NFER
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Report for The Royal Society

Retaining Science, Mathematics and Computing teachers

Jack Worth and Jens Van den Brande

National Foundation for Educational Research (NFER)

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Executive Summary

England's secondary schools face a significant teacher supply challenge over the next decade. However, secondary teacher numbers have been falling since 2010, due to increasing numbers of teachers leaving the state sector and insufficient numbers entering the profession. The teacher supply challenge is particularly acute in science, mathematics, and computing (SMC). Recruitment of new trainees has been consistently below target for several years, and retaining teachers is a particular challenge in SMC subjects.

The Royal Society has commissioned the National Foundation for Educational Research (NFER) to undertake exploratory research into the SMC teacher workforce in England. Using new analysis of international survey data, the research sheds new light on the reasons why rates of teachers leaving the profession are higher among SMC teachers compared to non-SMC teachers.

The key findings of this research are:

- Science, maths and technology (which includes computing teachers as well as teachers of other technology subjects in the study dataset) (SMT) teachers have different working patterns; for example, science teachers tend to work slightly longer hours, and spend more time planning and preparing lessons, whereas mathematics and technology teachers work shorter hours than non-SMC teachers.
- However, different working patterns do not seem to explain why science, mathematics and technology teachers' satisfaction with teaching is slightly lower than non-SMT teachers (although the differences in job satisfaction between SMT and non-SMT teachers are not significant, which is due in part to small sample sizes). Therefore, this suggests that different workload is unlikely to explain why SMC teacher leaving rates are higher.
- Science and maths teachers have lower levels of self-efficacy (belief in their own ability) in student engagement. Generally SMT teachers have lower levels of self-efficacy, relating to classroom management and instruction, than non-SMT teachers, although the differences are not statistically significant. Lower self-efficacy among SMT teachers seems to explain part of the reason why their satisfaction with teaching is slightly lower than among non-SMT teachers.
- Higher-paid options outside teaching is one often-cited reason why SMC leaving rates are higher compared to non-SMC teachers. The research literature finds evidence of this being the case.
- However, this may not necessarily imply that financial incentives are the only policy remedy. Ex-teachers of STEM and non-STEM subjects both gave 'workload' as the main reason for having left teaching. The government has launched a range of initiatives at encouraging school leaders to reduce unnecessary teacher workload. Focused efforts to reduce the science teacher workload may help to improve retention.
- High-quality professional development, especially for early-career teachers, is also likely to help improve teachers' self-efficacy, satisfaction and their likelihood of staying in teaching.
- Further research is required to understand more about the key reasons why SMC teachers have lower retention rates than non SMC teachers. We present some suggestions of potentially fruitful avenues to explore.

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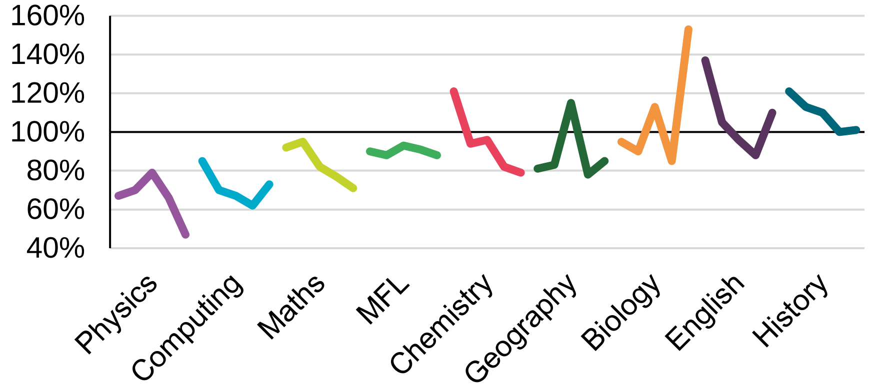
1. Introduction

England's secondary schools face a significant teacher supply challenge over the next decade. The Department for Education (DfE) forecasts that secondary schools will need 15,000 more teachers between 2018 and 2025 to meet a 15 per cent rise in pupil numbers. However, secondary teacher numbers have been falling since 2010, due to increasing numbers of teachers leaving the state sector and insufficient numbers entering (Worth *et al.,* 2019).

The teacher supply challenge is particularly acute in science, mathematics, and computing (SMC), as well as modern foreign languages. Figure 1 shows the most recent data on entry into postgraduate teacher training compared to the DfE's target, for a range of subjects. Recruitment for physics, computing and mathematics has been consistently below target since 2014/15. Recruitment for chemistry teacher training has steadily deteriorated since 2014/15 to a position of being 20 per cent below target in 2018/19. In contrast, recruitment to biology increased in 2018/19, which may be in response to an increase in the training bursary from £10-15,000 to £26,000.

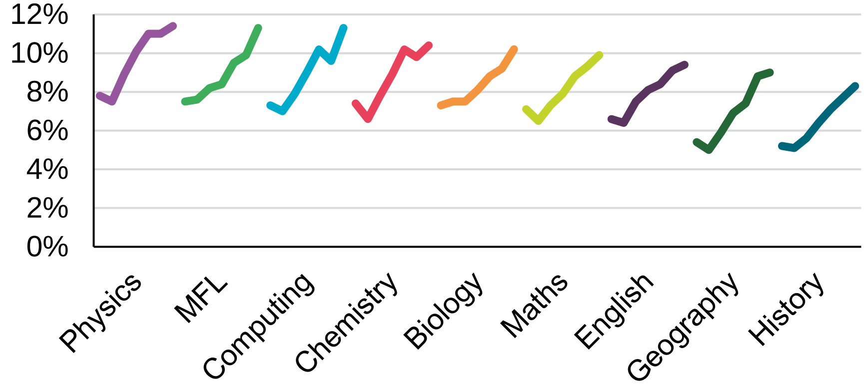
Retaining teachers is just as important as recruiting them for solving the teacher supply challenge: every teacher successfully retained is one less that needs to be recruited. However, retaining teachers is particularly challenging in SMC subjects. Figure 2 shows the proportion of teachers leaving teaching in the state sector between 2011/12 and 2017/18 by subject. It shows that leaving rates in all subjects have risen by around 3 percentage points since 2011. However, leaving rates are above average for physics, computing, chemistry, biology and mathematics (the 2017/18 average was 9.5 per cent).

Figure 1 Initial teacher training entrants in England compared to target (%), 2014/15-2018/19



Source: DfE, 2018a

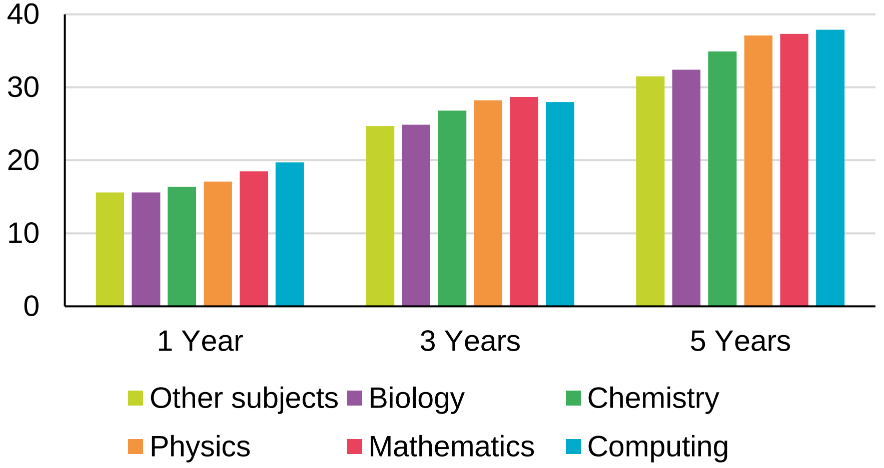
Figure 2 Proportion of working-age teachers leaving teaching in the state sector in England (%), 2011/12-2017/18



Source: DfE, 2018b

Retaining teachers in the first few years of their career is also more challenging for SMC subjects. Figure 3 shows the proportion of the 2010 cohort of newly qualified teachers that entered teaching in the state sector, but had left within the first five years. For non-SMC subjects, around a quarter of new entrants are no longer teaching in the state sector after three years and a third of new teachers are no longer teaching in the state sector after five years. Both figures are higher among teachers of biology, chemistry, physics, mathematics and computing.

Figure 3 Proportion of qualified teachers that entered state-sector teaching in 2010, who subsequently left (%)



Source: DfE, 2018b

1.1 Why are SMC teachers more likely to leave?

Previous research has highlighted a number of potential reasons why SMC teachers are more likely to leave teaching. The most often cited reason is that, as graduates in STEM subjects, SMC teachers have higher-paid alternative career options that make it less attractive to be a teacher. Graduate earnings data published by the Department for Education shows that graduates of computing, chemistry, physics and mathematics tend to earn more five years after graduation than average (STRB, 2018). Analysis of Labour Force Survey data by the Migration Advisory Committee confirms this same pattern, and shows that the gap in pay between non-teachers and teachers with degrees in the same subject is higher among STEM graduates (MAC, 2017).

