mascil
mathematics and science for life

Analysis of the British policy context

mathematics and science for life

mascil

mascil aims to promote a widespread implementation of inquiry-based teaching (IBL) in math and science in primary and secondary schools. It connects IBL in schools with the world of work making math and science more meaningful for young European students and motivating their interest in careers in science and technology.

The project mascil has received funding from the European Union Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

1.5 National Report of United Kingdom

Note: This report of the educational systems and policy contexts in England is written at a time when substantial changes are currently being made in almost all aspects of education affecting curriculum and assessment, governance structures of schools, teacher employment and training.

The focus is on schools in England as other constituent nations of the United Kingdom are increasingly adopting different directions. Scotland has always had a different education system whilst Wales and Northern Ireland often choose to adopt either new initiatives in response to suggested changes from England or indeed maintain the status quoi rather than making changes.

PART 1: A DESCRIPTIVE, EVIDENCE-BASED ACCOUNT OF THE NATIONAL CONTEXT

1. Introduction: school systems and structures

Although the education system in England in relation to school types and the curriculum, including associated assessment and qualifications, provides a complex textured landscape in this report this will be considered in a simplified way reflecting that for many young people up to age 16 there is but one common route. For the majority of pupils compulsory attendance at school from age 5 -16 involves attendance in Primary and Secondary sectors with transition between sectors age 11. The vast majority of pupils attend non-selective schools that cater for all children from a local area[55] and throughout they will experience the National Curriculum that defines in general terms programmes of study focussing on learning up to age 7 (Key Stage 1), from age 7 to 11 (key stage 2), from age 11 to 14 (key stage 3) and in the last two years of compulsory schooling at ages 15 and 16 (key stage 4). Although the governance and funding of schools has become increasingly complex over the last twenty years or so the National Curriculum which was first introduced in 1988 until recently ensured a relatively common curriculum experience for all pupils. Most recently different school types have different obligations as to whether

[55] A small minority of pupils (approximately 4%, DCSF, 2008) live in areas that maintain a selective system of secondary schooling in which the most able attend a Grammar school whilst the remainder attend other secondary schools that are in all ways other than intake similar in nature to the “comprehensive” schools elsewhere.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

they are legally obliged to ensure they follow the national curriculum. However, it seems likely that the influence of assessment, and the use of results of this in devising league tables of school performance, will ensure that there is not too much deviation from the National Curriculum as schools devise their own curricula.

There is a bewildering array of school types each of which is subject to different forms of governance and funding as well as legal obligations (for example, in relation to the National Curriculum). The current education policy is to encourage diversity of school type and schools that are independent from the traditional long-established structures of governance which saw schools controlled by locally democratically elected councils through Local Education Authorities (latterly known simply as Local Authorities).

The current government policy is to encourage Local Authority controlled schools to become 'Academies'. These are publicly-funded schools with some receiving funding from sponsors from business, faith or voluntary groups but with the bulk of funding coming directly from the government, not the Local Authority. They are run by a governing body that has oversight of matters such as the employment of staff and the curriculum (they don't have to follow the national curriculum and can set their own term times and school hours). Although having some independence Academies still have to follow the same rules on admissions, special educational needs and exclusions as other state-funded schools. As Academies are becoming established it can be observed that they often reinvent the 'community' that the Local Authority previously offered as they start to develop new communities by working with other schools in geographically local confederations or chains. In some cases Academies are supported substantially by a business sponsor that brings together a number of Academies under their banner and influence.

In this move to new structures the Education Minister (since 2010) is additionally encouraging, following the Swedish model, the development of free schools. These can be set up, subject to the direct agreement by the Minister of Education, by groups such as charities, universities, independent schools, community and faith groups, teachers, parents, businesses. Free schools are, like Academies, funded directly by central government and have more direct control over how they organize education. However, they can't use academic selection processes, but can set their own pay and conditions for staff and change the length of school terms and the school day. Like Academies they don't have to follow the national curriculum.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

This document gives a good overview of current school types and the ways in which they are governed:

http://newschoolsnetwork.org/sites/default/files/files/pdf/Differences%20across%20school%20types.pdf

Although there are many school types with different expectations about their need tocomply with a national curriculum there are two key levers of accountability that ensure some uniformity in the school experience of students: the publication of school performance in national testing and qualifications and inspection of schools.

There are, two types of schools emerging in the new era of school diversity that in similar ways promote a curriculum that is more connected with the world of work: University Technical Colleges and Studio schools. These types of schools are very new and only a few are currently open with more planned. However, they provide a potential model that MaSciL in England will wish to explore.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

UTCs are academies for 14- to 19-year-olds with a focus on providing something of a 'technical' education. They have university and employer sponsors and combine practical and academic studies. UTCs specialise in subjects that need modern, technical, industry-standard equipment – such as engineering and construction – which are taught alongside business skills and the use of ICT.

