	26.8	24.7	33.8	25.3	27.5	25.8	27.1
Remote	1.3	2.7	1.6	1.3	2.7	1.3	1.3	2.3	1.5
State									
New South Wales	28.6	32.7	29.4	35.5	33.6	35.4	41.7	31.6	39.6
Victoria	23.0	23.7	23.1	21.9	24.3	22.1	16.6	22.1	17.7
Queensland	25.6	22.4	24.9	20.0	16.2	19.8	20.2	23.1	20.8
South Australia	8.4	7.6	8.2	6.8	9.8	7.0	7.4	7.9	7.5
Western Australia	9.5	8.4	9.3	10.9	10.0	10.8	9.7	8.7	9.5
Tasmania	2.7	2.2	2.6	2.1	3.0	2.1	2.4	3.5	2.6
Northern Territory	0.9	1.3	0.9	0.9	0.9	0.9	0.8	0.9	0.8
Australian Capital Territory	1.4	1.8	1.5	1.9	2.3	1.9	1.3	2.1	1.5
Class size									
<21	5.4	9.1	6.2	6.3	5.7	6.3	7.2	6.7	7.1
21-25	45.8	42.5	45.1	43.6	43.5	43.6	40.2	38.9	40.0
>25	48.8	48.4	48.7	50.0	50.7	50.1	52.5	54.3	52.9
School size									
<500	7.7	13.0	8.8	8.0	12.7	8.3	10.8	9.1	10.4
500-1000	41.4	42.5	41.6	43.1	47.9	43.4	45.0	46.6	45.3
100-1500	38.3	36.5	37.9	36.4	34.7	36.3	33.8	35.8	34.2
>1500	12.7	8.1	11.7	12.4	4.7	11.9	10.4	8.6	10.0
School type									
Co-ed	86.9	91.2	87.8	84.0	85.7	84.1	87.5	89.1	87.8
Boys only	6.7	6.2	6.6	8.1	7.2	8.0	6.3	5.1	6.0
Girls only	6.5	2.6	5.7	7.9	7.0	7.9	6.2	5.9	6.1
% immigrant students									
<=30	74.3	78.5	75.2	72.5	74.4	72.6	72.5	73.1	72.6
>30	25.7	21.5	24.8	27.5	25.6	27.4	27.5	26.9	27.4
% of students speaking language other than English at home									
<=30	89.1	94.3	90.2	89.1	88.7	89.1	89.5	90.7	89.7
>30	10.9	5.7	9.8	10.9	11.3	10.9	10.5	9.3	10.3
% of students' parents with higher education qualifications in school									
<25	20.6	30.0	22.5	17.6	25.0	18.1	22.1	23.1	22.3
25-75	65.8	64.7	65.6	67.0	70.9	67.3	66.6	65.2	66.3
>75	13.6	5.2	11.9	15.4	4.1	14.7	11.3	11.7	11.4
% students studying vocational subjects									
<=30	84.3	80.7	83.6	86.2	84.4	86.1	85.8	82.2	85.1
>30	15.7	19.3	16.4	13.8	15.6	13.9	14.2	17.8	14.9

Table 10 Continued

Characteristic	Mathematics			Science			Technology		
	In-field	Out-of-field	Total	In-field	Out-of-field	Total	In-field	Out-of-field	Total
Government funding (%)									
Average	74.3	79.0	75.2	73.0	80.1	73.4	75.7	75.9	75.7
Standard deviation	22.5	19.1	21.9	23.1	19.2	22.9	21.0	21.6	21.2
Index of economic, social and cultural status of students (ESCS) ¹									
Average	0.210	0.101	0.188	0.255	0.138	0.247	0.189	0.199	0.191
Standard deviation	0.422	0.400	0.420	0.422	0.376	0.420	0.407	0.424	0.411
PISA reading score									
Average	497.3	482.5	494.3	500.7	487.8	499.9	493.3	493.9	493.4
Standard deviation	54.7	46.4	53.4	54.1	50.0	53.9	54.7	54.6	54.6
PISA mathematics score									
Average	488.1	473.7	485.1	492.1	491.5	490.5	486.5	484.1	486.0
Standard deviation	50.5	40.5	48.9	49.8	49.4	48.7	47.5	49.2	47.9
PISA science score									
Average	504.2	489.1	501.1	508.4	496.5	507.7	501.1	502.9	501.5
Standard deviation	53.8	45.6	52.6	53.0	46.8	52.7	51.2	51.5	51.2
School autonomy ²									
Average	0.708	0.682	0.702	0.715	0.680	0.713	0.703	0.697	0.702
Standard deviation	0.242	0.231	0.240	0.232	0.243	0.233	0.229	0.236	0.231
Staff shortage ³									
Average	-0.294	-0.186	-0.272	-0.362	-0.077	-0.344	-0.255	-0.257	-0.256
Standard deviation	0.932	0.878	0.922	0.940	0.831	0.936	0.936	0.936	0.936

Note: Weighted estimates. The ESCS and the three PISA scores are school averages. Excludes teachers teaching more than seven subjects.

1 Derived using principal component analysis of three items: 1) parental education 2) parental occupation 3) home possession.

2 Derived as simple composite index based on principals' responses to questions on 1) hiring and firing of teachers 2) setting staff salaries 3) formulating and deciding budget allocation 4) courses, textbooks and assessment 5) student admission and discipline.

3. Derived variable based on IRT scaling and responses to items on the availability of staff (both teaching and assisting) and their qualifications. Measures whether staff shortage hinders provision of instruction to students in schools.

Source: PISA 2015.

Above we noted that a lower proportion of out-of-field teaching, in all three subjects, occurs in schools where a high proportion of students' parents have higher education qualifications. Table 11 shows a relatively much smaller proportion of teachers teach out-of-field in schools where more than 75% of parents have higher education qualifications in all three sectors. In the government sector, many such schools could be selective schools, which are where many highly educated parents often send their children. The reader should view the estimates of out-of-field teaching in Catholic and independent schools where less than 25% of parents have higher education qualifications with caution because, as table 9 shows, these estimates are based on small sample sizes.

Table 11 Teaching out-of-field in government, Catholic and independent schools by proportion of students' parents with higher education qualifications in school (%)

Students' parents with higher education qualifications in school	Sector of school							
	Government		Catholic		Independent		All	
	In-field	Out-of-field	In-field	Out-of-field	In-field	Out-of-field	In-field	Out-of-field
<25%	81.4	18.6	79.1	20.9	88.9	11.1	81.4	18.6
25-75%	84.6	15.4	86.2	13.9	88.4	11.6	85.7	14.3
>75%	92.5	7.5	90.4	9.6	92.0	8.0	91.8	8.2
All	84.1	15.9	86.5	13.5	89.7	10.3	85.6	14.4

Note: Weighted estimates. Excludes teachers teaching seven or more subjects.

Source: PISA 2015.

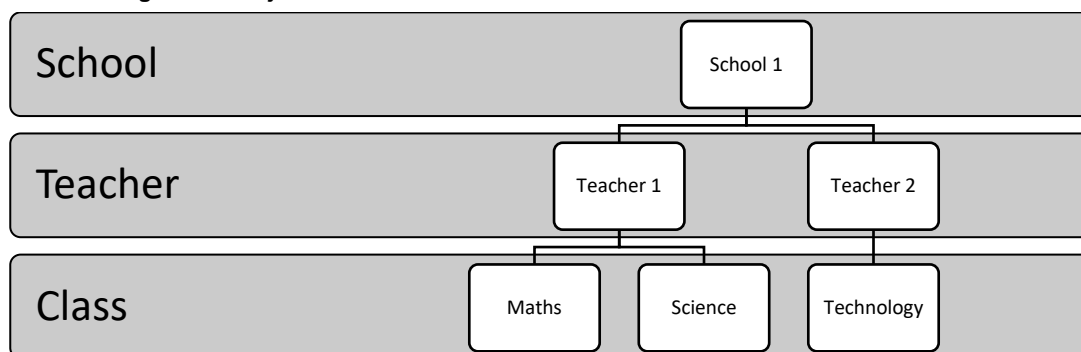
Method

The bivariate relationships described in the previous section suggests a possible role of staff shortage and school autonomy (school organisational practices) in explaining out-of-field teaching. To determine the true nature of these relationships it is important to control for other factors, some of which may be confounding or mediating these relationships. These factors may be teacher characteristics or school context variables. These sorts of issues typically arise in observational studies, like PISA, because of non-random allocation, which in this case is the way teachers are assigned to schools. While we can control for the observed confounders or mediators in the model, controlling for such unobserved factors is more difficult.²⁴

In this section, we outline a method to investigate the effects of various individual and school factors on the probability of out-of-field teaching in STEM subjects. In particular, we investigate the effect of staff shortage and school autonomy. The multiple regression framework for the model will allow us to identify possible confounders or mediators in these relationships.

The data described in the previous section can be organised in a three-level hierarchical structure as shown in figure 1. The data contain repeated records for teachers teaching multiple subjects. These records are identical in all respects except for the subject taught. Similarly, teachers teaching in the same school share the common school-level random effects. A possible model to fit to these data is a logistic multilevel model with random effects, which adjusts for these two sources of correlation. The failure to adjust for these correlations can distort the coefficient estimates and their standard errors.

Figure 1 Teaching STEM subjects: a three-level hierarchical structure



Multilevel models contain both fixed effects and random effects. The fixed effects are analogous to standard regression, or in our case logit, coefficients. The estimation of the random effects is indirect and can take the form of either random intercepts or random coefficients. To keep the model simple, we assume only random intercepts in the model. We can specify the model algebraically as:

$$y_{ijk}^* = \alpha_{0ijk} + \mathbf{W}_{ijk}\boldsymbol{\delta} + \mathbf{X}_{jk}\boldsymbol{\beta} + \mathbf{Z}_k\boldsymbol{\gamma} + \epsilon_{ijk}. \quad (1)$$

In this equation, y_{ijk}^* is the underlying, unobserved latent response variable, which measures the extent, on some scale, to which teacher j is assigned an out-of-field class i , in school k ; \mathbf{W}_i is a vector of class characteristics; \mathbf{X}_i is a vector of individual teacher characteristics and \mathbf{Z}_i is a vector of school

²⁴ Sometimes one may be able to use proxies, if available, for omitted variables.

characteristics. δ , β , and γ are vectors of parameters to be estimated and ϵ_{ijk} is the residual term whose distribution is standard logistic with mean 0 and variance $\pi^2/3$; and

	$\alpha_{0ijk} = \alpha_0 + \vartheta_{0k} + \mu_{0jk}$	(2)
--	---	-----

with $\vartheta_{0k} \sim N(0, \sigma_{\vartheta}^2)$ and $\mu_{0jk} \sim N(0, \sigma_{\mu}^2)$. The first term, ϑ_{0k} , is the school effect and the second term, μ_{0jk} , is the teacher effect. In practice, y_{ijk}^* is unobserved, but what we do observe is a binary dummy variable:

	$I_{ijk} = \begin{cases} 1 & \text{if } y_{ijk}^* > 0 \\ 0 & \text{otherwise} \end{cases}$	(3)
--	--	-----

where the value of one for this variable indicates out-of-field teaching and the value of zero indicates in-field teaching.