However, the most cited reason ex-teachers give for why they left teaching is workload (DfE, 2017). A recent survey of ex-teachers conducted by the DfE found that workload was the most-cited reason for having left among both STEM and non-STEM teachers. While this may be an important reason why teachers leave, it may not be an important reason for explaining different leaving rates between subjects.

Other common reasons for teachers leaving are feeling unsupported and undervalued by school leaders (Lynch *et al*., 2016; DfE 2017), government initiatives and pressure from Ofsted, pupil behaviour and a lack of part-time and flexible working opportunities (Worth *et al*., 2018; DfE 2017). Opportunities for progression and high-quality professional development are also factors that make it more likely teachers will stay in the profession (DfE, 2017; Allen and Sims, 2017). However, there is also no indication from the research that these issues are particularly prevalent among SMC teachers, so may not be factors that are likely to drive differences in leaving rates between subjects.

1.2 Motivation for this research

With this background in mind, the Royal Society has commissioned the National Foundation for Educational Research (NFER) to undertake exploratory research into the SMC teacher workforce in England. The research aims to shed new light on the reasons why rates of teachers leaving the profession are higher among SMC teachers compared to the other secondary teachers. We then aim to develop recommendations for policy actions to improve SMC teacher retention.

In particular we use new analysis of international survey data to explore two potential reasons why SMC teacher leaving rates are higher: a higher level/ different pattern of workload and lower self-efficacy. We also briefly review the literature on teacher pay, which is often cited as a leading reason why SMC teachers have higher leaving rates, but present no new analysis on this issue.

1.3 Data and methodology

Teaching and Learning International Study (TALIS)

We use data from the OECD’s Teaching and Learning International Study (TALIS). TALIS is an international survey of teachers that was conducted in 33 countries in 2013.

England participated in the study, but not the other UK countries. The England data is based on surveys from 2,496 teachers in 154 secondary schools (there was also a primary teacher study but England did not participate). The study was conducted again in 2018, and the findings are due to be published in June 2019. England participated in the 2018 cycle, including teachers in primary and lower secondary schools.

The survey collected data on a range of topics, which makes it a rich dataset for analysing the research questions of this study. The data contains information on teachers’ typical working hours, including a breakdown of different tasks, teachers’ perceptions of their initial training, job satisfaction, working conditions, professional development, learning environments and self-efficacy.

However, TALIS is an observational study, providing a cross-section of information at a single point in time. It cannot reveal causal relationships with any certainty, only associations between variables measuring the characteristics of different teachers.

We are interested in science, mathematics and computing teachers, but our analysis is limited by the definitions that are possible within the data. One of the survey questions asks what subject teachers teach (respondents could select more than one subject). The categories include science (covering physics, chemistry, biology and general science), mathematics and technology (covering ICT, computer science and also design and technology). Science and mathematics are consistent with groups of interest, but technology is broader than we would ideally like. Using data from the School Workforce Census, we estimate that computing (which includes both ICT and computer science) represents around 40 per cent of the 'technology' group, so the results do not necessarily apply solely to computing teachers.

Throughout this report we use the abbreviation "SMC" to mean teachers of sciences, mathematics and computing, where we can distinguish computing teachers from all technology teachers. As we are unable to distinguish computing teachers from all technology teachers in the TALIS survey, we use the term "SMT" teachers.

We are also limited by the sample sizes within the data, which are relatively small when looking at subject groups. Table 1.1 shows the number of teachers of each subject in our analysis. Combined with the complex sampling design, this means that the level of uncertainty is relatively high. Confidence intervals are presented throughout to demonstrate the level of uncertainty around the results. In the charts presented, if the confidence interval does not overlap the axis, then the average difference between the subject group and non-SMT teachers is statistically significant. We compare the working hours and views of science, mathematics and technology (SMT) teachers with the group of teachers that do not teach any of these subjects.

Table 1.1 Number of full-time teachers in TALIS

Subject	Number of full-time teachers
Science	347
Mathematics	438
Technology	303
Non-SMT	1,232
Total	**2,165**

Note: The sum of the subject totals sums to more than the overall total because teachers could select more than one subject.

A limitation of TALIS is that it does not measure teacher retention directly. We use a proxy: a scale that measures teachers' satisfaction with teaching[1]. NFER research has highlighted that job satisfaction is

[1] The scale is derived from responses to the extent of agreement with four statements: "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".

strongly correlated with intentions to leave the profession and is an important push and pull factor for actual decisions to leave (Lynch *et al.,* 2016; Worth *et al.*, 2018).

We also build a statistical model to understand the extent to which different factors (personal characteristics, working hours and self-efficacy) explain any differences in satisfaction with teaching between teachers of the different subjects.

Key SMC teacher supply data summaries

In section 6 we present a key data summary on the latest teacher supply data for SMC subjects. We present data on teachers of: biology, chemistry, physics, mathematics and computing.

We present data from the School Workforce Census (SWC), Teacher Supply Model (TSM), Initial teacher training (ITT) census and Higher Education Statistics Agency (HESA) data, which includes:

- Current headcount of teachers, and the latest projections of future need (TSM)
- Headcount of teachers entering and leaving the profession each year (SWC)
- Number of teachers training to teach each year, and the latest projections of future ITT needs (ITT census, TSM)
- Number of first year undergraduates in England studying degree subjects that DfE regards as relevant post A-level qualifications for teaching each subject (HESA data).

1.4 Structure of this report

Section 2 presents data from TALIS on the extent to which workload, job satisfaction and self-efficacy differ between SMC teachers and non-SMC teachers.

Section 3 explores the extent to which the differences in working pattern, self-efficacy and views on professional development explain why satisfaction with teaching is slightly lower among SMC teachers.

Section 4 briefly reviews the literature on relative pay as an explanation for why SMC teacher leaving rates are higher compared to non-SMC teachers.

Section 5 draws conclusions from this research and outlines some suggestions for policies to improve SMC teacher retention.

Section 6 presents a series of key teacher supply data summaries for each of the five SMC subjects: biology, chemistry, computing, mathematics and physics. These show the current situation and set out the future teacher supply challenge for each subject.

2. How do SMT teachers differ to non-SMT teachers?

2.1 Working hours

We compare the overall working hours of full-time science, mathematics and technology teachers with teachers who do not teach any of these subjects. We also compare the amount of time they report spending on teaching and a variety of non-teaching activities (which we refer to throughout as 'working pattern'). To ensure we compare like with like across subject groups, we only include full-time teachers in our analysis.

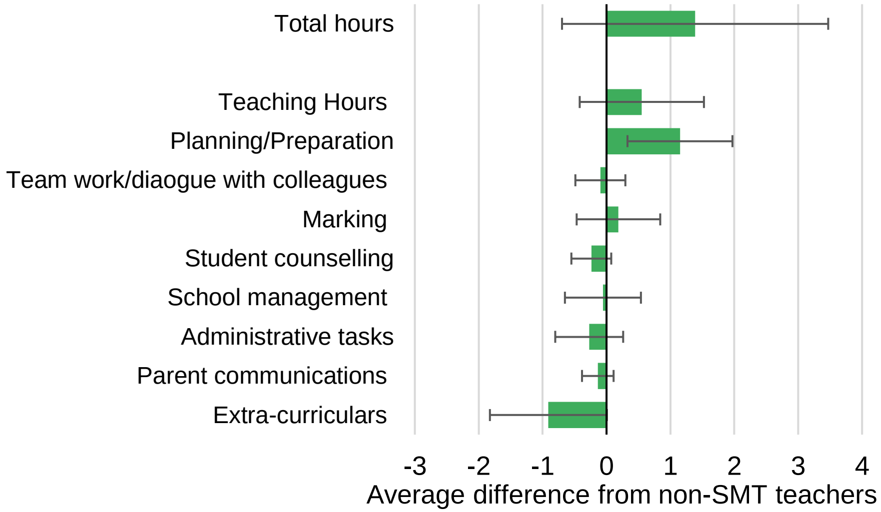
Across all full-time teachers in TALIS, the average weekly working hours in England is around 48 hours, which is consistent with other data sources such as the Labour Force Survey and Understanding Society (Worth *et al.*, 2018; Worth *et al.*, 2019). Average working hours are fairly similar across subjects, but there are some differences that we explore.

Figure 4 shows that, on average, science teachers work almost an hour and a half more per week than non-SMT teachers. Around half an hour of this difference is due to more time spent teaching. However, both estimates are uncertain due to the wide variation in working hours within each subject.

Science teachers spend around one hour more per week planning and preparing for lessons than non-SMT teachers, which is a statistically significant difference. This could be driven by the need for science teachers to regularly teach outside of their specialism, e.g. biology teachers teaching physics. The need to regularly teach outside of specialism is itself driven by a combination of general science teaching (particularly in Key Stage 3, but also in schools that do not offer separate sciences at GCSE) and/or have shortages of specialists in some subjects (e.g. physics). More time spent on planning and preparation among science teachers could also be due to the complexity of preparing for practical science lessons, or having fewer existing curriculum resources to apply in teaching so having to devise resources independently.