All UTCs:

- are sponsored by a local university and employers. It is also usual for Further Education[56] colleges and other educational institutions to work in partnership with them
- specialise in 2 curriculum areas (eg engineering and science)
- teach core GCSEs alongside technical qualifications, and we expect them to offer young people the opportunity to achieve the English Baccalaureate

From www.utcolleges.org

The core national curriculum requirements will be provided, but outside of the national curriculum, the subjects available at GCSE will depend on the UTC.

At 14-16 the split of time between general education/bridging core studies and technical studies is 60:40 respectively.

Broad technical studies would be e.g. engineering; experience of work, projects; and mentoring. Post-16, students will be able to continue with their studies or they may choose to do an apprenticeship, which might include part-time study at the UTC. If students choose to continue full-time study at the UTC the split of time between general education/bridging core studies and technical studies will become 40:60 respectively. The technical study will become more specialised and job-related

[56]Further Education (FE) Colleges traditionally cater for post-16 students and often run vocational and pre-vocational courses as well as providing for those wishing to follow traditional academic courses at all levels as well as basic skills courses for adults.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

- focus on disciplines that require highly-specialised equipment, for example, engineering, manufacturing and construction
- teach these disciplines alongside developing young people's business, ICT and design skills to prepare students for a range of careers and continuing education at 19
- have 500 to 800 students

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

Studio schools

Studio Schools are also new and innovative schools for 14- to 19-year-olds, backed by local businesses and employers. They often have a specialism, but focus on equipping young people with a wide range of employability skills and a core of academic qualifications, delivered in a practical and project-based way

Studio Schools are small - usually with around 300 pupils – providing courses leading to mainstream qualifications through project-based learning. This means working in realistic situations as well as learning academic subjects.

Students work with local employers and a personal coach, and follow a curriculum designed to give them the skills and qualifications they need in work, or to take up further education.

These schools are experimental and cater for a very small number of students. For example, by the end of 2014 about 14,000 students will study in Studio schools out of a total school population of about 3.1 million students in compulsory secondary education in England.

Details of the curriculum of Stephenson studio school

The studio school Key Stage 4 year

*The studio school year is divided into three units, each lasting seventeen weeks. In each unit students will work on a **Core Project** that focuses on a particular area of learning. Each **Core Project** will address a key question and students will be expected to originate a product.*

For example the key or driving question for the year 10 Core Project Leading Healthy Lifestyles is, 'How can I make my community healthier?' The final product is a local health campaign designed to change behaviour so that a target group adopts a healthier lifestyle.

The relationship between students' learning and the real world is further reinforced through the way that this work is commissioned. Core projects will be commissioned by local community organisations and businesses. The leading healthy lifestyles project will be commissioned by a local health organisation.

Over the course of a student's time at school, the units gradually become more open and increasingly challenging. This allows students to gradually adapt to project based

The project mascil has received funding from the European Union Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

> *learning, something that is a key feature of both working and university life.*
>
> *Students will also participate in a series of subject specific learning sessions to support preparation for exam success. Wherever possible these are linked to the context of the enterprise projects to ensure that learning connects with the real world. Further one-to-one and small group coaching sessions will help students with any areas of studies they are finding difficult.*

2. Wider policy perspectives

There has been much change in policies in relation to all aspects of education since the election of 2010 and the resulting coalition government. This has seen a marked politicization of education with policy direction being influenced by an underlying belief in local empowerment achieved through a smaller central state, markets and privatization (Hodgson and Spours 2012)[57]. Alongside this central thrust of policy direction, government ministers have also initiated changes in all aspects of curriculum and associated assessment and qualifications. Mathematics and Science are seen to be of central importance and prioritized alongside the learning of English language.

Extracts from a recent speech made by an education minister to the Confederation of British Industry[58]perhaps best indicate current policy intentions[59]:

> ***The next industrial revolution?***
>
> *Deindustrialisation was led by globalisation and technology: today, we face rapid shifts in global economic power and a new digital economy.*
>
> *If any of you saw Newsnight [current affairs TV programme] just the other week, the technologist Rohan Silva was talking about an 'hour-glass' shaped economy.*

[57]Ann Hodgson & Ken Spours (2012) Three versions of 'localism': implications for upper secondary education and lifelong learning in the UK, Journal of Education Policy, 27:2, 193-210, DOI: 10.1080/02680939.2011.587541

[58] Speech made by Liz Truss to the CBI, the major organization of employers in the UK.

[59]https://www.gov.uk/government/speeches/elizabeth-truss-speaks-about-curriculum-reform

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

In this emerging model there is wealth for the highly-skilled, who can harness new technologies.