We can calculate the probability of teaching out-of-field as follows:

	$\text{Prob}(I_{ijk} = 1) = \Phi(\alpha_{0ijk} + \mathbf{W}_{ijk}\delta + \mathbf{X}_{jk}\beta + \mathbf{Z}_k\gamma)$	(4)
--	---	-----

where Φ is the logistic cumulative distribution function. The log-likelihood function for this is:

	$\ln L = \sum_{i=1}^n I_i \ln \Phi(\mathbf{W}_i\delta + \mathbf{X}_i\beta + \mathbf{Z}_i\gamma) + (1 - I_i) \ln(1 - \Phi(\mathbf{W}_i\delta + \mathbf{X}_i\beta + \mathbf{Z}_i\gamma)).$	(5)
--	--	-----

which we can estimate using maximum likelihood.

Choice of explanatory variables

There are three types of explanatory variables, corresponding to the three hierarchical levels, to include in the model. Theory and previous research should guide the choice of the variables to include. At the lowest level, there is essentially just one variable and that is the subject that the teacher is assigned to teach. It is important to control for this as out-of-field assignments vary significantly by subject.

At the second level are variables relating to individual teachers, such as their demographic and work characteristics. Previous research suggests age and experience are associated with out-of-field teaching, with inexperienced, and younger, teachers more likely to be teaching out-of-field (Ingersoll 1999; Weldon 2016). In the model, we capture the effect of two different types of experience—overall teaching experience and experience in the current school. The rationale for including teachers' qualifications as an explanatory variable is that principals may consider teachers' qualifications in their out-of-field assignment decisions. Teachers with higher degrees, because of their deeper knowledge of the subject, may be preferred for in-field rather than out-of-field teaching, especially for classes in upper grades. The types of contracts teachers are employed on may influence principals' decisions (Zhou 2014). Teachers on fixed-term or temporary contracts may also have a lesser bargaining power with the principal in terms of subject preferences than teachers on permanent contracts.²⁵ It is almost by definition that the more subjects a teacher teaches, the more likely it will be that some of them will be out-of-field, which means controlling for this factor is important in order to obtain more accurate estimates for the effects of other variables. Similarly, we control for the number of subjects for which teachers are qualified. We expect the more subjects a teacher is qualified to teach, the less likely it will be that they teach out-of-field. We include a variable for the number of professional development

²⁵ The assignment to out-of-field teaching can be conceptualised as a joint decision of the principal and the teacher, with each party acting to maximise their own utility.

activities undertaken by teachers in the model because such activities can equip teachers with the qualifications necessary to teach subjects for which they do not have initial qualifications. We also include controls for teachers' satisfaction with the profession and their satisfaction with their current job.²⁶

At the highest level are variables about school characteristics. Previous research suggests association between out-of-field teaching and school sector and school location (Ingersoll 1999; Weldon 2016; McConney & Price 2009). We include average class size as an explanatory variable because Ingersoll (2004) shows it is related to out-of-field teaching in the United States. Principals may increase class sizes to avoid out-of-field classes, but physical size of classrooms and industrial relations agreements limit the use of this strategy.

School size has the potential to affect out-of-field teaching in a school. Larger schools, with more teachers and more classes, offer principals more flexibility in assigning teachers to classes because more combinations and permutations are possible.

When selecting variables to include in the model, it is important to look for multicollinearity among the variables, which can show up as high correlation between pairs of variables. This is indeed the case with respect to the three PISA scores that measure the average ability of students in schools in three different subject domains (see table A1 in appendix A for the correlation matrix). Including all three scores may introduce instability in the estimates of the regression coefficients. To avoid this, we only include the mathematics score in the model. It will be a proxy for the average ability of students in the school.²⁷

The correlation matrix also shows high correlation between the mathematics score and the average index of economic, social and cultural status (ESCS). The ESCS is a composite score built by the indicators of parental education, parental occupation and home possessions using principal component analysis. Rather than including ESCS as an explanatory variable in the model, instead we include only parental education.²⁸ Total school funding has various sources.

Most funding for government schools would be from public sources with a small proportion from parental levy. For many non-government schools, possible funding sources are governments, school fees and income from wealth investments, which can be considerable for some schools. Some schools may be sensitive about providing information about their sources of funding. Therefore, the variable measuring the proportion of a school's funding from government sources, we believe, may have large measurement error. The variable also has strong association with the sector of school, which has no measurement error. For these reasons, we exclude the variable measuring the proportion of funding from government sources from any further analysis.

²⁶ These variables illustrate the importance of being cautious in interpreting these relationships as causal because one could very well argue that out-of-field teaching causes teachers' dissatisfaction with their current job or profession. Equally well one can argue that principals may choose to assign out-of-field classes to teachers who show poor commitment to the school and teaching because they are unsatisfied.

²⁷ This is another example where one can argue the causation is in the opposite direction.

²⁸ The variance inflation factor for ESCS is particularly high and this was an additional reason for excluding it from the model specification.

Results

In this section, we report results from estimating the model in equation 4 for a range of specifications of the explanatory variables.²⁹ We report the results in two sections. The first section focusses on the effects of school autonomy and staff shortage on out-of-field teaching. The second contains analyses of the risk factors—teacher characteristics and school context—for out-of-field teaching, in terms of predicted probabilities.

Effects of school autonomy and staff shortage on out-of-field teaching

To understand the effects of school autonomy and staff shortage, we estimate sequentially the following seven models:

- model 1: base variance components model or null model, that is, without any explanatory variables
- model 2: includes school autonomy as the only explanatory variable
- model 3: includes school shortage as the only explanatory variable
- model 4: includes school autonomy and staff shortage as the only explanatory variables
- model 5: includes subject (level 1) variable as an additional explanatory variable
- model 6: includes teacher characteristics (level 2) as additional explanatory variables
- model 7: includes school characteristics (level 3) as additional explanatory variables.

The results from these models are in table 12. For ease of presentation, the table includes only the coefficient estimates of school autonomy and staff shortage variables. The full results for models 5-7 are in table B1 in appendix B. At the bottom of the table are various statistics for evaluating how well the data fit the models.

Model 1, the unconditional or intercept only model, has no explanatory variables. It provides an assessment of the appropriateness of using a three-level hierarchical model. The table shows that both the school level and teacher level variances are more than twice as large as their respective standard errors and, therefore, are significantly different from zero.³⁰ Other statistics in the table worth noting are the intraclass correlations. The first of these shows that 12.7% of the total variation in out-of-field teaching is due to differences between schools and the second shows 36% is due to differences between teachers within the same school. These results vindicate the decision to use a three-level hierarchical model. The average predicted probability of teaching out-of-field, not shown in the table, is 12.3%, which is very close to the 12.7% estimated from the raw data.³¹

²⁹ In estimating the models, we exclude observations for 97 teachers who did not report their fields of qualifications. All continuous variables are grand-mean centred.

³⁰ The Wald statistic calculated as $(\sigma^2_{\theta}/se)^2$ equals 23.2 and 22.6, respectively. Both these statistics are clearly greater than χ^2_1 and, therefore, the null hypotheses that the statistics are equal to 0 can be rejected.

³¹ The estimate of the constant term from a logit model is generally difficult to interpret as it refers to the probability of teaching a ‘typical’ STEM subject out-of-field by a ‘typical’ teacher in a ‘typical’ school. Instead, the margin, which is the predicted probability of teaching a class out-of-field averaged over the whole sample.

School autonomy is the only explanatory variable in model 2. The results from it show the effect of school autonomy is negative and significant, which means that teachers are less likely to be teaching out-of-field in schools that have high levels of autonomy. Similarly, the results for model 3 show that teachers are more likely to be teaching out-of-field in schools that report high levels of staff shortage. With both variables in the model (see model 4), the size of the effect for each variable becomes smaller. The model fit, in terms of the statistics in the bottom part of the table, remains largely unchanged from what it was in the earlier models.

Model 5 includes subject, the only level one variable, as an additional explanatory variable. While the coefficients of both school autonomy and staff shortage change very little, the model fit improves considerably. This suggests that subject is an important covariate in the model.

In model 6, which now includes teacher characteristics as explanatory variables, the coefficients for school autonomy and staff shortage are even smaller and no longer statistically significant. The model fit improves substantially for model 6, with pseudo R^2 increasing from 20.4% in model 5 to 38% now. This means that teacher characteristics account for a substantial variation in out-of-field teaching.

The results from model 6 suggest that some teacher characteristics either confound or mediate the relationships between school autonomy and out-of-field teaching and staff shortage and out-of-field teaching. A confounder influences both the independent and dependent variables (see figure 2) and distorts the true nature of the relationship between the two variables.³² A mediator provides a causal link between the independent and dependent variables (see figure 3). It shows the link between the independent and dependent variables to be indirect and via a third variable. Sometimes a direct link may also co-exist between the independent and dependent variables. Below we qualitatively discuss some of the confounding and mediating relationships.

Faced with a staff shortage in one area and a surplus in another, a school may ask some teachers to teach more subjects, not all of which they may have qualifications for. The more subjects a teacher teaches, the more likely it is that some will be taught out-of-field. In this way, the number of subjects a teacher teaches mediates the relationship between staff shortage and out-of-field teaching.

In contrast, the number of subjects a teacher is qualified to teach confounds the relationship between staff shortage and out-of-field teaching. This is because the numbers of subjects that teachers are qualified to teach affects whether a school experiences a staff shortage or not. For example, a school with all teachers qualified to teach just one subject is more likely to experience a staff shortage than a similar school with all staff qualified to teach two subjects. It is almost by definition that the more subjects that teachers are qualified to teach, the less likely they are to teach out-of-field.

Schools with high levels of autonomy also tend to have better funding and flexible budgets, otherwise the autonomy is limited. Such schools are then able to offer more professional development to teachers. The more professional development activities a teacher engages in, the more likely it is that some of them lead to qualifications to teach additional subjects, which in turn reduces the likelihood of teaching out-of-field. In this sense, professional development is a mediator between school autonomy and out-of-field teaching.

The employment contract is also a mediator between school autonomy and out-of-field teaching. This is because the better funding of more autonomous schools allows them to offer better (permanent)

³² The direction of the influence between the confounder and the independent variable in some instances can be in both directions.

employment contracts to teachers. In contrast, schools with tighter budgets, and consequently uncertain long-term funding, often resort to employing teachers on temporary contracts, which are often casual contracts offered on a daily basis to replace teachers on short-term absence, such as for sick leave or other non-teaching assignments. Temporary teachers thus often lack the qualifications for the subjects they are asked to teach. Thus, teachers on temporary contracts are more likely to teach out-of-field.