There are very few differences in the time science teachers spend on other non-teaching activities compared to non-SMT teachers, except for extra-curricular activities, which science teachers spend almost an hour less doing than non-SMT teachers. However, this difference is not statistically significant.

Figure 4 Average difference in working hours between science and non-SMT teachers



Note: The total of all the net differences in the different activities do not necessarily sum to the net difference in total hours because they come from separate survey questions.

Figure 5 shows that mathematics teachers work, in total, around two hours less per week than non-SMT teachers. Like science teachers, mathematics teachers spend slightly more time per week teaching and planning/preparing for lessons than non-SMT teachers. However, none of these differences are statistically significant. There is little difference in the amount of time mathematics teachers spend on marking, student counselling or parent communications compared to non-SMT teachers.

However, mathematics teachers spend around half an hour less per week on team work and dialogue with colleagues, almost an hour less on school management and administrative tasks and around an hour and a half less on extra-curricular activities than non-SMT teachers. These findings are all statistically significant.

Figure 6 shows that technology teachers work, on average, more than three and a half hours less per week than non-SMT teachers. While they spend slightly more time teaching, they spend slightly less time on many non-teaching activities. One plausible explanation for the lower working hours for technology teachers is reduced focus and attention from school leaders as, because it is does not contain subjects that count towards the EBacc, exam results are of less importance for a school's overall accountability measure.

Figure 5 Average difference in working hours between mathematics and non-SMT teachers

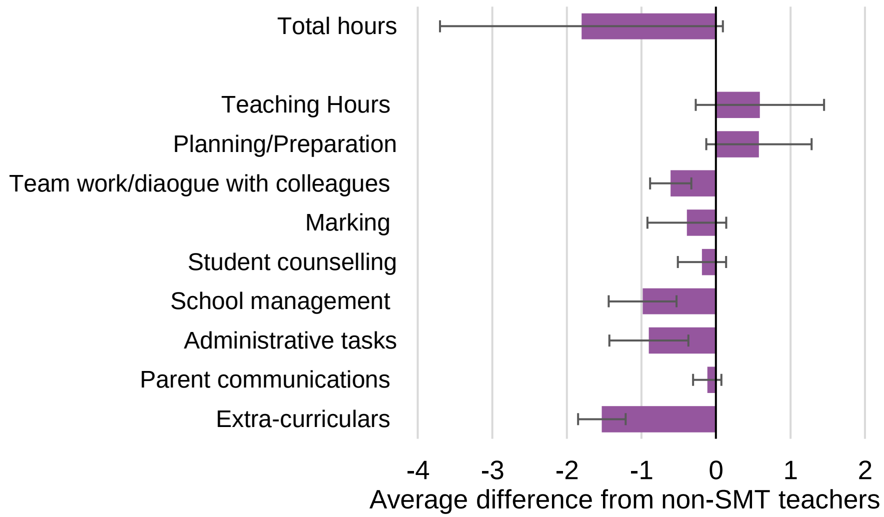
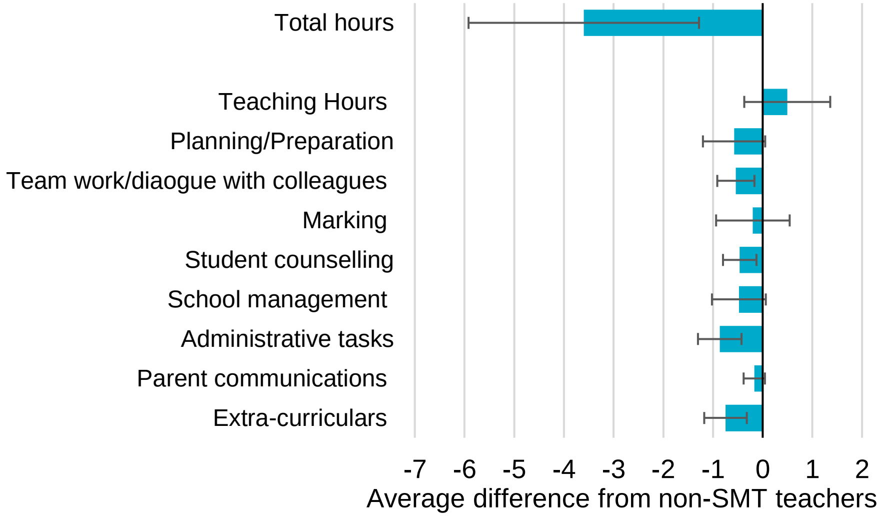


Figure 6 Average difference in working hours between technology and non-SMT teachers

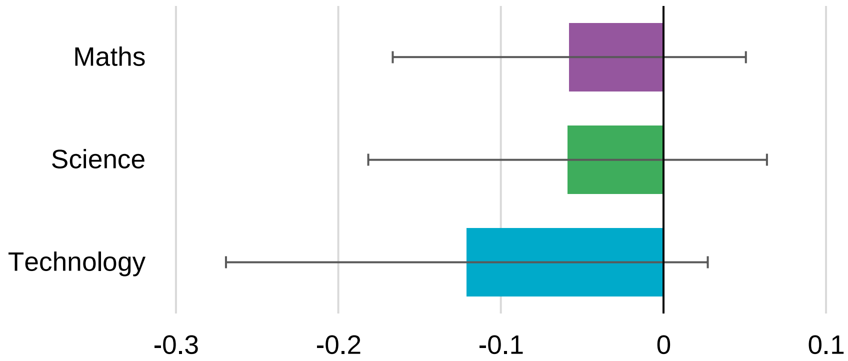


2.2 Satisfaction with teaching

As described in the methodology section, we use a 'satisfaction with the teaching profession' scale as a proxy for teacher retention. Figure 7 shows that science, mathematics and technology teachers each have slightly lower satisfaction with teaching compared to non-SMT teachers. This is equivalent to around 0.05 standard deviations for science and mathematics teachers and 0.1 standard deviations for technology teachers[2]. However, none of these differences are statistically significant, which may be due to the fact that the study is underpowered and did not have a large enough sample size to detect a difference between SMT teachers non-SMT teachers.

While this evidence is *consistent* with the fact that SMT teacher leaving rates are higher than non-SMT teacher leaving rates, it doesn't necessarily suggest that these observed differences in satisfaction are sufficient to *explain* the entire gap in leaving rates. There is likely to be a combination of factors explaining why the leaving rates of SMT teachers are higher than non-SMT teachers, and lower job satisfaction may explain part of it. It is not clear from this analysis to what extent differences in job satisfaction are driving differences in teacher leaving rates.

Figure 7 Average difference in 'Satisfaction with the profession' measure (compared to non-SMT teachers)



[22] Standard deviation is a measure of how spread out the data is between different individuals.

2.3 Self-efficacy

Self-efficacy is defined as an individual's belief in their ability to achieve their goals. The TALIS survey measures several aspects of self-efficacy, relating to:

- classroom management: the extent to which teachers feel they can control disruptive behaviour and get students to follow classroom rules
- instruction: the extent to which teachers feel they can craft good questions and provide alternative explanations when students are confused
- student engagement: the extent to which teachers feel they can help students value learning and motivate students who show low interest in school work.

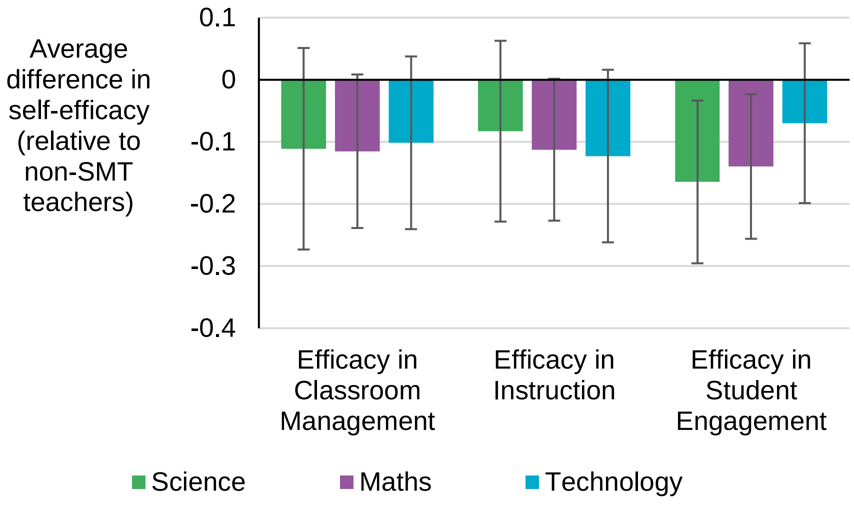
Self-efficacy could be an important factor in explaining teacher retention, as poor self-efficacy could have an impact on self-confidence which, in turn, could affect teachers' job satisfaction and result in them being more likely to leave teaching.

