

Must try harder: An evaluation of the UK government's policy directions in STEM education



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Background

STEM subjects in schools and colleges have received continuous support from the UK government and the devolved administrations for decades. There have been government-backed teacher training and continuing professional development of science and mathematics teachers, STEM employers have developed their own individual approaches to supporting curriculum materials and enrichment projects for students, and the scientific and learned bodies and STEM charities have supplied a range of support for STEM education and scientists. Despite all this action, during the past 30 years there has been a decline in the number of young people taking STEM subjects in the later stages of school, and a subsequent lack of STEM graduates and people with sufficient STEM background available for employment. So in the light of the continuous support already provided, what is the UK doing to address this situation?

Abstract

There is a common issue across Europe and the UK that vexes governments, employers and educationalists: the need for more young people to choose to study STEM subjects, become graduates in STEM subjects and then take up STEM careers. In addition, there is an urgent need for more STEM skills in the total workforce. For decades, the UK government has been committed to addressing this issue with a range of activities and strategies. Since the influential UK Government report conducted by Sir Gareth Roberts (2002), there have been policy and funding commitments by the various UK governments to improve outcomes for young people. These commitments have included incentives for people with industry experience and

for graduates with good degrees to enter teaching; adopting accountability measures for schools to improve outcomes for young people, including better progression to STEM subjects at student milestones of 16 and 19 years of age; developing the STEM curriculum, including bringing a more cohesive approach to the vast array of curriculum enrichment by industry, charities and government; using national strategies for school improvement; and providing national continuing professional development for teachers and support staff, particularly through the National STEM Learning Centre and Network. This presentation will consider the evidence of the impact of the various strategies and the implications for other jurisdictions.

Government policy and action

The UK is made up of four different countries, and although most strategic planning for STEM is at UK-level, there are different education policies in each of the four countries – England, Scotland, Wales and Northern Ireland. Each country has interpreted the overall STEM policy initiative differently, although all four remain committed to improving the supply of home-grown talent in science and engineering.

Like Australia, the UK government has had a commitment and vision for improving STEM over a number of years. The UK government's commitment is summarised in the Science and Innovation Investment Framework 2004–2014 (HM Treasury, 2004) and a subsequent STEM strategy (2014–2024) (Department for Business Innovation and Skills, 2014), which both reiterate the aim for the UK to be the best place in the world for science and business.

In 2004, education was given a key role in achieving immediate and significant improvement in:

- the quality of science teachers and lecturers in every school, college and university, ensuring national targets for teacher training are met
- the results for students studying for General Certificate of Secondary Education (GCSE) levels in science
- the numbers choosing science, engineering and technology subjects in post-16 education and in higher education
- the proportion of better qualified students pursuing research and development careers
- the proportion of minority ethnic and women participants in higher education.

In 2006, targets were derived from these changes. It is these targets that provide the framework for this paper.

Changes in educational policy context

This commitment to improving the support for STEM research and development, as well as STEM education, has had cross-party political collaboration and support from industries and charitable trusts committed to STEM. The implementation of the STEM strategy was initially successful, with a cohesive program throughout 2004–2010; however, progress was slowed by the economic recession from 2007 onwards and by a number of changes in education policy in England. The recent systemic reform to a 'school-led self-improving' system introduced by the coalition government in *The importance of teaching* (Department of Education, 2010) has impacted on the implementation of the STEM policy, and at times conflicted with it. The leadership of the

curriculum, assessment and school improvement is now the responsibility of school leaders. The responsibilities for schools in England were transferred from 153 locally elected local education authorities to individual schools and self-appointed school groupings called academies, with many being part of multi-academy trusts; around 1200 organisations are now responsible for schools.

There continues to be a commitment to supporting professional learning for teachers of STEM subjects through continued government funding for Maths Hubs, Computing Hubs and Science Learning Partnerships. However, individual schools/multi-academy trusts need to provide some funding towards the continuing professional development of their staff; and with austerity budgets beginning to bite now in UK education, some head teachers are unable/unwilling to prioritise support for improvements in teaching in STEM subjects, which jeopardises the quality of teaching.

Initial teacher education is now mainly school-based and led by teaching schools that collaborate with university teacher training programs (for more information, see Gov.UK, 2016). This has resulted in a reduction of recruitment of teachers of STEM subjects, which is impacting on the quality of teaching.