Figure 2 Three-variable confounding model

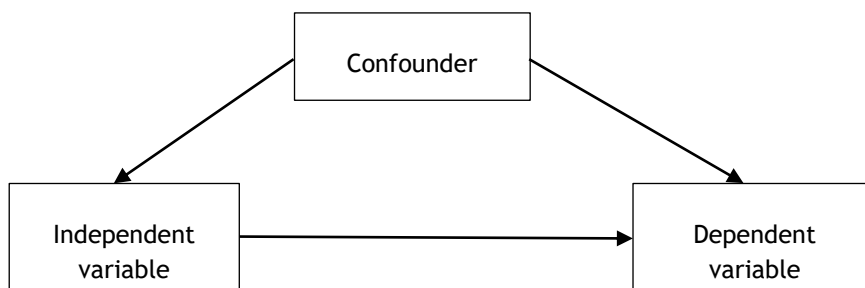
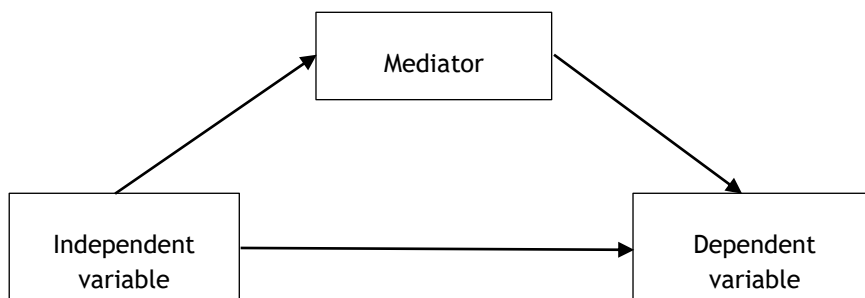


Figure 3 Three-variable mediation model



Model 7 extends the specification to include school context variables, which results in only a slight improvement in the pseudo R^2 to 38.6%, but the two information criteria suffer because in their calculation there is a penalty for estimating every additional parameter. The coefficients of the teacher variables change very little from the previous model. The size of the coefficients of school autonomy and staff shortage not only are smaller, but their signs are reversed. Again, this suggests some school context variables could be either mediating or confounding the effects. For example, we argue that sector of school is a confounder in the relationship between staff shortage and out-of-field teaching. As discussed above, non-government schools, because of their better funding, experience less staff shortage. Thus, the sector of school has an effect on the level of staff shortage experienced by a school. Teachers teaching in non-government schools are more likely to be employed on permanent contracts and thus less likely to be teaching out-of-field.

In summary, the analyses suggest that the effects of staff shortage and school autonomy on out-of-field teaching are mediated and confounded by a number of teacher and school context variables. Therefore, it would be incorrect to conclude, simply on the basis of the results from model 7, that no relationship exists between these two factors and out-of-field teaching. The analyses in this study show the pathways

through which school autonomy and staff shortage affect out-of-field teaching. Many of these pathways are complex and influenced by the unobserved school funding and budget variables.

Table 12 Effects of school autonomy and staff shortage on out-of-field teaching in STEM subjects Australia, 2015

Explanatory variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	Log odds	Log odds	Log odds	Log odds	Log odds	Log odds	Log odds
Organisational variable (level3)							
School autonomy	Excl.	-0.484**	Excl.	-0.389*	-0.396	-0.056	0.041
Staff shortage	Excl.	Excl.	0.170***	0.154**	0.147**	0.098	-0.020
Level 1 variables	Excl.			Excl.	Incl.	Incl.	Incl.
Level 2 variables	Excl.			Excl.	Excl.	Incl.	Incl.
Level 3 variables	Excl.			Excl.	Excl.	Excl.	Incl.
Constant	-2.551***	-2.551	-2.541***	-2.542***	-4.226***	-3.257***	-2.988***
Random effects parameters [#]							
School (variance) σ_g^2	0.653 (0.135)	0.643 (0.134)	0.626 (0.133)	0.621 (0.132)	0.782 (0.168)	0.718 (0.188)	0.622 (0.168)
School teacher (variance) σ_{μ}^2	1.198 (0.332)	1.188 (0.331)	1.195 (0.330)	1.189 (0.329)	2.096 (0.534)	0.267 (0.378)	0.308 (0.378)
Intraclass correlation [#]							
School	0.127 (0.024)	0.126 (0.024)	0.122 (0.024)	0.122 (0.024)	0.127 (0.025)	0.168 (0.035)	0.147 (0.034)
Teacher school	0.360 (0.045)	0.358 (0.045)	0.356 (0.045)	0.355 (0.045)	0.467 (0.050)	0.230 (0.084)	0.220 (0.082)
Information criterion							
Akaike (AIC)	5057	5055	5051	5051	4679	4152	4158
Bayesian (BIC)	5077	5082	5079	5085	4727	4330	4500
McKelvey & Zavoina pseudo R ²	0.087	0.088	0.088	0.089	0.204	0.380	0.386

Notes: * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent.

[#] standard errors in parenthesis.

All continuous variables are grand-mean centred.

Model 1: base variance components model or null model.

Model 2: including school autonomy and school shortage as explanatory variables.

Model 3: including subject (level 1) as explanatory variable.

Model 4: including teacher characteristics (level 2) as explanatory variables.

Model 5: including school characteristics (level 3) as explanatory variables.

Source: PISA 2015.

Predicted probabilities

The results from the above models are in terms of logits or log odds. Alternatively, we can convert these to odds ratios or relative risk. The results presented in any of these metrics are still difficult to interpret and explain, especially when interaction terms are in the model specification (Williams 2012; Mize 2019). An alternative is to present the results in terms of probabilities or predictions. For example, we can compare the probability of out-of-field teaching for a teacher on a temporary contract in a government school with a similar teacher in a Catholic or independent school. The calculations of such probabilities however are not straightforward because of the non-linear nature of logistic models.

One option is to calculate the probability at specific values for each independent variable in the model.³³

In practice, instead of reporting these individual probabilities, most studies report some type of

³³ Alternative terms for the prediction are adjusted prediction and margin. The marginal effect is the difference in the margins for different levels of a given explanatory variable. For example, the marginal effect of gender is the difference

‘average’. There are a number of different ways of calculating the average. Here we first fix the value of the variable of interest and then calculate the predicted probabilities with all other variables varying over their observed sample values. These probabilities are then averaged over the whole sample.³⁴ This measure, sometimes also referred to as the predictive margin or average adjusted prediction, adjusts or controls for all other variables in the model and has better statistical properties than other ‘averages’ (Cameron & Trivedi 2005).

Our focus in this section is on the average adjusted predictions from model 7 extended to include a number of interaction terms. We call this model 8. Interaction terms will extend our understanding of the relationships between different variables in the model. For example, they will show if the probability of out-of-field teaching varies by teacher’s age in different STEM subjects. The results for model 8 in terms of log odds are in table B1 in appendix B. Adding the interactions improves the model fit, with pseudo R^2 increasing to 42.5%.

Main effects

Table 13 shows the predicted probabilities for all categorical variables (main effects) in the model.³⁵ The probabilities of teaching out-of-field in mathematics, science and technology are 18.7%, 5.1% and 17.1%, respectively, which are close to the overall sample proportions. The result for science reflects the grouping of its sub-domains into a single group.

The probability of out-of-field teaching increases with the number of subjects that a teacher is teaching. It is 4.2% for a teacher who teaches just one subject. This means that a small number of teachers who despite teaching just a single subject are actually unqualified to teach these subjects. The probability of out-of-field teaching increases to 13.5% for those teaching two subjects and 23% for those teaching more than two subjects.³⁶

Teachers who are qualified to teach only one subject have a much higher probability of teaching out-of-field than teachers who are qualified to teach more than one subject—36% compared to 9.5%. This means that, all else being equal, the out-of-field teaching should decline over time because most new teachers in training have to have at least two teaching methods.

The probability of out-of-field teaching is substantially higher for teachers in remote locations (21.1%) than for teachers in other locations (less than 12.9%). Similarly, teachers working in small schools are more likely to be teaching out-of-field than are teachers in larger schools. For example, the probability is 14.2% for a teacher in a school with less than 500 students compared to 9.7% for one in a school with more than 1500 students. In large schools, with a lot more classes and teachers, it is easier to design schedules that avoid out-of-field assignments.

A teacher’s chances of teaching out-of-field depend on the state or territory they teach in. The probability varies from 10% for a teacher in the Northern Territory to 18.6% for a teacher in the Australian Capital Territory. These two estimates however have wide confidence intervals because of

in the adjusted prediction of being a male compared to that being a female. The calculations take account of the random effects at the teacher and school levels.

³⁴ An alternative, often reported in the literature, is the average prediction at the means, whereby all other independent variables are set at their sample means instead of their observed values.

³⁵ The calculation of margins for continuous variables can only be at specific values. Alternatively, we can calculate the marginal effects of continuous variables. These calculations show the marginal effects for all variables were statistically insignificant.

³⁶ Includes STEM and non-STEM subjects.

relatively small numbers of teachers from these two territories in the sample. Among the states, out-of-field teaching is least likely in New South Wales. The cause of this variation could be state differences in how teacher workforces are managed.

Other significant main effects relate to:

- age—teachers aged 50 years or older are less likely to be teaching out-of-field than those aged 30-49 years
- employment contract—teachers on permanent contracts are less likely to be teaching out-of-field than those on temporary contracts
- experience (number of schools)—teachers in their first school, which includes most first-year teachers, are less likely to be teaching out-of-field than other teachers
- professional development activities—teachers who have undertaken more than three activities are less likely to be teaching out-of-field than those who have undertaken less than this number.

There are two possible explanations why older teachers (50 years and over) are less likely to be teaching out-of-field. First, preferences of older, and generally more experienced teachers, may carry more weight in the schools' decisions on assigning teachers to classes. Here we assume teachers on the whole prefer to teach in-field. Second, schools themselves assign older teachers to in-field classes, especially senior classes where teacher experience and qualifications are important, to retain experienced teachers in the school.

Employment contract is a strong predictor of out-of-field teaching. Often those on temporary contracts are casual teachers. Schools hire them, frequently on a daily basis, to replace teachers on sick leave, on professional development or other temporary non-teaching assignments. Schools often assign them to out-of-field classes. Furthermore, temporary teachers, even those on longer, fixed-term contracts, have less bargaining power in negotiating with schools about the subjects they teach. Some may undertake, voluntarily or involuntarily, out-of-field teaching to avoid redundancy.

Surprisingly, the probability of out-of-field teaching is significantly lower for teachers at their first school, which includes most first-year teachers.³⁷ This seems to contradict the common belief that new teachers in a school are 'thrown in at the deep end', which includes assignment to out-of-field classes. It could be argued that by minimising out-of-field teaching for first-year teachers, schools are helping to ease their transition into the profession. Out-of-field teaching, on top of other challenges of pedagogy and classroom management, could be overwhelming for the best of first year teachers. Thus, schools are perhaps more sensitive to their needs than what people generally believe. Ensuring a smooth introduction to the profession for first-year teachers can only help their retention, which has been of concern for a number of years.

The fourth point indicates the possible positive role of professional development activities in reducing out-of-field teaching. It should be emphasised that this is not a causal effect as it is not possible to infer from the results whether professional development activities reduce out-of-field teaching or if indeed teachers who teach in-field undertake more professional development activities. Further qualitative research can explore the type of professional development activities that are undertaken and if indeed they lead to qualifications to teach additional subjects.

³⁷ Some first-year teachers on casual contracts may be at their first school, but others may have already worked in multiple schools.