Figure 8 shows that SMT teachers have lower self-efficacy in classroom management and instruction than non-SMT teachers. The differences are equivalent to around 0.1 standard deviations, but are not statistically significant, which means there is uncertainty as to whether these differences are due to more than just chance.

Self-efficacy in student engagement appears to be an important factor for SMT teachers. In particular, science and mathematics teachers report finding it more challenging to engage their students in learning. Both groups report lower self-efficacy in student engagement of around 0.15 standard deviations, compared to non-SMT teachers, and these differences are statistically significant. Lower self-efficacy with student engagement among science and mathematics teachers could be that pupils find it more difficult to engage with the subject content because it is more abstract or challenging than in other subjects. Another potential, albeit speculative, explanation is the impact of the higher-stakes exam pressure from accountability measures (e.g. EBacc) on student anxiety in science and maths, which makes engagement more challenging.

These differences in self-efficacy could help to explain why SMT teachers have slightly lower job satisfaction than non-SMT teachers, and potentially explain part of the reason why retention rates are lower. We explore this analysis formally in the following section.

Figure 8 Average difference in self-efficacy measures (compared to non-SMT teachers)



2.4 Professional development

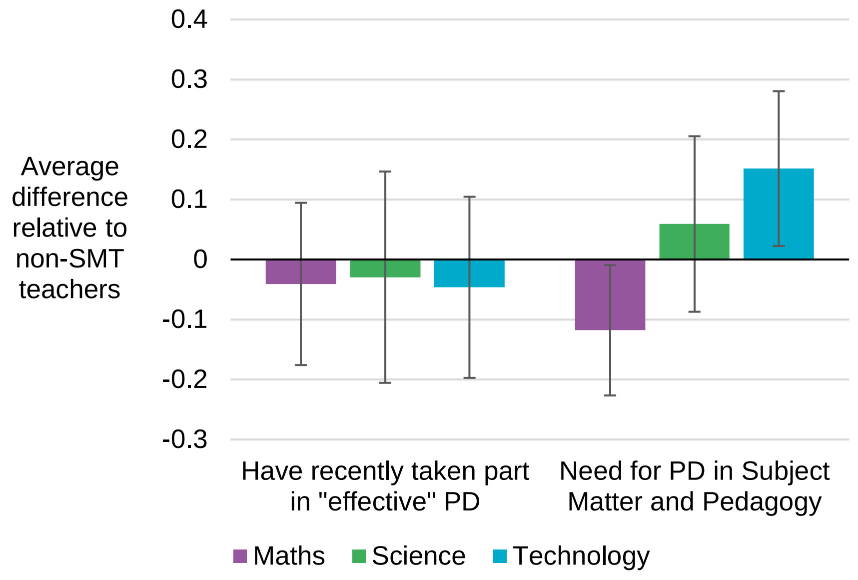
TALIS measures teachers' views on the professional development (PD) they have been involved in. One scale asks those teachers who have recently participated in PD (the vast majority in the survey) about whether the PD they participated in had features associated with "effective" PD. These features are identified from the wider research literature, and include: PD with a group of colleagues, PD involving active and collaborative learning and PD that is over an extended time period.

As shown in Figure 9, we find that there is no difference between SMT and non-SMT teachers in the extent to which their recent PD has included features of "effective" PD.

TALIS also measures teachers' views on their need for PD in subject matter and pedagogy. This is a scale covering teachers' views on their need for more knowledge of their subject and of the curriculum, pedagogical competency in their subject, student evaluation and behaviour management, and assessment practice.

We find that mathematics teachers are significantly less likely than non-SMT teachers to identify a need for PD, whereas technology teachers are significantly more likely than non-SMT teachers to identify a need for PD. Science teachers are slightly more likely to identify a need for PD, but the difference is not statistically significant.

Figure 9 Average difference in professional development (PD) measures (compared to non-SMT teachers)



3. Do differences in working pattern and self-efficacy explain differences in satisfaction?

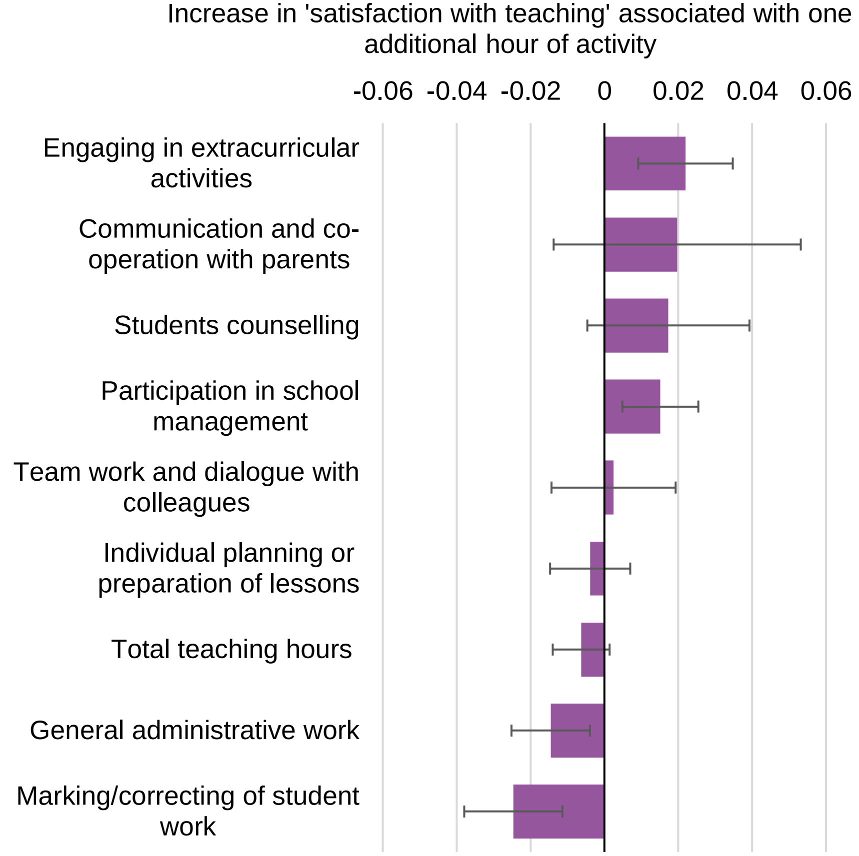
Our analysis in section 2 finds that SMT teachers have slightly lower job satisfaction than non-SMT teachers, although this difference is not statistically significant. We also find that science teachers spend more time planning and preparing lessons than non-SMT teachers, and that SMT teachers have lower self-efficacy across a number of areas, especially science and mathematics teachers with student engagement.

Do these differences in working patterns and self-efficacy help to explain differences in job satisfaction, and therefore contribute, at least in part, to potentially explaining lower retention rates among SMT teachers? We use a series of regression models to explore this.

Figure 10 shows that the association between teacher working hours and satisfaction with teaching depends on the nature of the activities that the time is spent on. Teachers who spend more time engaging in extra-curricular activities and participating in school management tend to, all other things being equal, have higher satisfaction with teaching, while teachers who spend more time marking student work and doing administrative tasks tend to, all other things being equal, have lower satisfaction with teaching.

However, there is no statistically significant relationship between time spent teaching and planning/preparing lessons, and satisfaction with teaching. This suggests that although science teachers spend significantly more time than non-SMT teachers planning and preparing lessons, this is unlikely to explain differences in satisfaction with teaching, or therefore retention.

Figure 10 The relationship between teacher working hours and satisfaction depends on what the time is spent doing



Our regression modelling confirms this. Figure 11 shows the difference in satisfaction with teaching between each SMT subject and non-SMT teachers, from several different regression models.

The first row shows the underlying differences in satisfaction with teaching. It echoes the findings of Figure 7 but shows slightly different results because it treats teachers who selected more than one subject slightly differently.

By introducing different factors into our model one by one, we can see if the differences in satisfaction get bigger or smaller as a result. If after introducing a particular factor, the gap moves towards zero, then it suggests that the factor that has been added helps to explain part of the underlying difference.