The government introduced in 2010 a revised national curriculum, which is a more knowledge-based curriculum. In science, there is less emphasis on inquiry-based learning and an increased requirement for mathematics skills. In mathematics, there is more emphasis on problem-solving in unfamiliar situations and making connections between different areas of mathematics. Consequently, this affects students' knowledge and understanding of the use and application of STEM skills. Nowhere is the detrimental effect of this policy change more evident than in the international test results for UK pupils.

There have been changes to the assessment of student attainment and progress that have affected evidence of the long-term impact of the STEM strategy. In 2009, the testing of students at ages 7 and 14 was removed, and testing at age 11 was reduced to English and mathematics only, science being assessed only through non-moderated teacher assessment. This has reduced the status and teaching of science in primary schools. In 2013, all national examinations for 16 year olds were changed from modular to terminal examinations, which has affected the uptake of triple science.

Changes to the accountability framework for schools have affected the assessment of the long-term impact of the 2004 STEM strategy. From 2006, schools were required to offer access to 'triple science' (biology, chemistry and physics) for higher-attaining students, to increase the likelihood of them progressing to sciences post-16. However, from September 2015, all 11 year

olds have to take EBacc¹ subjects, and the different pathways in science work against more students taking triple science, and have reduced the uptake of design and technology. This could have an impact on students taking STEM pathways and careers.

Impact of policy changes in Europe and the UK

To ascertain the impact of the UK government's STEM policy since 2004, it is important to have a robust evidence base. With the shift of the locus of control to schools, a removal of standardised comparators of student progress and the dispersal of the national curriculum, it is challenging to find a consistent baseline by which to judge the outcomes of the policy. Given this difficulty, this paper reviews the available evidence of impact against the targets set in 2006, namely:

- changes in student attainment and progress data, nationally and internationally
- the uptake of science and progression to study and career pathways post-16 science
- the impact on the quality of teaching as indicated by the findings from the inspection system in England by the Office for Standards in Education, Children's Services and Skills
- impact on teacher recruitment, retention and continuing professional development programs.

Attainment progress and uptake of STEM subjects by young people

National results

Overall, the 2006 target to increase year-on-year the number of young people (16 to 18 year olds) taking General Certificate of Secondary Education A levels in physics, chemistry and mathematics has been met with increases since 2009 in the number of students entered for A levels in mathematics, further mathematics, physics and chemistry, and an increase in the number of students attaining grades of A* to C in each of these subjects. There is a gender issue, with fewer girls taking physical science and mathematics.

¹ The English Baccalaureate (EBacc) is a school performance measure. It allows people to see how many students get a grade C or above in the core academic subjects at key stage 4 in any government-funded school. To pass the science element of the EBacc, pupils need to do one of the following: (1) get an A* to C in core and additional science GCSE (in core and additional science, pupils take 2 modules in each of the 3 main sciences: biology, chemistry and physics); (2) take 3 single sciences at GCSE and get an A* to C in at least 2 of them (the single sciences are biology, chemistry, computer science and physics); (3) get an A* to C in GCSE science double award (in science double award, pupils take 2 GCSE exams that cover the 3 main sciences: biology, chemistry and physics).

There were targets set to improve take-up and attainment in science for 16 year olds (General Certificate of Secondary Education level):

- an entitlement from 2008 for all higher-attaining students to study triple science²
- to continually improve the number of students achieving A* to B and A* to C grades in two General Certificate of Secondary Education science subjects.

There was an increase in the numbers of students taking triple science up to 2013, though a decrease in attainment. Conversely, there was a decrease in the numbers and attainment of those taking double science, but this has been reversed recently since the introduction of the EBacc.

Results in General Certificate of Secondary Education mathematics have shown a steady increase from 2007 to 2013, though changes to entry policies and introduction of terminal examinations have had some negative effect on attainment levels.

On the whole, the government STEM policy to increase attainment and progress in science pre- and post-16 was reasonably successful until 2013, when there was a decrease in take-up of triple science. A recent evaluation of the Triple Science Support Programme (STEM Learning, 2016) provides evidence that this is caused by the introduction of terminal assessment and the EBacc accountability measure. This is exacerbated by many post-16 providers only accepting students with A* to A grades in triple science to progress onto post-16 courses. Ultimately, this could reduce the numbers of students progressing to STEM study post-19, and hence to STEM careers and pathways. This is an example of two government policies that appear to conflict and give rise to unintended consequences.