Table 13 Predicted probability of out-of-field teaching in STEM subjects in Australia, 2015 (main effects only)

Explanatory variable	Level	Probability	SE	95% confidence interval	
Subject	Mathematics	0.187	0.010	0.168	0.206
	Science	0.051	0.005	0.041	0.061
	Technology	0.171	0.010	0.151	0.190
Gender	Female	0.130	0.012	0.106	0.154
	Male	0.134	0.006	0.122	0.146
Age (years)	<30	0.114	0.008	0.098	0.130
	30-49	0.131	0.006	0.119	0.144
	>49	0.123	0.006	0.111	0.136
Qualification	Lower than bachelor	0.129	0.019	0.093	0.166
	Bachelor	0.126	0.005	0.115	0.136
	Higher than bachelor	0.132	0.011	0.110	0.153
Hours of work	Full-time	0.129	0.005	0.119	0.139
	Part-time	0.116	0.012	0.092	0.141
Employment contract	Permanent	0.121	0.005	0.112	0.131
	Temporary	0.156	0.015	0.126	0.185
Experience (years)	1	0.130	0.016	0.099	0.162
	2-5	0.124	0.008	0.109	0.140
	>5	0.128	0.007	0.114	0.142
Exp. in current school (years)	1	0.109	0.029	0.053	0.165
	2-5	0.131	0.013	0.106	0.156
	>5	0.127	0.006	0.116	0.138
Experience (no. of schools)	1	0.110	0.011	0.088	0.132
	2-5	0.133	0.006	0.122	0.144
	>5	0.121	0.010	0.103	0.140
No. of subjects currently teaching	1	0.042	0.006	0.031	0.053
	2	0.135	0.009	0.118	0.152
	>2	0.230	0.010	0.210	0.250
No. of subjects qualified to teach	1	0.360	0.017	0.327	0.393
	>1	0.095	0.005	0.085	0.104
Professional development activities	<=3	0.142	0.008	0.127	0.158
	>3	0.118	0.005	0.107	0.128
Sector	Government	0.128	0.007	0.114	0.142
	Catholic	0.127	0.014	0.099	0.154
	Independent	0.111	0.013	0.085	0.137
Location	Metropolitan	0.129	0.006	0.117	0.142
	Provincial	0.116	0.009	0.098	0.135
	Remote	0.211	0.058	0.097	0.324
State/territory	New South Wales	0.105	0.008	0.090	0.121
	Victoria	0.149	0.012	0.125	0.173
	Queensland	0.125	0.011	0.104	0.145
	South Australia	0.142	0.014	0.114	0.170
	Western Australia	0.139	0.019	0.101	0.177
	Tasmania	0.139	0.020	0.099	0.179
	Northern territory Australian Capital Territory	0.100 0.186	0.034 0.026	0.033 0.135	0.168 0.237

Table 13 Continued

Explanatory variable	Level	Probability	SE	95% confidence interval	
School size	<500	0.142	0.016	0.110	0.174
	500-1000	0.132	0.007	0.118	0.147
	1000-1500	0.126	0.008	0.111	0.141
	>1500	0.097	0.014	0.070	0.124
Class size	<21	0.130	0.019	0.092	0.168
	21-25	0.122	0.007	0.108	0.136
	>25	0.131	0.007	0.117	0.144
School type	Co-ed	0.127	0.005	0.117	0.136
	Boys only	0.138	0.021	0.098	0.179
	Girls only	0.115	0.019	0.078	0.153
% immigrant students	<=30	0.128	0.006	0.116	0.139
	>30	0.124	0.011	0.102	0.146
% students speaking language other than English at home	<=30	0.129	0.005	0.119	0.139
	>30	0.105	0.017	0.073	0.138
% students' parents with higher education qualifications	<25	0.128	0.014	0.100	0.156
	25-75	0.127	0.006	0.116	0.138
	>75	0.105	0.021	0.064	0.145
% students studying vocational subjects	<=30	0.125	0.005	0.115	0.135
	>30	0.138	0.013	0.112	0.164

Source: PISA 2015.

Interactions

Interaction terms in the model allow us to examine how the predicted probability of out-of-field teaching for a given variable varies across the values of another variable(s). Given that there are so many explanatory variables, a model with all interaction terms would be nearly impossible to estimate. Therefore, we focus on the variation in the probability of out-of-field teaching for a selected number of variables by subject, sector of school and employment contract. We use graphs to assess and report the results.³⁸

Interactions by subject

Figures 4 to 11 show the interaction effects between subject and the other variables.³⁹ Parallel plots of the probabilities indicate no interaction effect. For example, figure 6 shows parallel plots for the three subjects for different levels of professional development activities. Similarly, there is no interaction between subject and the proportion of students in the school taking vocational subjects (see figure 11).

In figure 4, the crossing over of the probability plots for mathematics and technology teachers is a clear indication of an interaction effect between age and subject. The increasing probability of out-of-field teaching with age for teachers teaching technology suggests the subject may have been less common as a method option in initial teacher training when many older teachers completed their teacher training. Over time, as older teachers retire, the probability of out-of-field teaching for older technology teachers

³⁸ According to Greene (2010), statistical testing of partial effects, and interaction terms in particular, in non-linear models can be uninformative and sometimes contradictory. Graphical presentations are an informative way to present the results and increasingly preferred for applied work (Mize 2019).

³⁹ Although we calculate the 95% confidence intervals for each estimate, for clarity we do not show them in these graphs.

will then decline. The gap in the probability between the youngest and oldest is proportionately wider for mathematics than science teachers.

Figure 5 shows the interaction effect between gender and subject. The largest gender difference of 4.5 percentage points relates to teachers teaching mathematics, with males less likely to be teaching out-of-field than females.

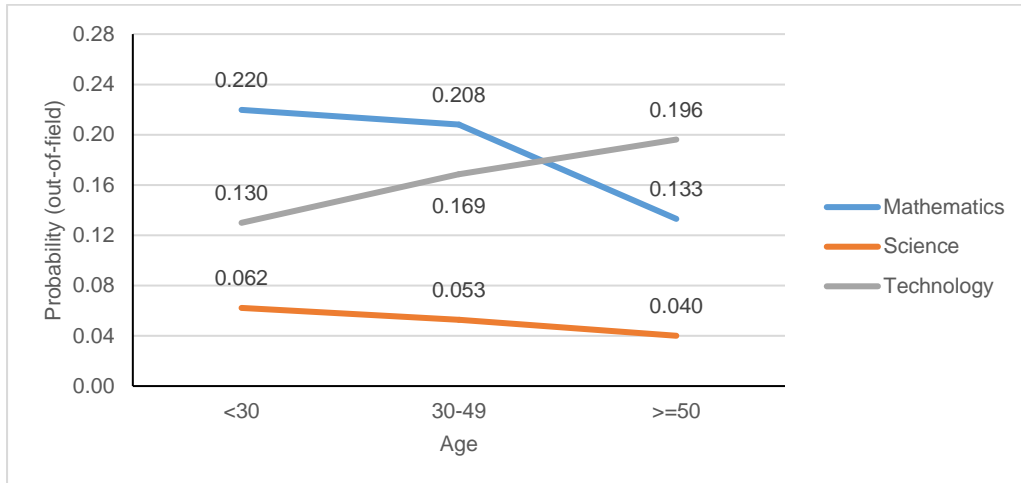
Similarly, figure 7 shows evidence of interaction between sector of school and subject. While teachers in independent schools are least likely to be teaching out-of-field in mathematics and science, they are most likely to be teaching out-of-field in technology. This could mean that independent schools have a different regard for mathematics and science compared to technology. It is possible that they see mathematics and science as 'academic' subjects and, by ensuring qualified teachers teach these subjects, they are meeting parental expectations as well as upholding the academic brand of the school. On the other hand, technology subjects may be perceived less academic because some of these subjects may contain vocational content and are not as important for maximising university entrance scores.

Location of school has a differential role in out-field teaching across the three STEM subjects (see figure 8). Remote locations have a relatively larger effect on out-of-field teaching in mathematics than in the other subjects. This may be related to differences in the difficulties in recruiting teachers across disciplines in these locations. The general shortage of mathematics teachers could be even more acute in remote locations where teacher labour markets are thinner. As schools have to comply with the mandatory requirements of teaching certain hours of mathematics at each level, any shortfall in qualified mathematics teachers is made up by assigning teachers qualified in other subjects to mathematics classes.

Teachers in girls only schools are generally slightly less likely to be teaching out-of-field (see table 13), but as figure 9 shows this is because they are much less likely to teach out-of-field in mathematics as in the other two subjects they are more likely to teach out-of-field.

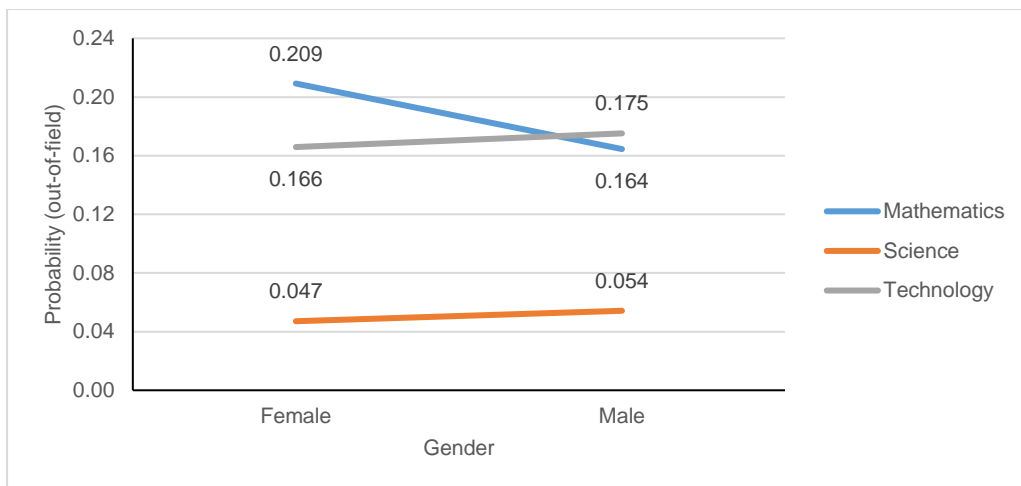
Figure 10 shows the moderating influence of the size of school on out-of-field teaching varies with subject. It shows, teachers in small schools (less than 500 students) are relatively more likely to be teaching out-of-field in mathematics. Small schools suffer from economy of scale when competing for scarce mathematics teachers in a tight labour market.