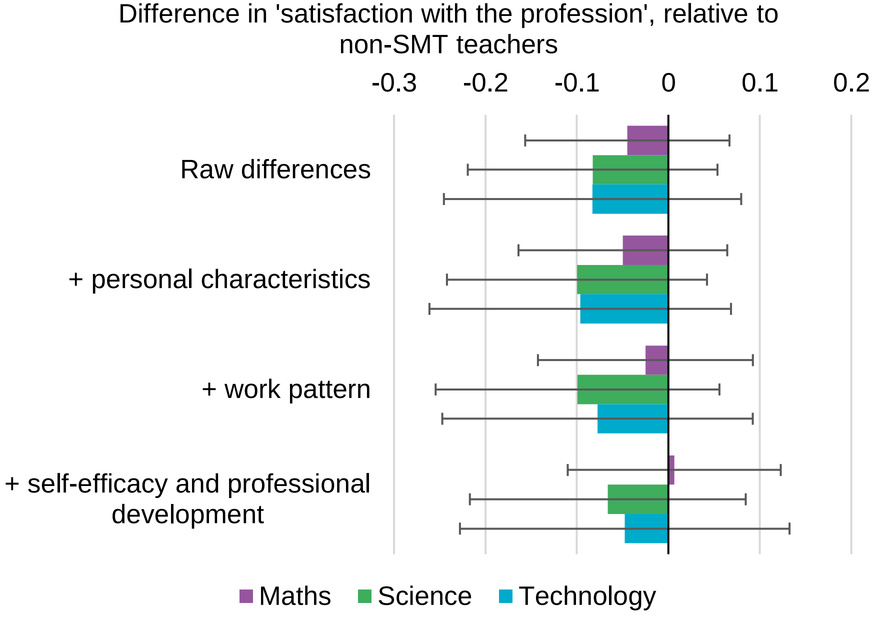
The second row shows the differences in satisfaction after controlling separately for gender and experience. The between-subject differences do not change much and, if anything, get slightly larger. This suggests that differences in personal characteristics do not explain between-subject differences in satisfaction.

The third row shows the differences in satisfaction after controlling separately for the amount of time teachers spend on different activities (as well as their personal characteristics). This makes a small difference for mathematics teachers as they spend less time doing extra-curricular activities and school management, both of which are associated with greater satisfaction. However, controlling for working pattern makes very little difference for science or technology teachers. This confirms that although science teachers spend significantly more time than non-SMT teachers planning and preparing lessons, this is unlikely to explain their lower satisfaction with teaching.

The final row shows the differences in satisfaction after controlling for teachers' self-efficacy and professional development needs (as well as work pattern and characteristics). As the gap to non-SMT teachers closes, this shows that low self-efficacy, in particular, helps explain lower satisfaction with teaching among SMT teachers.

None of the differences in job satisfaction between SMT and non-SMT teachers are statistically significant, which suggests that these differences should be seen as indicative and not be interpreted with any degree of certainty.

Figure 11 Self-efficacy makes the biggest difference in explaining why SMT job satisfaction is slightly lower



4. How important is relative pay for explaining differences in leaving rates?

Section 3 provides some indication that differences in self-efficacy may explain part of the reason why SMT teachers have lower retention rates. However, given the high level of uncertainty and the difficulty in translating differences in job satisfaction directly into differences in retention rates, this is far from conclusive. Therefore, other reasons are likely to also contribute to explaining why SMC teachers have lower retention rates.

One of the most cited reasons as to why SMC teachers have lower retention rates is that they have higher-paid and more attractive career options outside of teaching. In this section we briefly review the recent research on this issue.

4.1 Relative pay as a reason for lower SMC teacher retention rates

Pay is not one of the key reasons cited by most ex-teachers for why they left teaching (Smithers and Robinson, 2003; DfE, 2017). NFER research found that teachers who leave the profession see their pay fall in the first year after leaving and not recover over the next four years to the level it was in the last year before they left teaching (Worth *et al.,* 2018). This suggests that most working-age teachers' decisions to leave the profession are not primarily motivated by the prospect of higher pay in the short- or medium-term. A review of the literature on economic influences on teacher labour market decisions by Hutchings (2011) found that *"salary is rarely the key attraction of moves into other employment"*.

However, research has found a relationship between higher pay outside of teaching relative to teachers' pay and higher rates of teachers leaving the profession (Dolton and van der Klaauw, 1999; Worth *et al*., 2019). Hutchings' review of the evidence concludes that *"there is evidence that relative wage levels are a factor in some decisions to leave, but this is clearly not the case for the majority".* This effect tends to be larger among teachers in their first few years of teaching and especially for teachers of shortage subjects such as SMC (Allen *et al.*, 2016).

Data from the government's database of longitudinal educational outcomes (LEO) shows that STEM-subject graduates tend to earn more in the labour market than graduates of other subjects (STRB, 2018). This suggests that the pay difference between teaching and alternative careers outside of teaching is higher for SMC teachers. This is likely to be at least part of the reason why leaving rates are higher among SMC teachers, particularly in the first few years of their teaching careers.

Recent research has argued that targeting pay increases or salary supplements at teachers of shortage subjects, such as science and mathematics, could have an impact on their relative undersupply (Sims, 2018). This research draws on evidence from randomised controlled trials in the United States to highlight the positive impact that bonuses for shortage teachers could have on teacher retention. It estimates that retention payments targeted at this group could be less costly than the alternative of training new replacement teachers.

Teachers' pay is not generally differentiated by subject. Historically pay has been set according to national pay scales, determined by years of service. Since 2014 schools have had more freedom to determine teacher pay, and have been encouraged to link pay increases to performance rather than years of experience. However, school leaders have not made much use of this freedom, either due to financial constraints, the desire to maintain fairness across different teachers, or both (Sharp *et al*., 2017).

Generous bursaries have been used for many years to attract graduates into teacher training in shortage subjects. There is no recent comprehensive evaluation of how cost effective bursaries are, but the example of biology in 2018/19 (see biology key data summary below for an example) shows that they may have an important effect on the likelihood of graduates entering teaching. The Department for Education recently published data on the destinations of ITT entrants with and without bursaries (DfE, 2018b). However, the two groups are not directly comparable as there are underlying reasons why these groups differ, so comparisons do not inform an understanding of the effectiveness of bursaries. A comprehensive evaluation would need to rigorously estimate the counterfactual, i.e. estimate what the rate of entry into and retention in teaching would have been for the same individuals but under a different bursary level.

Physics and mathematics have tended to attract the largest bursaries. For entry in 2019/20, biology, chemistry and computer science also attract the highest bursaries.

The DfE recently piloted a new form of bursary for mathematics, which reduces the up-front payment for training (from £30,000 to £20,000) and includes early-career retention payments (£5,000 in third and fifth years, with higher payments if the teacher is working in a challenging area). In its recent teacher recruitment and retention strategy, the DfE committed to extending this phased bursary model to more subjects, which is likely to include sciences and computer science (DfE, 2019).

5. Conclusions and policy implications

5.1 Conclusions

SMC teachers have higher rates of leaving teaching than teachers of other subjects, which is concerning for teacher supply. There is also increasing concern over short-term SMC teacher supply due to the number of entrants to teacher training having been consistently below the numbers required to maintain supply, particularly for physics, mathematics, chemistry and computing. The number of biology teacher trainees is above the target this year: while this potentially fills emerging ‘science teacher’ shortages, it means many new teachers are likely to be teaching sciences outside of their specialism once they are in the classroom. If these trends are sustained, it is likely to change the balance of expertise within science departments over time, increasing expertise gaps in physics and chemistry.

A number of factors may potentially explain why SMC teacher leaving rates are higher. Higher-paid options outside teaching is one often-cited reason, and the research literature finds evidence of this being the case. However, other factors such as workload may also help to explain the difference. SMT teachers have different working patterns; for example, science teachers tend to work slightly longer hours, and spend more time planning and preparing lessons, whereas mathematics and technology teachers work shorter hours than non-SMT teachers. However, we do not find that the different working patterns explain why science, mathematics and technology teachers’ satisfaction with teaching is lower than non-SMT teachers. Therefore, this indicative evidence suggests that different workload is unlikely to explain why SMT teacher leaving rates are higher.

We also find that science, mathematics and technology teachers have lower self-efficacy: on average, they have lower belief in their ability to manage their classrooms, effectively instruct and engage students in learning. We find that lower self-efficacy among SMT teachers seems to explain part of the reason why satisfaction with teaching is lower among SMC teachers compared to non-SMT teachers.

The research has a few limitations. Satisfaction with teaching is only a proxy for retention. While the research literature has strongly linked job satisfaction and retention, differences in satisfaction between teachers of different subjects don’t necessarily fully explain all of the differences in retention rates between subjects. Another limitation of the data is the uncertainty attached to the estimates as the sample sizes by subject are relatively small.

5.2 Policy implications

What should policymakers and school leaders do differently to improve retention of SMC teachers? And what can other stakeholders (such as the Royal Society, the learned societies and other bodies) do to support them to do so.

The research literature suggests that lower pay in teaching relative to alternative careers is likely to be the main explanation for why SMC teacher leaving rates are higher, although lower self-efficacy may explain part of the differences in retention rates. However, it doesn’t necessarily follow that the best policy remedy is to focus on these areas.

For example, DfE research found that, similar to non-STEM teachers, the main reason given by former STEM teachers for having left teaching was workload (DfE, 2017). Therefore, while workload may not explain why there are *differences* in retention rates between SMC and non-SMC teachers, it *is* likely to explain why leaving rates are generally high *across* all subjects. Action to reduce workload should therefore by promoted. The government has launched a range of initiatives aimed at encouraging school leaders to reduce unnecessary workload, including toolkits, reports from advisory groups and inspection of approaches to teacher workload as part of the new Ofsted inspection framework.