International results

In contrast to the national attainment data, the outcomes of international tests show no positive increase. Students' performance in mathematics, science and reading in England has remained stable in PISA, with students performing at a level similar to the OECD average in mathematics and reading, and significantly better than the OECD average in science.

The results in the Trends in International Mathematics and Science Study (TIMSS) and the Progress in International Reading Literacy Study (PIRLS) 2011 show that at age 10, England has fallen in science but risen in reading, it has plateaued in mathematics at ages 10 and 14 between 2007 and 2011, and it has plateaued in science at age 14. The removal of national testing of

² All pupils aged 14 to 16 have to take science, but it can be taught as triple science – encompassing biology, chemistry and physics taught separately in substantial depth – worth three GCSEs. Alternatively, the three sciences can be taught as integrated or combined science, called 'core and additional science' or 'double science', worth two GCSEs.

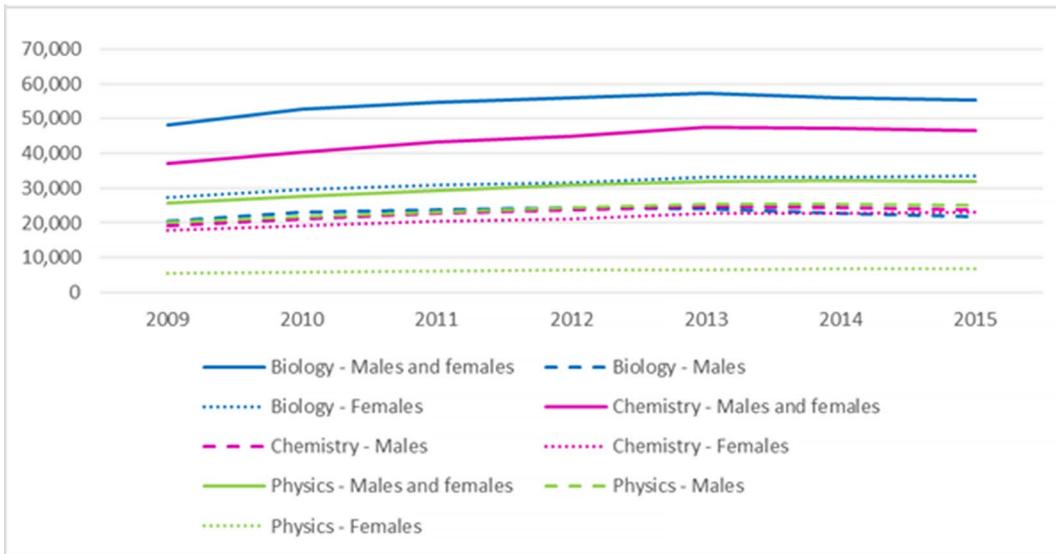


Figure 1 Year-on-year A level entries – Science

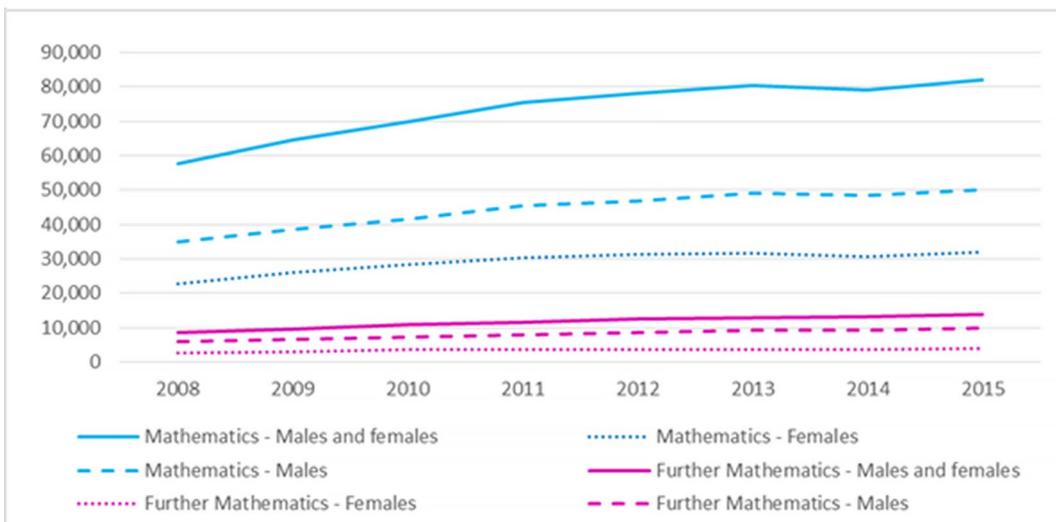


Figure 2 Year-on-year A level entries – Mathematics and Further Mathematics

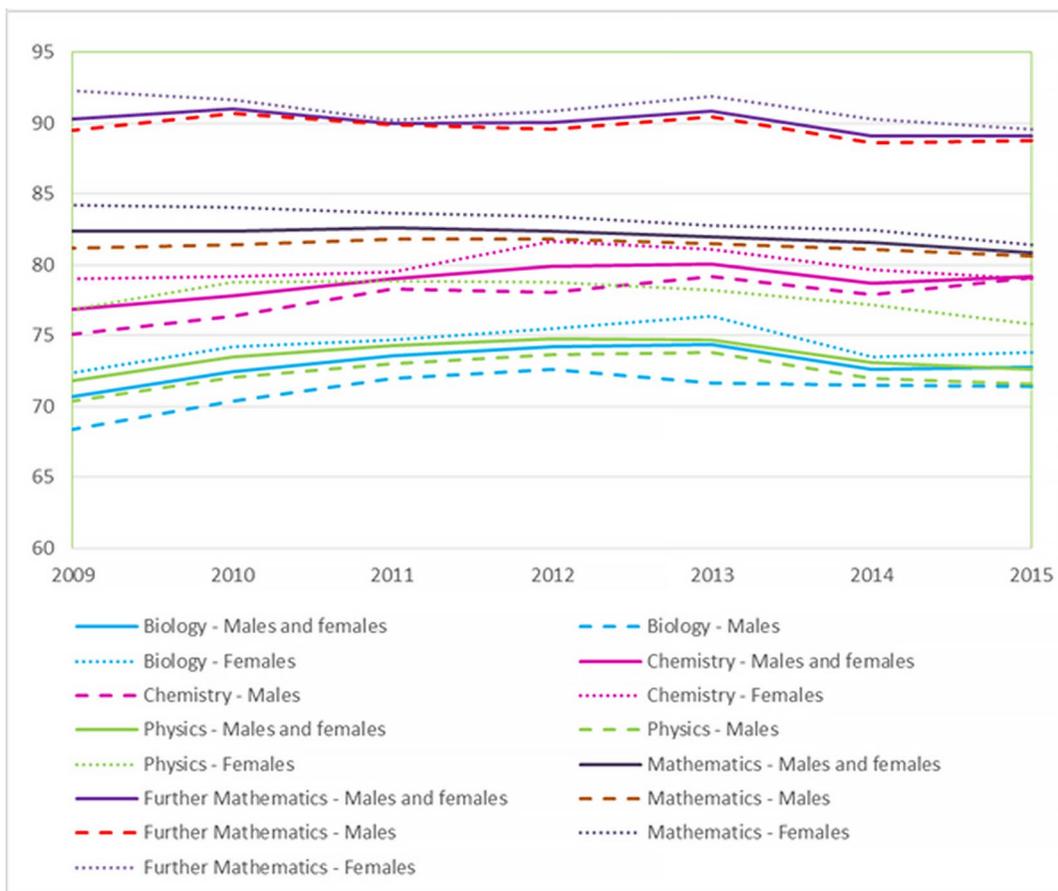


Figure 3 A level results: Percentage of cohort achieving A* to C in science and mathematics