Figure 4 Predicted probability of out-of-field teaching by subject and age



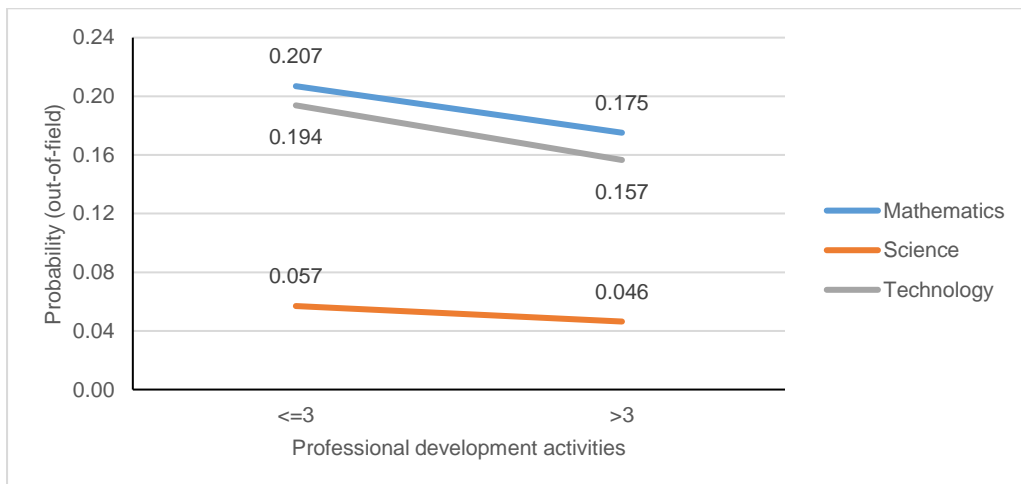
Source: PISA 2015.

Figure 5 Predicted probability of out-of-field teaching by subject and gender



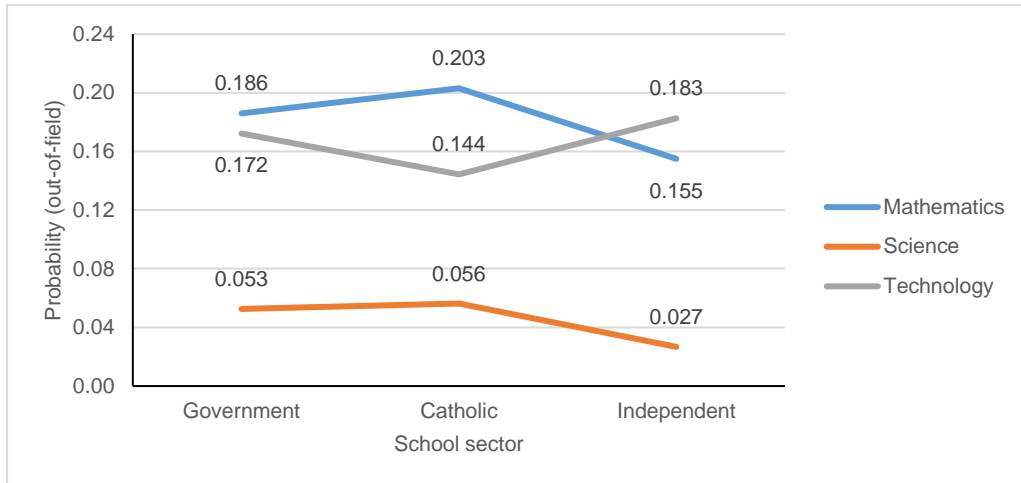
Source: PISA 2015.

Figure 6 Predicted probability of out-of-field teaching by subject and number of professional development activities undertaken



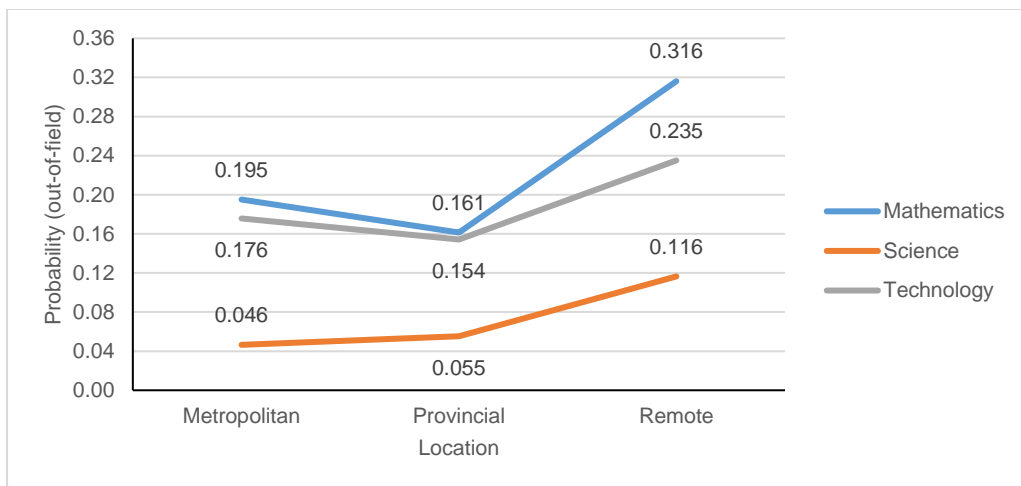
Source: PISA 2015.

Figure 7 Predicted probability of out-of-field teaching by subject and school sector



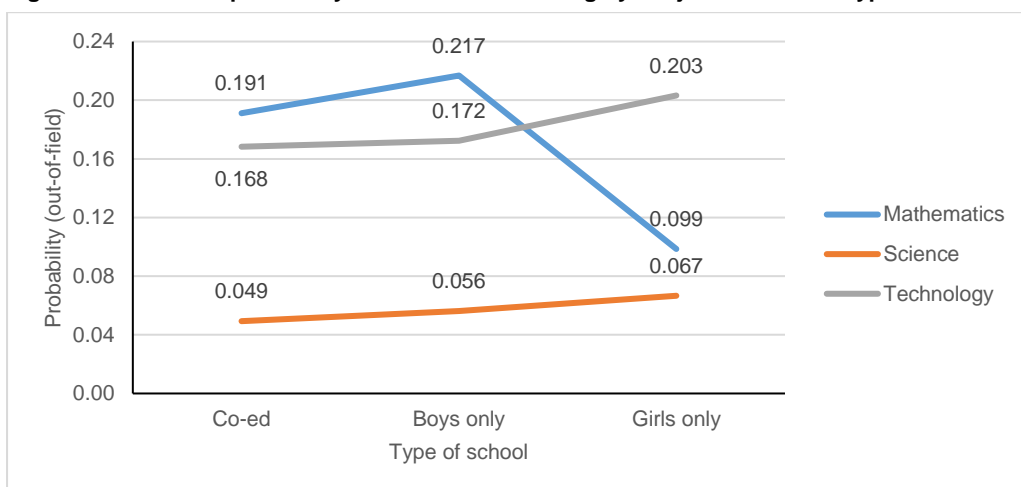
Source: PISA 2015.

Figure 8 Predicted probability of out-of-field teaching by subject and location



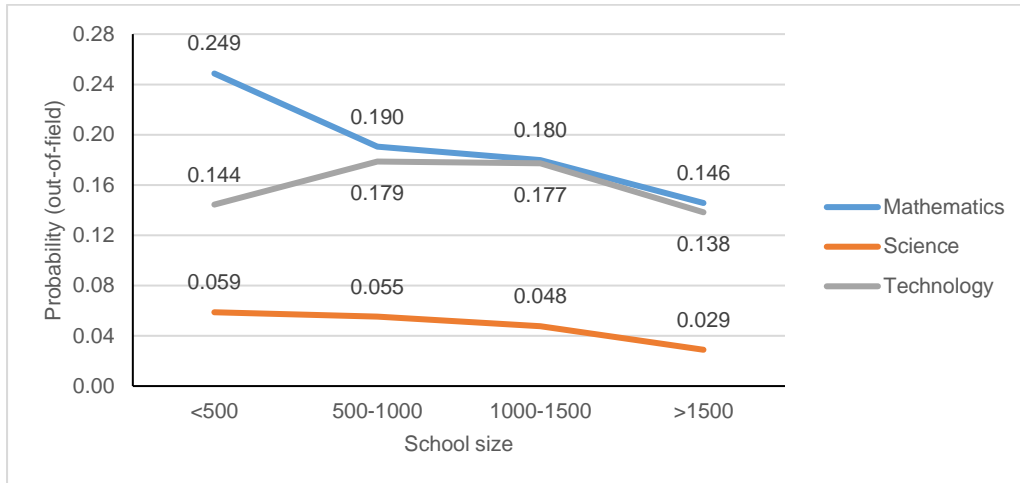
Source: PISA 2015.

Figure 9 Predicted probability of out-of-field teaching by subject and school type



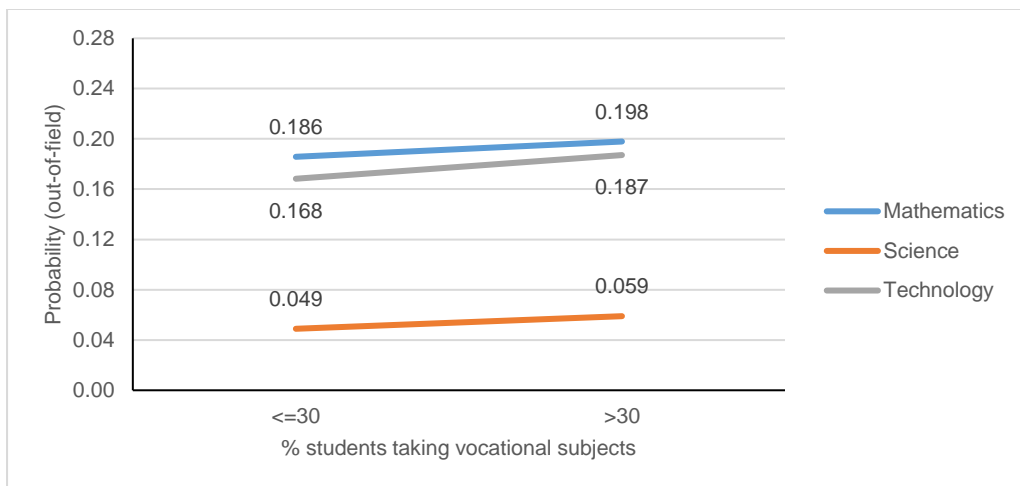
Source: PISA 2015.

Figure 10 Predicted probability of out-of-field teaching by subject and school size



Source: PISA 2015.

Figure 11 Predicted probability of out-of-field teaching by subject and % of students taking vocational subjects



Source: PISA 2015.

Interactions by sector

The sector of school is an indicator of the total funding available to schools, with generally more funds available to non-government schools than to government schools. Schools with more funding have a competitive advantage in the teacher labour market when recruiting teachers with the appropriate subject level qualifications. Sector also reflects the level of autonomy the school has, particularly in relation to teacher hiring and firing. Non-government schools have more autonomy than government schools. Schools with more autonomy are more likely to have larger discretionary components in their budgets.

Figure 12 shows the effect of teacher's age on out-of-field teaching varies by sector of school. The differences are most at the two ends of the age spectrum. Younger teachers (under 30 years or age) and older teachers (50 years and over) in independent schools are much less likely to be teaching out-of-field than teachers of similar ages in the other two sectors.

Teachers' experience in terms of the number of schools they have taught in has a different effect on out-of-field teaching across the three school sectors (see figure 13). Teachers at their first school, which

includes most first-year teachers, are much less likely to teach out-of-field in government and independent schools than in Catholic schools.