For science teachers, the focus of efforts to reduce workload should focus on planning and preparation time. Increasing teachers' level of specialisation in fewer science subjects and/or on fewer different year groups, can reduce a teacher's workload because they can focus on mastering a narrower set of content, and include more content that they are already familiar with (see Sims, 2019). As teachers become more familiar with the content they are teaching, this may also improve self-efficacy and job satisfaction, making teachers more likely to stay in teaching.

We find there are few differences between subjects in terms of whether recent PD has been effective, or whether teachers feel they need more PD in subject matter or pedagogy. Likewise, this doesn't imply that PD is unimportant for improving retention. A recent non-experimental study of a science CPD programme showed that it was associated with improved retention (Allen and Sims, 2017). High-quality PD, especially for early-career teachers, is also likely to help improve teachers' self-efficacy, improving their satisfaction and likelihood of staying in the profession (Skaalvik and Skaalvik, 2014).

The Education Endowment Foundation has recently funded experimental studies of CPD programmes that may help to improve teacher retention (see Education Endowment Foundation, 2018), and will help to build the evidence base for how to improve retention through CPD.

Teacher pay is important to consider as part of any measures to improve SMC teacher retention. It is the government's easiest 'policy lever' to pull, although public finances are likely to continue to be tight in future years. Higher pay for SMC teachers may lead more to consider entering teaching and more to consider staying in teaching for longer. However, SMC teacher trainees already attract generous bursaries and these have not improved recruitment and retention to the levels required to maintain supply. This suggests there are limits to the effectiveness of financial incentives as a policy solution, although without a comprehensive assessment of the effectiveness of existing bursaries and financial incentives, it is difficult to tell.

Since 2014, schools have been given discretion over how to pay teachers, meaning that it is difficult for government policy to target salary rises at particular groups of teachers. As explained in section 4, phased bursaries are one mechanism of raising the pay of early-career SMC teachers, while delivering the higher pay directly to teachers and not requiring school leaders to pay teachers of different subjects, but with similar experience levels, differently. The DfE's extension of the phased bursary model to other shortage subjects beyond mathematics is welcome and will greatly improve the current incentive structure (DfE, 2019). It would, however, also be desirable to evaluate the impact of this change, to gather more information on how responsive teacher labour market decisions are to financial incentives.

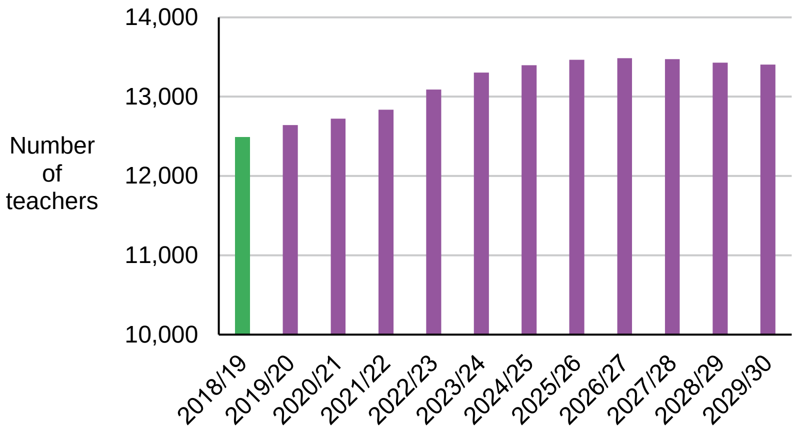
6. Key teacher supply data summaries

This section presents a series of key teacher supply data summaries for each of the five SMC subjects: biology, chemistry, physics, mathematics and computing. These show the current teacher supply situation and set out the future teacher supply challenge for each subject.

The key findings across the five summaries are that:

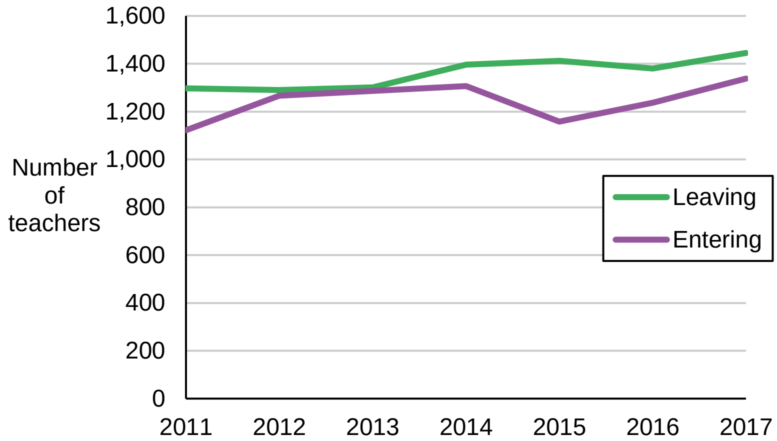
- Pupil growth over the next five years in particular means that the number of science and mathematics teachers needs to increase to meet demand. However, the forecast need for computing teachers over the next five years is flat. This is because the forecast includes both growth in the number of computer science teachers and declines in the number of ICT teachers.
- The main assumption is that the increase in teacher numbers will need to be met with increased recruitment to teacher training: the targets for science and mathematics all increase over the next five years. Again, computing is slightly different because it combines forecast growth in computer science and decline in ICT.
- We use higher education data to estimate the number of undergraduates currently studying, as a proxy for the size of the potential pool of future teachers. By comparing this to the forecast number of trainees required in the year after they graduate, we derive a proxy of the proportion of the graduate cohort that needs to be recruited to meet future targets. The findings differ considerably by subject:
    - The proxy measure suggests that the future ITT need for biology and computing represents a relatively small proportion of current undergraduate cohort: around 4 per cent.
    - The future ITT need for chemistry represents 17 per cent of the current undergraduate cohort. The future ITT need for physics represents 36 per cent of the current undergraduate cohort. Given the competing career options open to these graduates, these are large proportions that are required.
    - The future ITT need for mathematics represents 39 per cent of the current undergraduate cohort. However, this assumes a narrow definition of mathematics specialism, which is limited to those with mathematics degrees. Graduates of other degree subjects with quantitative components (e.g. economics, accounting) may also make suitable mathematics teachers, so the potential pool may in fact be wider than this.

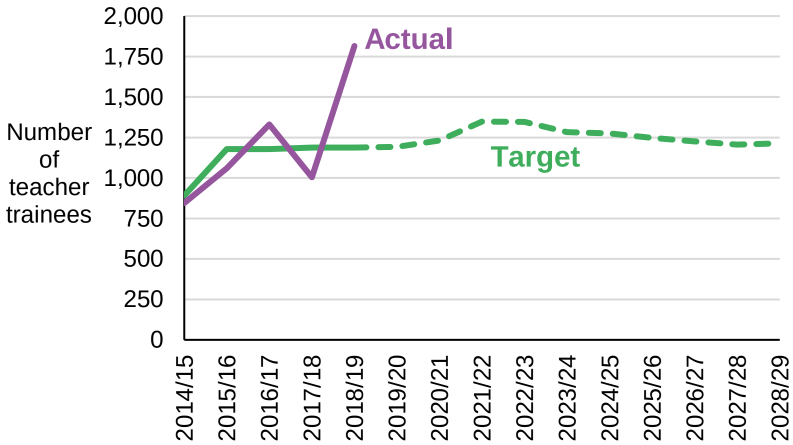
6.1 Biology – Key teacher supply data summary



The current headcount of biology teachers in England is **12,489**. To keep pace with the projected increase in secondary pupil numbers over the next decade, DfE project that the sector will need **around 1,000 more biology teachers** by 2026/27.

The headcount of biology teachers entering the profession each year has **increased slightly** over the last six years. However, this has still lagged behind the number leaving teaching, with **1,445 biology teachers leaving in 2017**. The cumulative effect has been a net loss of around 800 biology teachers since 2011.



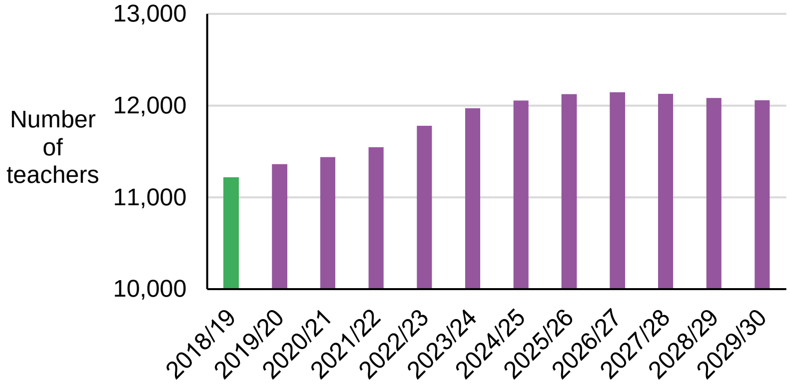


The historic teacher trainee targets for biology have remained stable in recent years. The number of **actual trainees** has been below the target in 3 out of the last 5 years. However, 2018/19 saw a large increase of 800 trainees from the previous year, probably due to the increase in bursary from £10-15,000 to £26,000.