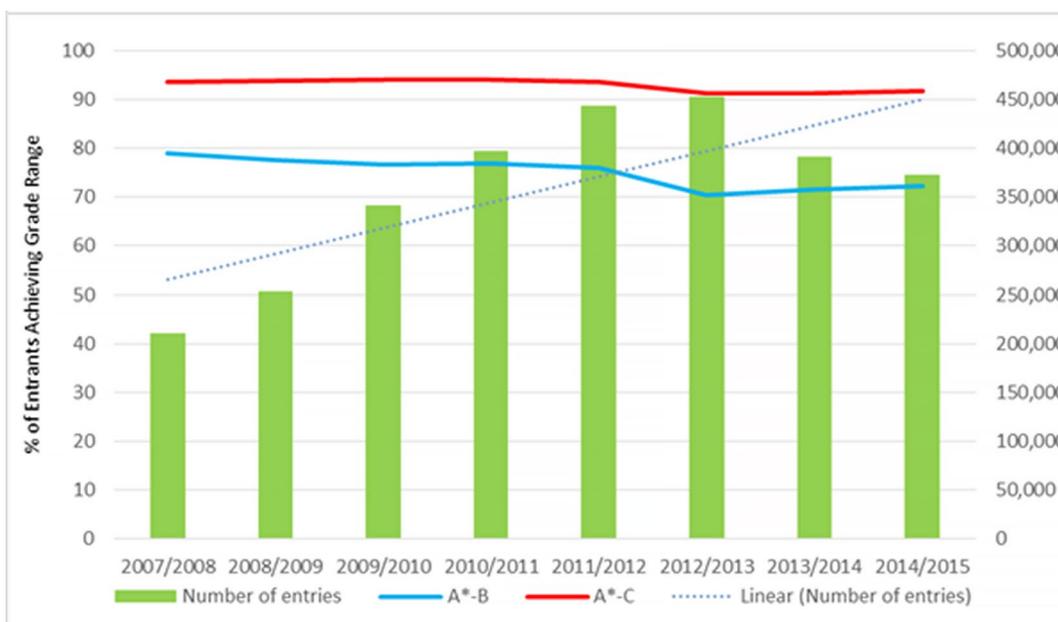


Figure 4 Biology, chemistry and physics combined – GCSE entrants and grade attainment

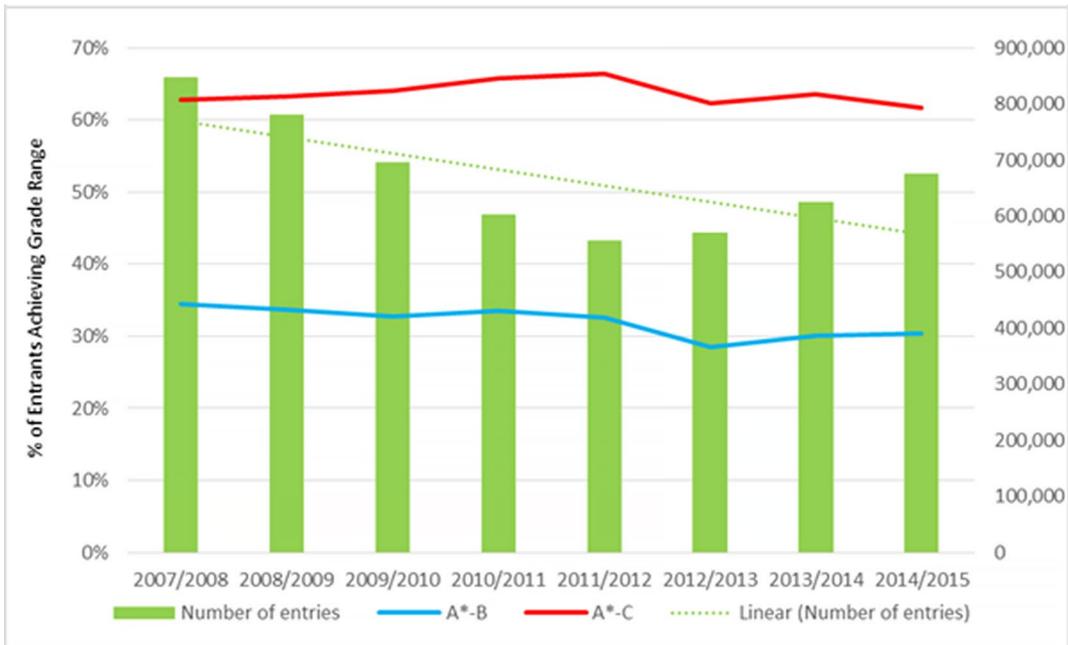


Figure 5 Core and additional sciences combined – GCSE entrants and grade attainment



Figure 6 Mathematics GCSE entrants and grade attainment

science at age 11 has reduced the teaching of primary science, which could partly account for these decreases. Also, more than national tests, international assessments test students' ability to use and apply knowledge, skills and processes in unfamiliar contexts. Coupled with the 2011 policy change from an enquiry-based to a knowledge-based curriculum, this is another example of unintended consequences resulting from policy change.