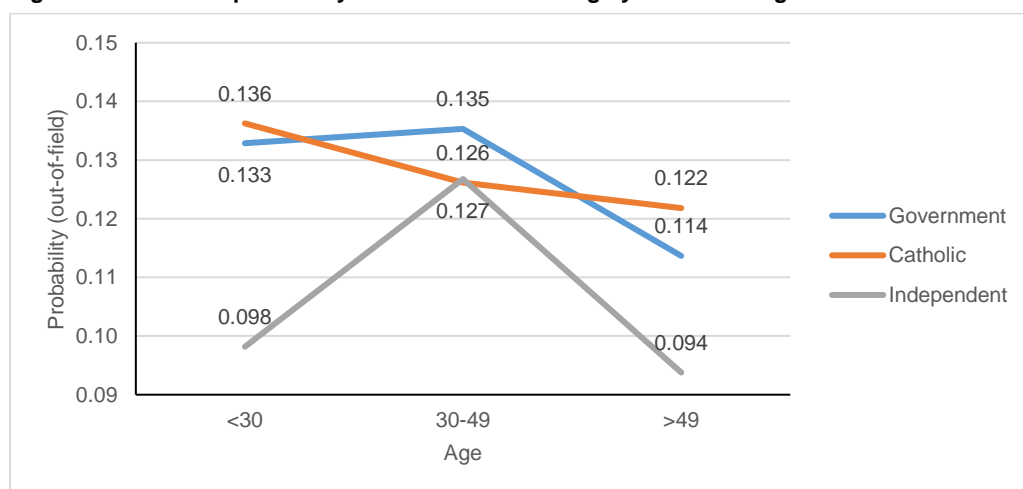
Figure 14 shows professional development activities have a relatively larger effect on out-of-field teaching for teachers in Catholic schools than in other schools. The probability of teaching out-of-field drops by 4.5 percentage points for teachers in Catholic schools who have completed more than three professional development activities compared to those who have completed fewer than this number.

Teachers on permanent employment contracts, in all three sectors, have more or less the same probability of teaching out-of-field, but this is not case for teachers on temporary contracts (see figure 15). While the probability is much higher for temporary teachers in government and Catholic schools, it is in fact lower for teachers in independent schools. This suggests employment contracts may be used for different purposes in the independent sector than in the other two sectors.

The education level of parents is also an indicator of school funding. Highly educated parents, who also generally have higher incomes, tend to send their children to more expensive independent and Catholic schools or selective government schools. These parents have higher expectations in terms of the quality of education for their children. It is thus unsurprising to find, after controlling for all other factors, teachers are less likely to be teaching out-field in schools where more than 75% of parents have higher education qualifications (see table 13). Figure 16 suggests some evidence of an interaction effect between parental education and sector of school. While the probability plot for teachers in government schools follows what we would expect, with the probability of out-of-field teaching declining with the proportion of parents with higher education qualifications, the plots for teachers in non-government schools do not follow this pattern. However, the estimates for non-government schools where less than 25% of students' parents have higher education qualifications are unreliable because they are based on very small sample sizes (see tables 9 and 11).

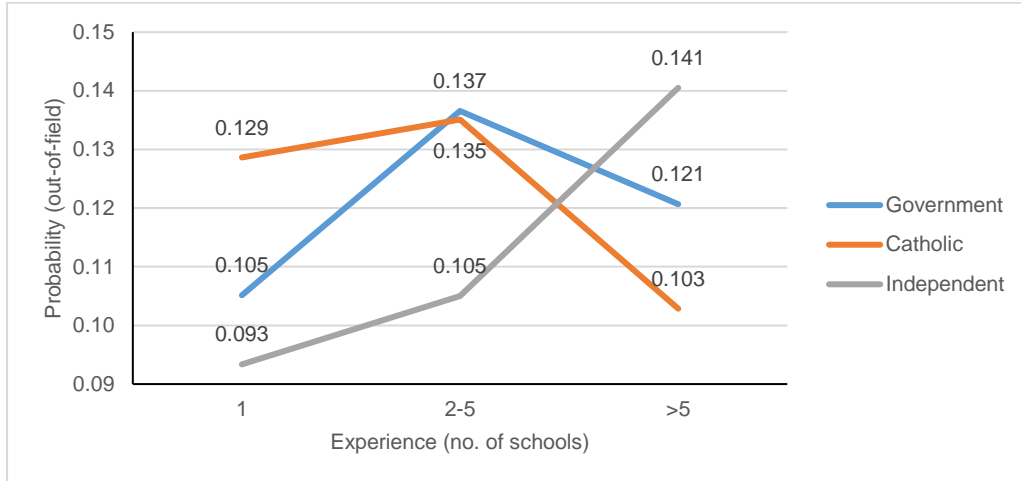
The probability of teaching out-of-field is higher for teachers in schools where more than 30% of students take vocational subjects than in schools where this proportion is less than this. The change in the probability is, however, much larger for teachers in non-government schools.

Figure 12 Predicted probability of out-of-field teaching by sector and age



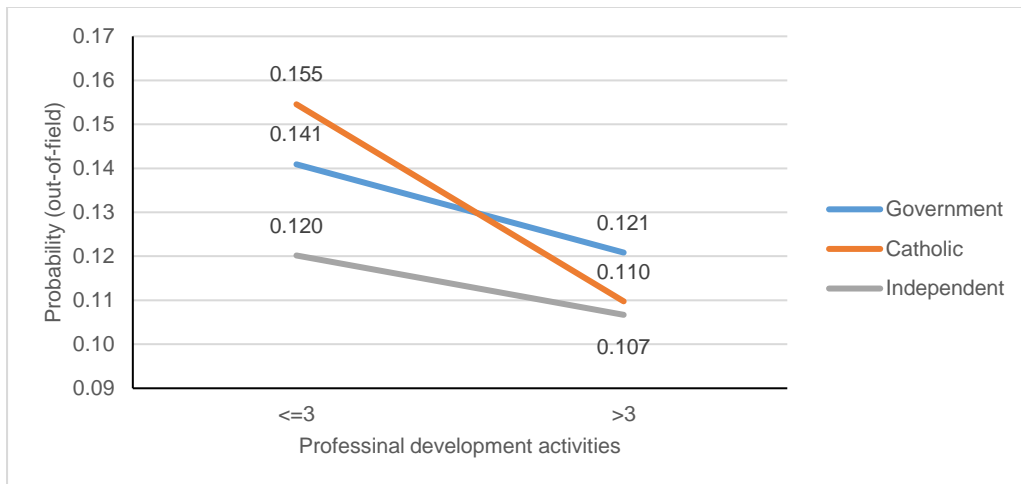
Source: PISA 2015.

Figure 13 Predicted probability of out-of-field teaching by sector and experience (no. of schools taught in)



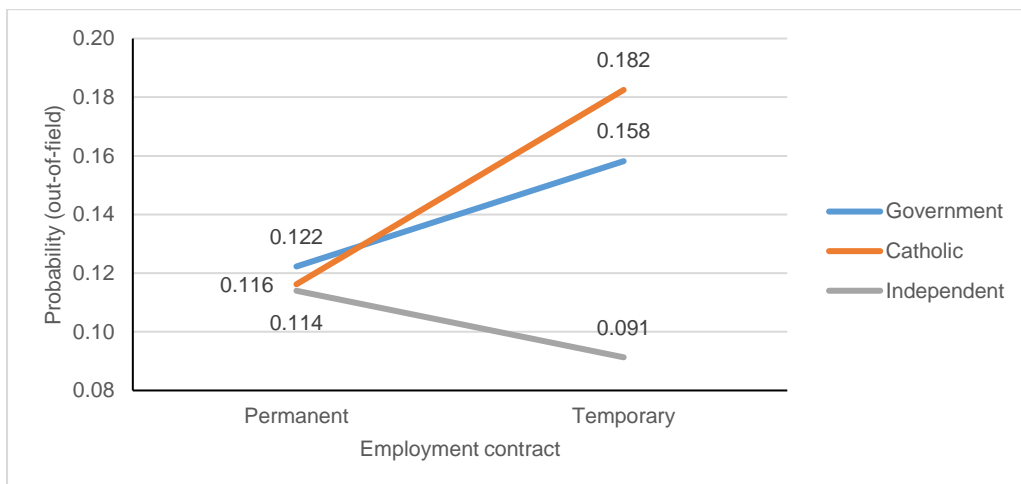
Source: PISA 2015.

Figure 14 Predicted probability of out-of-field teaching by sector and professional development activities



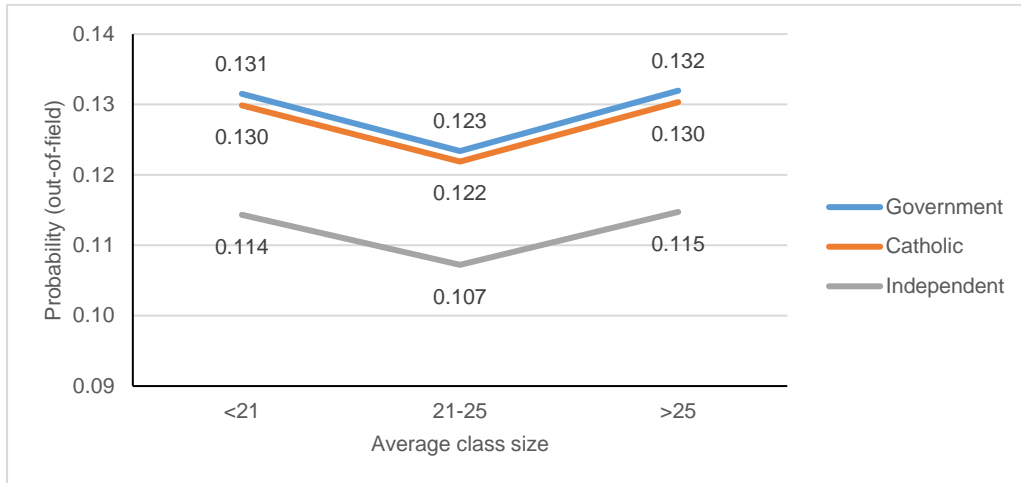
Source: PISA 2015.

Figure 15 Predicted probability of out-of-field teaching by sector and employment contract



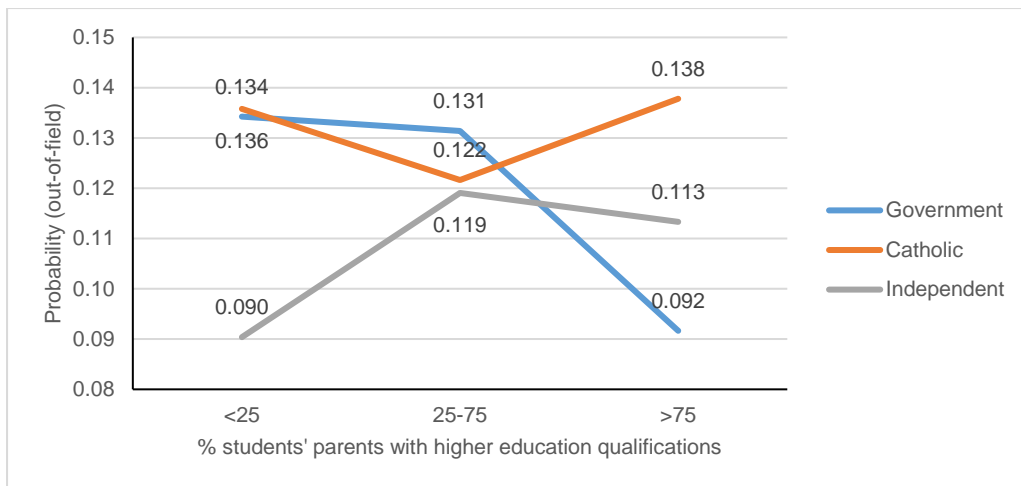
Source: PISA 2015.