There are around 32,300 first year undergraduate students in 2017/18 who study degree subjects related to biology[3] and hence are the potential pipeline of biology specialist teachers. This cohort of students will graduate in 2020/21, when the ITT target will be 1,232 teachers. The ITT target is therefore the equivalent of about **4% of the total graduating cohort in the relevant biology-related subjects**.

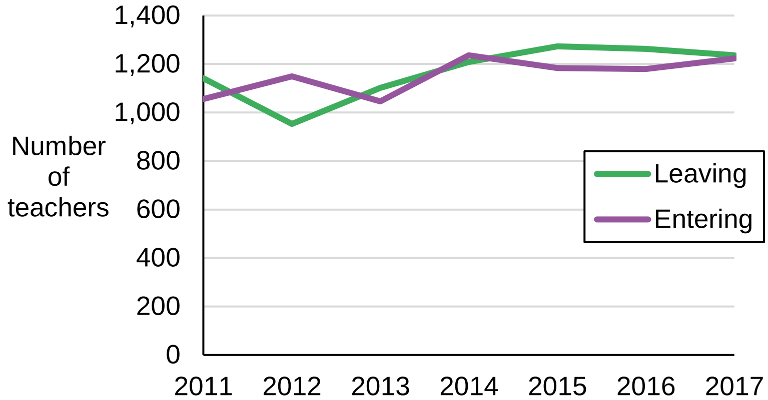
[3] This excludes medicine students. While DfE counts medicine as a specialism for teaching biology, this is a separate vocational track which we think is unlikely to form a major part of the pool of potential biology teachers.

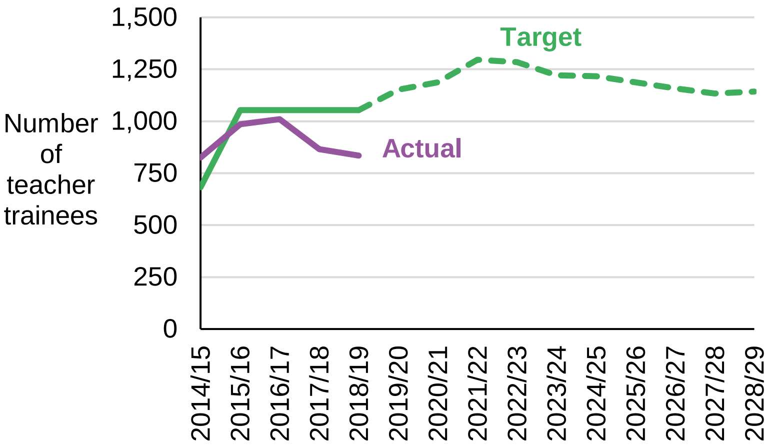
6.2 Chemistry – Key teacher supply data summary



The current headcount of chemistry teachers in England is **11,217**. To keep pace with the projected increase in secondary pupil numbers over the next decade, DfE project that the sector will need **around 900 more chemistry teachers** by 2026/27.

The headcount of chemistry teachers entering the profession each year has **increased slightly** over the last six years. Although this has roughly equalled the number leaving teaching, with **1,223 chemistry teachers leaving in 2017**. This has resulted in the overall chemistry teacher workforce being similar in size to what it was in 2011.



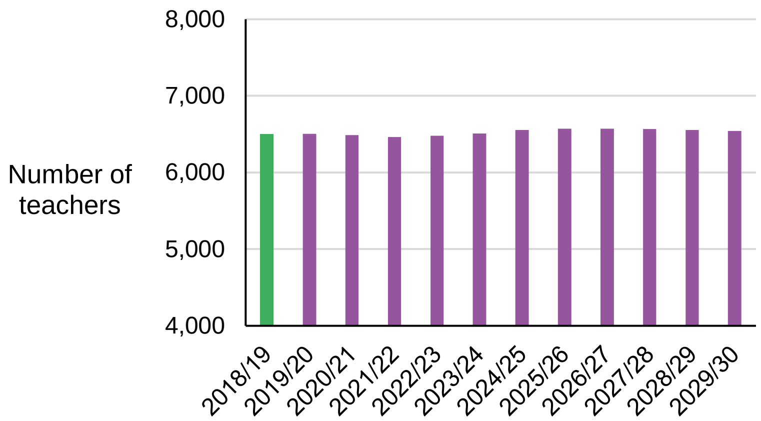


The historic teacher trainee targets for chemistry have not been matched by the **number of actual trainees** for the last 4 years in a row. In fact, the number of trainees has decreased year on year for the last two years. Teacher trainee targets in chemistry are forecast to rise, increasing the supply challenge in this subject.

There are 6,800 first year undergraduate students in 2017/18 who study degree subjects related to chemistry[4] and hence are the potential pipeline of chemistry specialist teachers. This cohort of students will graduate in 2020/21, when the ITT target will be 1,187 teachers. The ITT target is therefore the equivalent of about **17% of the total graduating cohort in the relevant chemistry-related subjects**.

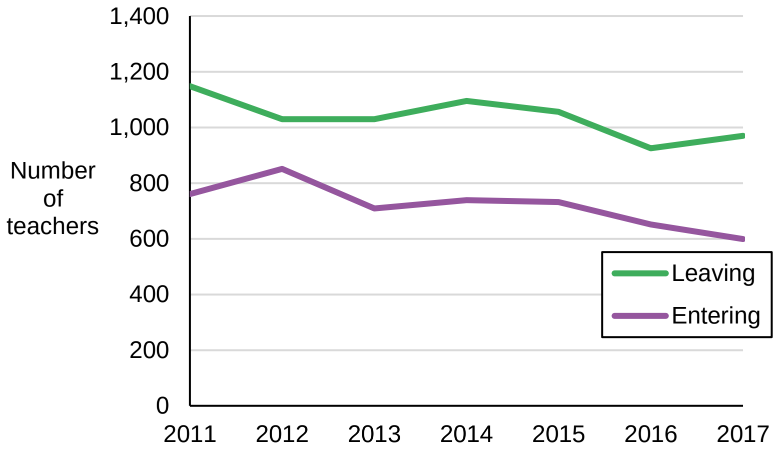
[4] This excludes medicine students. While DfE counts medicine as a specialism for teaching chemistry, this is a separate vocational track which we think is unlikely to form a major part of the pool of potential chemistry teachers.

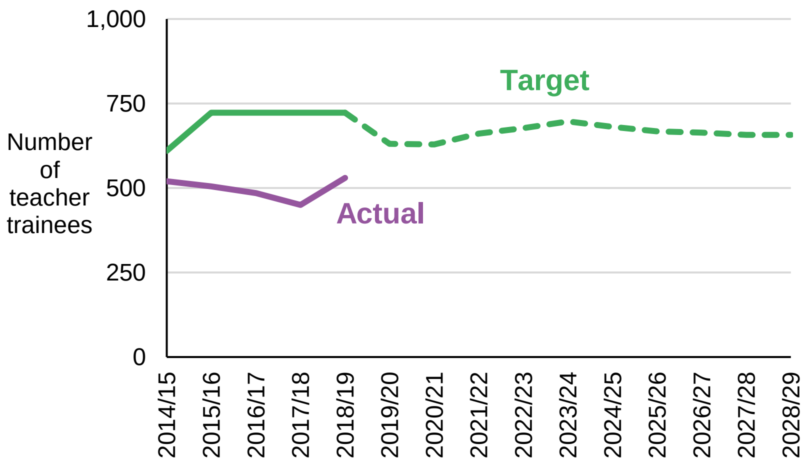
6.3 Computing – Key teacher supply data summary



The current headcount of computing teachers in England is **6,504**. The DfE projects that the sector needs to remain broadly stable in the coming years. Computing is defined by DfE as both computer science and ICT teachers: computer science is increasing in size and ICT is reducing in size.

The headcount of computing teachers entering the profession each year has **decreased slightly** over the last six years. Furthermore, this has lagged behind the number leaving teaching, with **970 computing teachers leaving in 2017**. The cumulative effect has been a net loss of around 2,200 computing teachers since 2011.

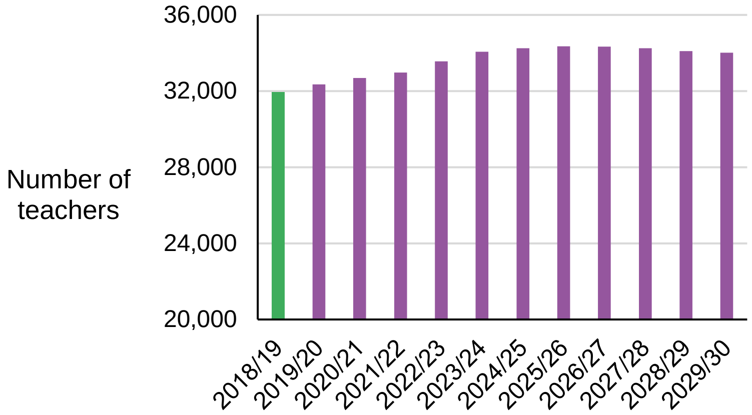




The historic teacher trainee targets for computing have not been met by the **number of actual trainees** for the last 5 years in a row. Teacher trainee targets are forecast to remain stable. However, the challenge remains training more computer science teachers to meet demand, while reducing the number of ICT teachers.