Take-up of degrees, apprenticeships and employment

There has been mixed improvement in the take-up of degrees, apprenticeships and employment in STEM areas. There is a very slight increase in the take-up of undergraduates studying STEM subjects, with around 45 per cent of undergraduate numbers in STEM subjects (Gatsby Foundation, 2014).

There has been minimal increase in uptake of STEM apprenticeships and vocational pathways. Of the three categories of apprenticeships (levels 2 to 4), the expansion in government-funded apprenticeships at level 2 has not been in STEM subjects. There has been an increase in science, engineering and technology (SET) apprenticeships from 20 950 in 2002/03 to 38 950 in 2012/13, while non-SET apprenticeships have risen sixfold in the same period.

Despite government policy and commitments in STEM, there continues to be a skills gap in the STEM area, with a year-on-year increase (12 to 19 per cent) of UK employers reporting difficulties in finding suitable STEM graduate recruits (UK Commission for Employment and Skills, 2014). The increase in attainment pre- and post-16, and the increased take-up of STEM subjects at A level, suggests that the STEM policy to increase the number of UK young people progressing to STEM careers and pathways has yet to be totally successful and is in jeopardy of delinking due to conflicting government policies.

Recruitment, retraining and retention of STEM specialist teachers

The government prioritises recruiting, retraining and retaining of teachers in STEM subjects so as to improve the quality of teaching in those subjects. By recruiting the best people into teaching, training them well initially and maintaining their skills and effectiveness through professional development, it is intended that the outcomes for young people will improve too.

There are yearly targets for teacher recruitment, and support for the recruitment and training of specialist teachers in maths and science, with scholarships for top graduates (Department for Education, 2015) and

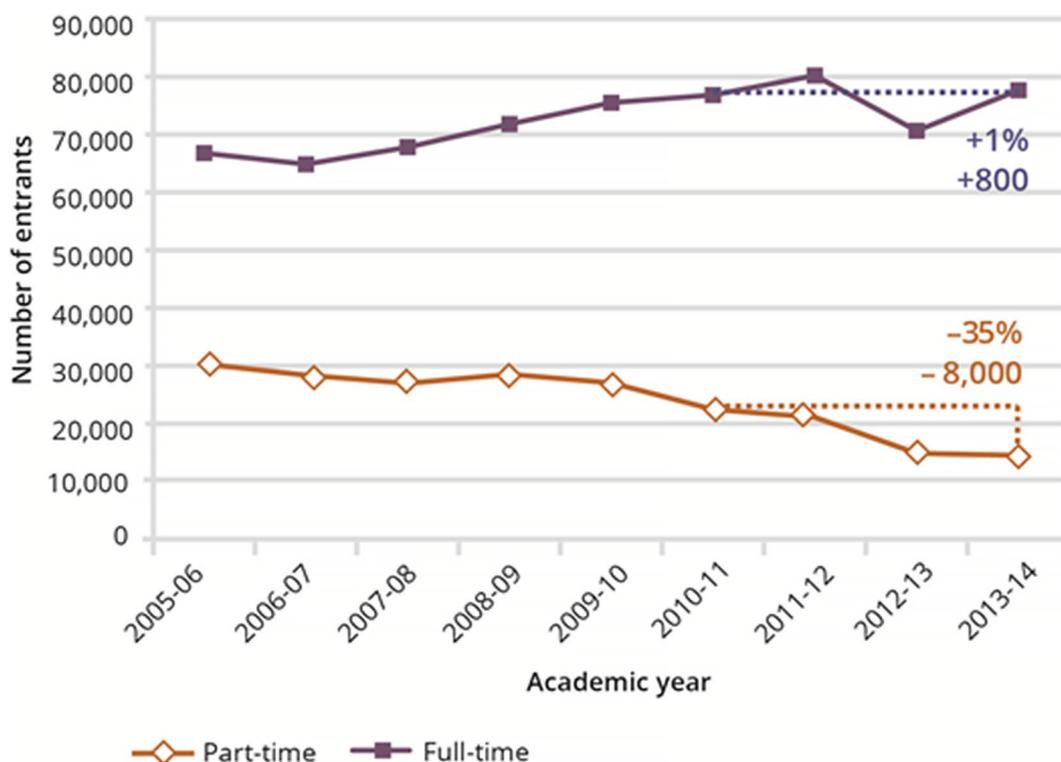


Figure 7 UK and other EU entrants to undergraduate STEM courses registered at English higher education institutions, 2006–07 to 2013–14

additional funding to retrain existing teachers on subject knowledge enhancement programs.