Figure 16 Predicted probability of out-of-field teaching by sector and average class size



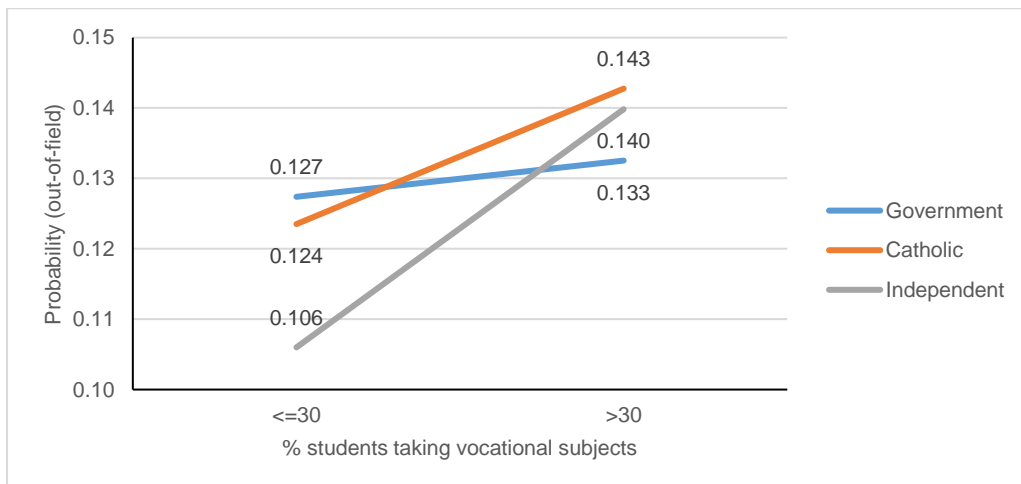
Source: PISA 2015.

Figure 17 Predicted probability of out-of-field teaching by sector and % of parents with higher education qualifications



Source: PISA 2015.

Figure 18 Predicted probability of out-of-field teaching by sector and % of students taking vocational subjects

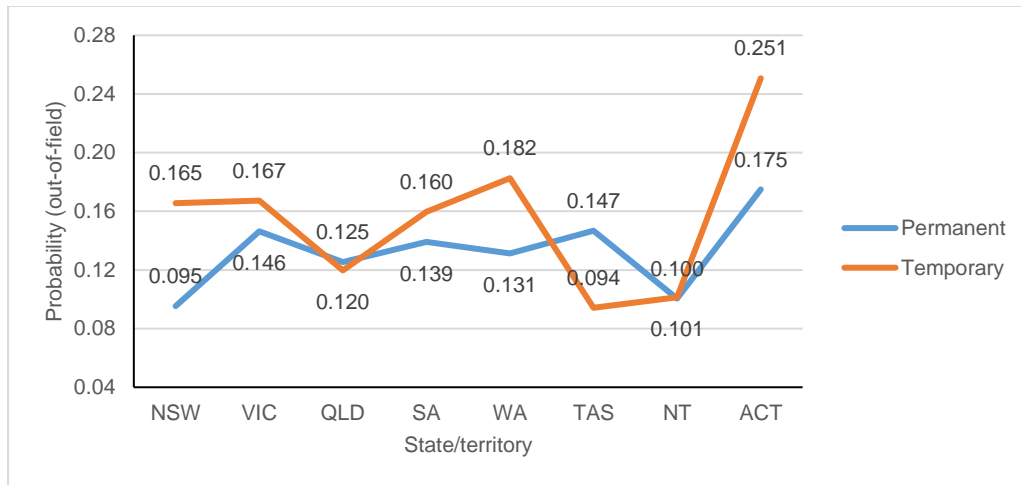


Source: PISA 2015.

Interaction between employment contract and state/territory

Figure 19 shows evidence of interaction between teachers' employment contracts and the state/territory they teach in. First, we already know out-of-field teaching is least likely for teachers in New South Wales (see table 13), but figure 19 shows that this is mainly because teachers on permanent contracts in this state are much less likely to be teaching out-of-field. Second, the probability of teaching out-of-field is not much different for teachers on temporary contracts in the two largest states, New South Wales and Victoria, but for teachers on permanent contracts the difference is 5.1 percentage points. Third, there is very little difference in the probability for permanent and temporary teachers in Queensland. Finally, Tasmania is the only state in which teachers on temporary contracts are less likely to teach out-of-field than those on permanent contracts.⁴⁰

Figure 19 Predicted probability of out-of-field teaching by employment contract and state/territory



Source: PISA 2015.

⁴⁰ As the confidence intervals for the two estimates are wide and overlapping, one must not read too much into this result.

Conclusion

This study reports on out-of-field teaching in STEM subjects (mathematics, science and technology) at Year 10 in Australian secondary schools using data from PISA 2015, which is a nationally representative survey of students, teachers and principals. It investigates the effect of staff shortage and school organisational practices (measured as school autonomy in the model) on out-of-field teaching. It also provides estimates of the probabilities of out-of-field teaching for teachers in specific contexts.

The study links data from the student, teacher and principal components of PISA 2015 using a common school identifier to create a unique dataset on teachers. For each teacher, the data contain a unique record for each subject they teach, which means there are between one and three records for each teacher. We define out-of-field teaching as when a teacher teaches a subject that was not part of their teacher education or training programme or other professional qualification. In the data, the sub-domains of science are unidentified. This means out-of-field teaching in science is under-reported. Consequently, controlling for all other factors, the predicted probabilities of teaching out-of-field in mathematics, science and technology are 18.7%, 5.1% and 17.1%, respectively. Although these estimates are based on data on teachers teaching Year 10 only, they provide a reasonable estimate of the average across all levels because generally out-of-field teaching is more common at junior levels and less common at senior levels.

The results show teachers are more likely to be teaching out-of-field in schools that report staff shortages. Other factors (confounders and mediators), correlated with both staff shortage and out-of-field teaching, however, drive this relationship. For example, sector of school is a confounder in this relationship as is the number of subjects that a teacher is qualified to teach. On the other hand, the number of subjects a teacher teaches is argued to be a mediator.

The study finds an inverse relationship between school autonomy, which is a proxy for school organisational practices, and out-of-field teaching, with more autonomy associated with less out-of-field teaching. As with staff shortage, other factors drive this relationship. Professional development activities and employment contract mediate the relationship, while sector of school confounds it.

Thus, there is evidence to support both the deficit (staff shortage) and organisational (school autonomy) hypotheses for explaining out-of-field teaching in these data. This is in contrast to Ingersoll (2004) who finds little evidence in support of the deficit or shortage hypothesis. The pathways linking staff shortage and school autonomy to out-of-field teaching are however complex and include intervening and moderating factors.

A full understanding of the results from this study requires knowing the role of school funding and school budgets in out-of-field teaching. We do not have direct measures of these in the data, but we can infer their likely roles through the effects of other factors in the model. For example, we can use sector of school as a proxy for the amount of funding available to schools. Independent and Catholic schools generally have more funding available than government schools. Here funding is from all sources, including student fees, government grants and income from endowments and other investments. The proportion of parents in the school with higher education qualifications is also an indicator of the funds available to schools, but this measure is probably weaker and less reliable as it is self-reported.

Similarly, school autonomy can be a proxy for flexible budgets or the discretionary component of the budget. We assume high levels of autonomy correspond to high levels of discretionary funding, because

without such funding autonomy is most likely to be limited. We should emphasise that with respect to budgets, it is the slack in the budget or the discretionary component of it that is important, not its overall size. This is because tight budgets, without a sufficient discretionary component constrains schools in the crucial decisions on staffing. As school autonomy is associated with sector of school, with independent schools with the highest level of autonomy and government schools with the least, we can infer from this that independent schools are most likely to have flexible budgets, followed by Catholic and government schools.

Funding affects a school's capacity to effectively participate in the teacher labour market. Those with better funding and flexible budgets can compete more effectively for qualified teachers, especially teachers qualified for subjects in demand, while those with not as good funding may find recruitment difficult and may consequently experience staff shortages.

With adequate funding schools can operate with a degree of slack in their staffing, which then gives them flexibility to meet short-term demand fluctuation from within the existing staff rather than having to rely on the external labour market. Short-term demand can eventuate from teachers going on sick leave or teachers temporarily doing non-teaching duties such as professional development or school sport. Meeting the short-term demand from existing staff carries less risk of teachers being assigned to out-of-field classes than meeting the demand from the riskier external labour market of casual teachers. Tight budgets mean schools are forced in using casual teachers to address short-term shortfalls in staffing. Casual teachers are frequently not qualified to teach the subjects they are assigned to teach.

Funding affects the type of employment contracts and professional development that schools can offer teachers. Employment contracts have a role in the type of teachers that will be attracted to a school as well as on teacher retention. With better funding schools can offer permanent contracts to teachers, which are associated with less out-of-field teaching. Professional development can be a strategy that schools can use to equip teachers with the skills and knowledge to teach additional subjects and thus reduce out-of-field teaching. Digital technologies have the potential to deliver professional development to a wide group of teachers, including those in remote locations and small schools. There is an obvious role for universities, teacher training organisations and subject associations to develop appropriate professional development activities that allow teachers to acquire subject qualifications.

The number of subjects that teachers are qualified to teach clearly affects out-of-field teaching. The more subjects they are qualified to teach, the less likely it is that they will be teaching out-of-field. From a policy perspective it is impractical to demand all teachers have qualifications to teach all subjects. The question then is what is the optimal number that ensures teachers have the depth of skills and knowledge to teach the subject. Currently many jurisdictions require new teachers to have qualifications to teach at least two subjects. The effect of this will take a while to filter through the system and over time it will reduce out-of-field teaching. It is however unclear the effect of this policy on student outcomes because when teachers have to specialise in two subjects, they will have a breadth of knowledge but the depth in each may be less.

The study identifies several other risk factors for out-of-field teaching and calculates the associated predicted probabilities. The significant teacher-level risk factors are the number of subjects a teacher teaches, the number of subjects a teacher is qualified to teach, age, employment contract, professional development and experience in terms of the number of schools a teacher has worked in. School context risk factors are the location and the state or territory where the school is and school size. The analyses show evidence of interactions between many of these factors. Some of these findings are not new and

others have reported similar results although the calculation of the predicted probabilities is something unique to this study. The variation in the probability among some groups of teachers have logical explanations, for other groups, however, the explanations are more complex and require further research.

Finally, addressing out-of-field teaching is more challenging for some schools because of structural barriers, such as location and size. While we know that school autonomy is related to less out-of-field teaching, simply giving more autonomy without the necessary funding may not solve the problem. Schools can mitigate the problem to a certain extent by adopting a hiring policy that mandates teachers are qualified to teach at least two subjects. For existing teachers, incentives could be offered for professional development that qualifies them to teach additional subjects. While a general teacher shortage in a particular field can cause out-of-field teaching, its effect will vary across schools and will depend on a range of factors as discussed in this study.