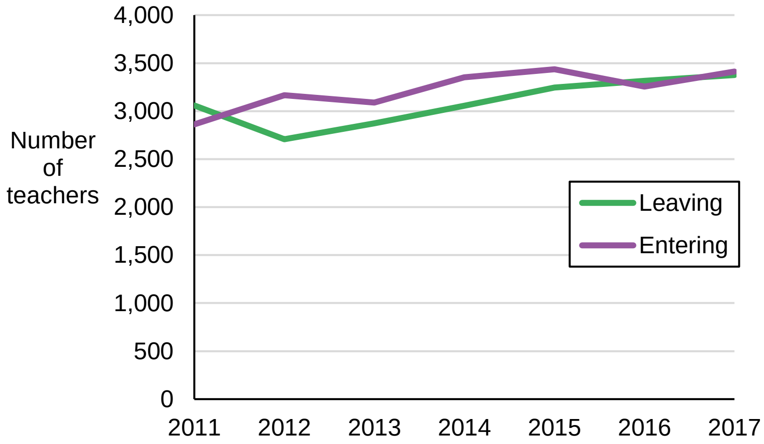
There are around 17,500 first year undergraduate students in 2017/18 who study degree subjects related to computing and hence are the potential pipeline of computing specialist teachers. This cohort of students will graduate in 2020/21, when the ITT target will be 629 teachers. The ITT target is therefore the equivalent of about **4% of the total graduating cohort in the relevant computing-related subjects**.

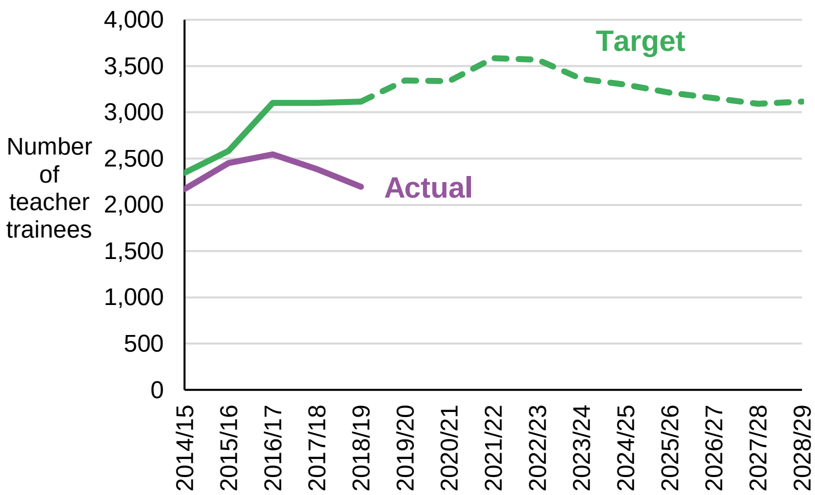
6.4 Mathematics – Key teacher supply data summary



The current headcount of mathematics teachers in England is **31,927**. To keep pace with the projected increase in secondary pupil numbers over the next decade, DfE project that the sector will need **around 2,400 more mathematics teachers** by 2026/27.

The headcount of mathematics teachers entering the profession each year has **increased slightly** over the last six years. However, the number leaving teaching has also increased for five consecutive years, with **3,376 mathematics teachers leaving in 2017**. The mathematics teacher workforce has increased by more than 900 teachers since 2011.

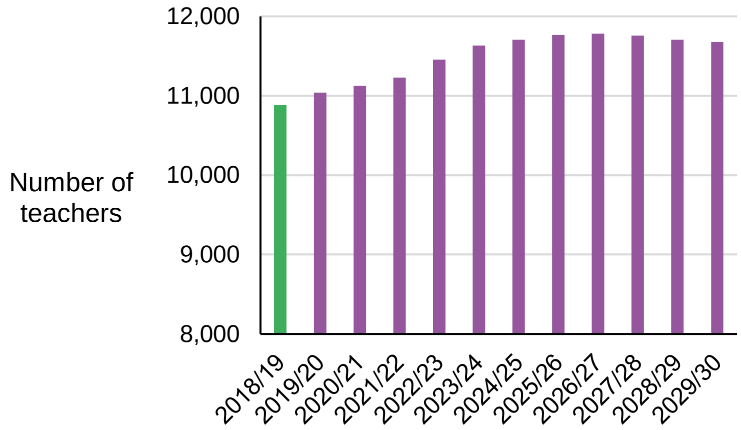




The historic teacher trainee targets for mathematics have increased in recent years. The **number of actual trainees** has not met these targets for the last 5 years in a row. Teacher trainee targets in mathematics are forecast to rise further, hence the challenge is increasing in this subject.

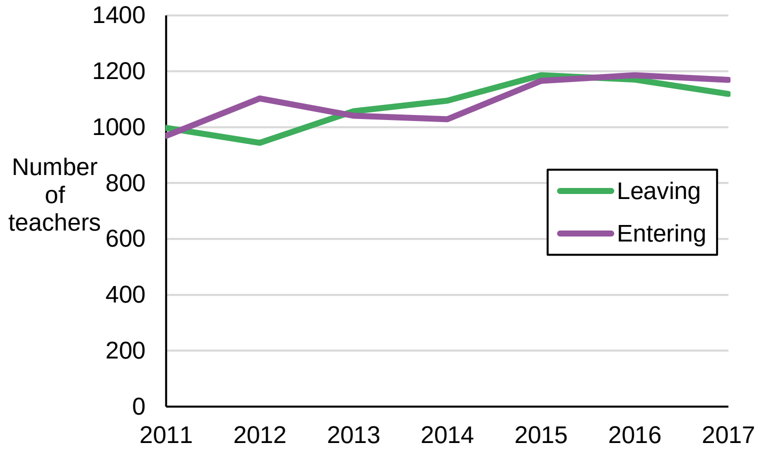
There are around 8,500 first year undergraduate students in 2017/18 who study degree subjects related to mathematics and hence are the potential pipeline of mathematics specialist teachers. This cohort of students will graduate in 2020/21, when the ITT target will be 3,337 teachers. The ITT target is therefore the equivalent of about **39% of the total graduating cohort in the relevant mathematics-related subjects**.

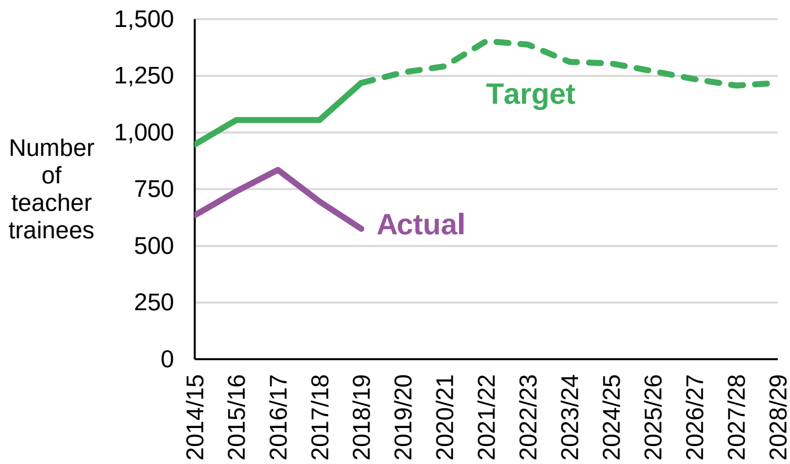
6.5 Physics – Key teacher supply data summary



The current headcount of physics teachers in England is **10,878**. To keep pace with the projected increase in secondary pupil numbers over the next decade, DfE project that the sector will need **around 900 more physics teachers** by 2026/27.

The headcount of physics teachers entering the profession each year has **increased slightly** over the last six years. Although this has roughly equalled the number leaving teaching, with **1,119 physics teachers leaving in 2017**. This has resulted in the overall physics teacher workforce remaining the same size as it was in 2011.





The historic teacher trainee targets for physics have increased in recent years. The **number of actual trainees** have not kept up with these targets for the last 5 years in a row. Teacher trainee targets in physics are forecast to rise further, hence the challenge is increasing in this subject.

There are around 3,600 first year undergraduate students in 2017/18 who study degree subjects related to physics[5] and hence are the potential pipeline of physics specialist teachers. This cohort of students will graduate in 2020/21, when the ITT target will be 1,292 teachers. The ITT target is therefore the equivalent of about **36% of the total graduating cohort in the relevant physics-related subject**.

[5] This excludes engineering graduates. While DfE counts engineers as specialisms for teaching physics, this is a separate vocational track which we think is unlikely to form a major part of the pool of potential physics teachers.

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