During the global recession (2007 to 2010), when more people entered teaching, the targets were almost reached. However, the recruitment of teachers with STEM qualifications has declined in recent years. There has been an improvement in the British economy, which has made it harder to attract people into teaching, and, as mentioned earlier, changes to teacher training, with the introduction of a school-based training program, which appear to have severely affected the take-up in STEM subjects. Again, there is an indication of conflicting government priorities having a negative effect on STEM education.

Teacher recruitment, retention and student outcomes

It is clear from the recent position paper (Office of the Chief Scientist, 2015) that the Australian government is taking measures to transform STEM teaching in Australian primary schools, focusing on initial teacher education and professional development. The English government has provided extensive continuing professional development for teachers of STEM subjects over many years (see Appendix 1). Employers support STEM education by funding programs including single employer-based activities and continuing professional development for teachers. A group of STEM employers, the Wellcome Trust and the UK government contribute to Project ENTHUSE,³ which provides teachers with bursaries for sustained career-enhancing continuing professional development through the National STEM Learning Centre in York.

Given this plethora of continuing professional development available to teachers, the question is this: does it make an impact on the STEM outcomes the government has set? To answer this, we can examine the evidence from the evaluation of continuing professional development projects and from the inspection of schools in England carried out by the Office for Standards in Education, Children's Services and Skills.

The most recent inspection report in science by the Office for Standards in Education, Children's Services and Skills (2013) indicates that the majority of the teachers observed were skilful in teaching interesting science lessons, with the majority of the lessons (69 per cent) rated as good or outstanding.

³ Project ENTHUSE is a unique partnership of government, charities and employers that have come together to bring about inspired STEM teaching through the professional development of teachers, technicians and support staff across the UK. Current ENTHUSE participants include the Department for Education, Wellcome Trust, BAE Systems, Biochemical Society, BP, Institution of Engineering and Technology, Institution of Mechanical Engineers, Rolls-Royce, and the Royal Society of Chemistry.

They found that:

- 'A very low proportion of the subject leaders in the survey had received specific professional development in providing leadership for science. However, schools that had provided science-specific professional development were much more likely to be judged as outstanding in their overall effectiveness of science.' [page 6 summary]
- 'There was a strong correlation between a school's provision of continuing professional development (CPD) for teaching science, and the overall effectiveness of science.' [paragraph 28]
- The mathematics report indicates a much more mixed view of the improvements in the teaching of mathematics, while the achievement and provision in design and technology in 2011 were good in about two-thirds of the primary schools and just under half of the secondary schools, particularly where up-to-date technologies were used and explained accurately to students. However, a lack of subject-specific training for teachers undermined efforts to develop students' knowledge and skills, particularly in using electronics, developing control systems and using computers to aid in designing and making.

The government in England has funded subject-specific continuing professional development science through the National Science Learning Network for 10 years, and it is here that the best effects of strong and strategic policy directions can be seen. The Network has considerable evidence that those teachers who access sustained subject-specific professional development:

- improve teaching and learning, thus increasing uptake and achievement in science
- improve in their subject and pedagogical knowledge, skills and confidence, resulting in better outcomes for young people
- develop strong leadership in science
- help to recruit and retain excellent teachers
- enrich teaching, and support young people's engagement, progression and awareness of STEM careers (National Science Learning Network, 2015).

This evidence concurs with the hypothesis that professional development in science has positive results on improving teaching and learning. The government funding for professional development in mathematics and design technology has been less sustained and not yet fully evaluated for its impact.

InGenious, a European project across 26 European countries, also found that continuing professional development had an impact on improving students' interest in STEM careers and increased their likelihood of take-up (Stem Learning, 2014; see also InGenious and the Science Learning Network, 2014). The evaluation of

the project identified four factors that improved teaching and influenced students' future choice of career:

- interesting classroom and extra-curricular activities
- inputs from experts, through learning resources as well as direct interaction with teachers and students
- embedding real-life applications of STEM knowledge and STEM career information within teaching materials
- sustained professional development for teachers through interactive and online resources as well as face-to-face opportunities.

Impacts of continuing professional development

The UK government policy to support STEM education has had some positive impact on the attainment and progress of students in science. There has been an increase in the uptake of sciences pre- and post-16, and some limited increase in up-take of STEM degrees, but less improvement in vocational areas. There is clear evidence that to increase students' attainment and interest in STEM pathways and careers, teachers of STEM subjects need sustained subject-specific continuing professional development to improve their subject and pedagogical knowledge, their confidence, their competence, and their leadership, to motivate them to stay in teaching and make good career progression.