Questions for further research include:

- Why are teachers at their first school, which includes most first-year teachers, less likely to teach out-of-field? We postulate this could be a deliberate strategy of schools to ease new teachers' transition into the profession, but this needs verification with further research.
- What professional development activities influence out-of-field teaching? Do digital technologies have a role in delivering professional development to reduce out-of-field teaching?
- What explains the state and territory differences in out-of-field teaching? For example, why are teachers on permanent employment contracts in New South Wales less likely to teach out-of-field than similar teachers in most other states and territories?
- Why are female teachers more likely to teach out-of-field in mathematics?
- Why is a teacher in a girls only school less likely to teach out-of-field in mathematics than teachers in other schools?

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Appendix A Pairwise correlation between selected variables

Table A1 Pairwise correlations: selected teacher and school context variables

Variable	Variable											
	1	2	3	4	5	6	7	8	9	10	11	12
1 Age (years)	1.00											
2 Experience (years)	0.83	1.00										
3 Experience in current school (years)	0.55	0.66	1.00									
4 School funding from government	-0.07	-0.09	-0.05	1.00								
5 School sector ¹	0.03	0.06		-0.74	1.00							
6 % speaking language other than English at home	-0.02	-0.04		0.04	-0.14	1.00						
7 % parents with higher ed. Qualifications	0.07	0.09	0.04	-0.61	0.50	0.08	1.00					
8 % immigrant students	-0.02	-0.02		-0.07	-0.04	0.79	0.20	1.00				
9 ESCS	0.07	0.10	0.04	-0.65	0.59	-0.10	0.87	0.04	1.00			
10 PISA reading score	0.07	0.10	0.04	-0.55	0.47	0.04	0.68	0.22	0.73	1.00		
11 PISA maths score	0.08	0.10	0.06	-0.55	0.45	0.06	0.71	0.23	0.75	0.89	1.00	
12 PISA science score	0.08	0.10	0.05	-0.55	0.47		0.70	0.16	0.76	0.92	0.94	1.00

Note: Weighted estimates. Only includes correlations with $p < .01$.

1 Government=1 Catholic=2 Independent=3

2 <25% with higher education qualifications=1 25-75% with higher education qualifications=2 >75% with higher education qualifications=3

Source: PISA 2015.

Appendix B Regression results for models 5, 6, 7 and 8

Table B1 Determinants of out-of-field teaching in STEM subjects in Australia, 2015

Explanatory variable	Model 5		Model 6		Model 7		Model 8	
	Log odds	SE	Log odds	SE	Log odds	SE	Log odds	SE
<i>Organisational variable (level 3)</i>								
School autonomy	-0.396	0.277	-0.056	0.243	0.041	0.267	0.044	0.270
Staff shortage	0.147**	0.073	0.098	0.066	-0.020	0.076	-0.013	0.078
<i>Level 1 variable</i>								
Subject (base science)								
Mathematics	1.981***	0.168	1.842***	0.168	1.842***	0.167	2.79***	0.609
Technology	2.101***	0.196	1.667***	0.182	1.693***	0.184	1.329**	0.609
<i>Level 2 variable</i>								
Gender (base female)								
Male			-0.075	0.111	-0.086	0.112	0.184	0.255
Age group (base 30-49)								
<30			-0.038	0.167	-0.005	0.166	0.215	0.375
>49			-0.238*	0.129	-0.252*	0.131	-0.397	0.329
Qualification level (base bachelor)								
Lower than bachelor			0.039	0.239	0.026	0.239	0.048	0.246
Higher than bachelor			-0.002	0.148	0.079	0.149	0.08	0.150
Hours of work (base full-time)								
Part-time			-0.151	0.170	-0.156	0.178	-0.165	0.187
Employment contract (base permanent)								
Temporary			0.466**	0.185	0.462**	0.185	-0.061	0.380
Experience (base >5 yrs)								
1			-0.122	0.450	-0.119	0.445	-0.242	0.422
2-5			0.082	0.187	0.084	0.186	0.047	0.191
Exp. in current school (base >5 yrs)								
1			0.001	0.238	-0.034	0.238	0.027	0.237
2-5			-0.028	0.137	-0.063	0.137	-0.046	0.142
Exp. (no. of schools) (base 2-5)								
1			-0.278	0.170	-0.317*	0.171	-0.416**	0.210
>5			-0.137	0.133	-0.132	0.135	-0.2	0.180
No. of subjects currently teaching (base 1)								
2			1.723***	0.234	1.644***	0.230	1.674***	0.231
>2			2.599***	0.233	2.548***	0.232	2.611***	0.235
No. of subjects qualified to teach (base 1)								
>1			-2.417***	0.180	-2.412***	0.182	-2.494***	0.190
Professional development (base >3)								
<=3			0.275**	0.112	0.298***	0.113	0.199	0.283
Satisfaction with current job			-0.003	0.067	0.015	0.067	0.027	0.069
Satisfaction with profession			-0.068	0.066	-0.083	0.067	-0.099	0.069

Table B1 Continued

Explanatory variable	Model 5		Model 6		Model 7		Model 8	
	Log odds	SE	Log odds	SE	Log odds	SE	Log odds	SE
<i>Level 3 variable</i>								
Average PISA mathematics score					-0.003	0.002	-0.003	0.002
Sector (base government)								
Catholic					-0.082	0.160	-0.355	0.383
Independent					-0.112	0.210	-0.765*	0.447
Location (base metro)								
Provincial					-0.134	0.160	0.222	0.313
Remote					0.866*	0.524	1.268*	0.751
State/territory (base Queensland)								
New South Wales					-0.272	0.191	-0.426**	0.215
Victoria					0.275	0.189	0.253	0.199
South Australia					0.179	0.219	0.169	0.218
Western Australia					0.169	0.255	0.075	0.286
Tasmania					0.192	0.266	0.257	0.305
Northern territory					-0.334	0.553	-0.347	0.533
Australian Capital Territory					0.653**	0.282	0.561**	0.277
School size (base <500)								
500					-0.092	0.199	-0.083	0.429
1000-1500					-0.148	0.223	-0.27	0.453
>1500					-0.569*	0.310	-0.899	0.656
Class size (base >25)								
<21					0.010	0.248	-0.006	0.261
21-25					-0.086	0.134	-0.109	0.137
School type (base co-ed)								
Boys only					0.120	0.252	0.174	0.478
Girls only					-0.123	0.251	0.402	0.510
% immigrant students (base <=30)								
>30					-0.039	0.170	-0.049	0.179
% students speaking language other than English at home (base <=30)								
>30					-0.363	0.244	-0.325	0.258
% students' parents with higher ed. qualifications (base 25-75)								
<25					0.065	0.157	0.035	0.166
>75					-0.159	0.213	-0.559	0.501
% students studying vocational subjects (base <=30)								
>30					0.160	0.172	0.166	0.328
<i>Interactions</i>								
Subject # Gender								
Mathematics # Male							-0.597**	0.281
Technology # Male							-0.095	0.314

Table B1 Continued

Explanatory variable	Model 5		Model 6		Model 7		Model 8	
	Log odds	SE	Log odds	SE	Log odds	SE	Log odds	SE
Subject # Age								
Mathematics # <30							-0.099	0.374
Maths # >49							-0.364	0.342
Technology # <30							-0.591	0.438
Technology # >49							0.639*	0.367
Subject # Professional development								
Mathematics # <=3							0.027	0.295
Technology # <=3							0.101	0.336
Subject # Sector								
Mathematics # Catholic							0.097	0.334
Maths # Independent							0.527	0.496
Technology # Catholic							-0.36	0.349
Technology # Independent							0.9	0.495
Subject # Location								
Mathematics # Provincial							-0.545*	0.330
Maths # Remote							-0.332	0.720
Technology # Provincial							-0.434	0.371
Technology # Remote							-0.764	0.933
Subject # School size								
Mathematics # 500-1000							-0.402	0.510
Maths # 1000-1500							-0.312	0.530
Maths # >1500							-0.03	0.743
Technology # 500-1000							0.424	0.534
Technology # 1000-1500							0.598	0.553
Technology # >1500							0.832	0.742
Subject # School type								
Mathematics # Boys only							0.049	0.620
Maths # Girls only							-1.448**	0.613
Technology # Boys only							-0.136	0.553
Technology # Girls only							-0.086	0.554
Subject # % students studying vocational subjects								
Mathematics # >30%							-0.156	0.324
Technology # >30%							-0.098	0.373
Sector # Age								
Catholic # <30							0.132	0.399
Independent # >49							0.268	0.319
Catholic # <30							-0.334	0.472
Independent # >49							-0.249	0.372
Sector # Employment contract								
Catholic # Temporary							0.332	0.418
Independent # Temporary							-0.765	0.726
Sector # Exp. No. of schools								
Catholic # 1							0.335	0.383
Catholic # >5							-0.235	0.325
Independent # 1							0.233	0.499
Independent # >5							0.679*	0.370

Table B1 Continued

Explanatory variable	Model 5		Model 6		Model 7		Model 8	
	Log odds	SE	Log odds	SE	Log odds	SE	Log odds	SE
Sector # Professional development								
Catholic # <=3							0.311	0.278
Independent # <=3							-0.065	0.312
Sector # % students' parents with higher ed. qualifications								
Catholic # <25%							0.145	0.652
Catholic # >75%							0.763	0.606
Independent # <25%							-0.471	0.541
Independent # >75%							0.478	0.571
Sector # % students studying vocational subjects								
Catholic # >30%							0.173	0.389
Independent # >30%							0.397	0.522
Contract # State/territory								
Temporary # New South Wales							0.967**	0.478
Temporary # Victoria							0.308	0.472
Temporary # South Australia							0.309	0.564
Temporary # Western Australia							0.641	0.620
Temporary # Tasmania							-0.629	0.751
Temporary # Northern Territory							0.087	0.713
Temporary # ACT							0.77	0.978
Constant	4.226***	0.251	-3.257	0.236	-2.988	0.360	-3.056	0.557
Random effects parameters								
School (variance) σ_{δ}^2	0.782	0.168	0.718	0.188	0.622	0.168	0.666	0.175
Sch>teacher (variance) σ_{μ}^2	2.096	0.534	0.267	0.378	0.308	0.378	0.341	0.385
Intra-class correlation								
School	0.127	0.025	0.168	0.035	0.147	0.034	0.155	0.034
Teacher>school	0.467	0.050	0.230	0.084	0.220	0.082	0.234	0.082
Information criterion								
Akaike (AIC)	4679		4152		4159		4161	
Bayesian (BIC)	4727		4330		4500		4864	
McKelvey & Zavoina pseudo R ²	0.203		0.380		0.386		0.425	

Notes: *significant at 10 per cent; **significant at 5 per cent; ***significant at 1 per cent.

Model 5: including subject (level 1) as explanatory variable.

Model 6: including teacher characteristics (level 2) as explanatory variables.

Model 7: including school characteristics (level 3) as explanatory variables.

Model 8: including interactions.

Source: PISA 2015.