There are still insufficient people available for employment in STEM companies in the UK, and people with STEM degrees entering and staying in teaching, which is partly due to the age profile of the country, the economic recession and, possibly, some conflicting government policies. You can pose the question: if the government had not had the STEM strategy, would the situation be worse?

What can Australia learn from UK approaches?

There are a range of strategies and approaches used in the UK to increase the interest and take-up of young people into STEM study and career pathways that Australia might like to consider.

It is helpful to have a clear, sustained, long-term government vision, strategy and funding for STEM research and development, strategies to increase citizens' awareness of the importance of STEM to the economy, and strategies for inspiring young people to take up STEM pathways.

Learning from UK and Europe, it is clear that constant fluctuations and changes in government education policies and funding have not been helpful in providing

consistent and cumulative improvements. The best outcomes for young people and for sustainability in the STEM arena will come through an integrated approach that has all political party agreement for implementation and evaluation of impact over a sustained period. Setting realistically timed outcomes and targets in partnership with the teaching profession will bring about sustained change.

An effective partnership between government, industry (particularly STEM employers) and charitable trusts focused on STEM is vital to providing sustainable commitment and funding for STEM development. Together, these organisations can enrich the STEM curriculum, provide teachers with opportunities to learn about STEM knowledge and skills in context, and gain up-to-date knowledge about careers, which will entice more students into STEM career pathways. Funding teacher continuing professional development is very cost-effective – one teacher can influence a minimum of 250 students per year, or more than 10 000 students during a teaching career.

There are a range of measures with proven impact that, with sustained funding, will increase the likelihood of young people taking STEM study pathways. These include:

- culturally valuing an interest in and expertise in STEM subjects, on par with success in sports and cultural pursuits
- making teaching financially and culturally appealing, and attracting and keeping the highest calibre of teachers in STEM subjects
- the support of school leaders for teachers of STEM subjects to receive regular, high-quality subject-specific professional development to improve subject content and pedagogical knowledge, subject-specific leadership development and their knowledge of career pathways for young people
- teachers having access to up-to-date online information and curriculum-based resources about cutting-edge developments in STEM subjects, which help embed information about career pathways in the curriculum
- access to experts from the world of STEM for both teachers and students, to enhance the curriculum and teaching
- a clear pathway of STEM knowledge and skills across the curriculum, so students develop them and understand how they are used in context
- sufficient time for teachers to prepare, implement and evaluate the impact of the changes to the curriculum, assessment and accountability measures
- a coordinated and cohesive approach to enrich and enhance the experiences of ALL young people in

STEM subjects, through formal and informal learning opportunities

- training teachers, schools leaders and professional development providers in effective strategies for the evaluation of the impact of continuing professional development.

It is a combination of these strategies and partnerships that are likely to make a difference to attracting sufficient young people to take up STEM pathways and careers in the future.

Appendix I

Current government-funded continuing professional development projects in England

- The National Science Learning Network, consisting of around 45 Science Learning Partnerships, mainly based in teaching schools
<http://www.stem.org.uk>
- A national network of 34 Maths Hubs based in schools, coordinated by the National Centre for Excellence in the Teaching of Mathematics
<http://www.ncetm.org.uk>
- The Further Maths Support Programme, focused on A level mathematics for 16 to 18 year olds
<http://www.furthermaths.org.uk>
- Core Maths, aimed at increasing the number of post-16 students studying the subject, and designed to maintain and develop real-life maths skills
<http://www.core-maths.org>
- A national network of Master Teachers in computing, coordinated by the British Computer Society and through Computing at School (CAS)
<http://www.computingatschool.org.uk>
- STEM Ambassador program enabling employees with STEM expertise to provide support in STEM subjects and activities in schools
<http://www.stemnet.org.uk/ambassadors>
- The National STEM Clubs Programme, support for out-of-school STEM meetings
<http://www.stemclubs.net>
- Your Life campaign, aimed to increase the number of boys and girls progressing to A level maths and physics and beyond
<http://yourlife.org.uk>
- Stimulating Physics Network, through the Institute of Physics, providing support and resources for schools struggling to deliver high-quality physics lessons
<http://www.stimulatingphysics.org>

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