At the other end of the scale, there are lots of low-paid, low-qualifications jobs - local, manual labour which cannot be easily automated or outsourced.

But in the middle, white-collar, middle-class jobs are now threatened by high-powered computers and highly-educated graduates across the world.

This is an era of unprecedented competition.

Compete or fall behind

And it leaves us with a question. How do we respond?

In an era where human capital is more important than physical capital, it means we need to improve education.

The evidence is quite clear here: countries with higher attainment have higher growth rates. And the association between test scores and growth rates increased by a third between 1960 and 2000.

This should worry us. PISA - the OECD international student assessment - ranks us only 25th in reading, 27th in maths and 16th in science.

If we develop a world-class education system - but only if we develop a world-class education system - we have a chance to become one of the high-skilled, highly-educated societies that takes advantage of the new order.

Nowhere is this clearer than in maths, science and engineering.

Maths, for example, is the only school subject which has been proven to add to earnings, by up to 10% at A level, even when every other factor is taken into account.

Pupils who are ahead of their peers in maths at age 10 tend to be earning 7% more at the age of 30. Those working in science or technological careers are paid, on average, 19% more than other professions. The earnings return for a level 3 apprenticeship in engineering or manufacturing is double that of arts, media or business administration apprenticeships.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

This is great for those individuals - but the real importance of these numbers is what they tell us about the UK economy.

Higher wages are a sign of employer need - of the relatively high value and productivity of STEM[60]-educated staff.

They suggest that excellent STEM education is of essential economic importance - a level of demand that we can't afford to ignore.

The German example - PISA shock

……

One of the big myths about Germany is the supposed purity of its vocational education. They have, in fact, been moving in the opposite direction - and it shows that deciding between vocational or academic education is a false choice.

The result of these decade-long reforms was impressive. In 2000, Germany was behind England. By 2009, they'd overtaken us.

The 'PISA schock', as it become known, shows what can be done when there is focused education reform.

Now compare England to Germany. We've already seen our PISA ranking is unnervingly low.

TIMMS - an international benchmarking of maths and science teaching - shows we have stagnated in maths, and for 10-year-olds, our science scores have dropped.

In Japan, 85% take advanced maths, equivalent to at least AS level, in upper secondary.

In Taiwan, the figure is 70%.

In England, it's 13%.

A rounded curriculum

[60] Science, Technology, Engineering and Maths

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

This is why we are changing the system - starting with curriculum reform.

We're learning from Germany here. Whatever pupils want to do after school, and whether vocational or technical training is right for them, a solid academic core helps them get there. ……

Maths

So what are we actually doing in each subject?

I want to start with maths - the most important for our future.

At primary, we're encouraging children to become fluent in their times tables at a younger age, removing calculators from primary tests - and introducing a new curriculum giving children a stronger foundation in the vital elements of maths, like arithmetic and fractions.

Our schools spend less time teaching maths than most countries - TIMSS 2011 ranked us 39 of 42 for maths teaching time at age 14. In the subject where we are behind, we are doing less. So improving secondary maths is a top priority.

We're making GCSEs[61] more challenging and rigorous, with pupils covering more content and more non-routine problems which expect students to apply themselves in different ways - in areas like ratios, proportions, interest-rates.

….

Sciences

We're being equally ambitious in the sciences.

GCSE and A level content will be deeper. And as more and more scientific disciplines require maths, we're increasing the maths component of the sciences. In biology, for example, pupils will be better prepared for biomechanics or genetics - opening up more options to our young people.

And thanks to our curriculum reforms, we've started to see real progress in the numbers of students taking sciences.

[61] GCSEs (General Certificate of Secondary education) are nationally recognized qualifications taken by all students at age 16.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

This year, the number of girls doing chemistry or physics at GCSE hit record levels - catching up with the boys. Looking at the numbers over the previous decade, we have seen a massive improvement.

….

DT[62] and computing

We're also making sure students can apply this knowledge, too.

Our new design and technology courses focus on the practical application of science. It will expose students to the most exciting and transformative technologies - 3D printing, robotics, biomimicry, computer-aided design.

And computer skills are being brought in earlier, too. Coding - one of the essential skills of the 21st century - will now start at age 5. We are aiming to develop one of the most rigorous computing curricula in the world, where pupils will learn to handle detailed, abstract computing processes and over-11s will learn 2 programming languages.

….

***A challenge to employers** [the audience]*

And I want to challenge you to follow this example.

We are rebalancing the curriculum towards high-value subjects - in maths, the sciences, DT, computing, English and the languages. We have unblocked the pipeline of future engineers, mathematicians, linguists - and in time, you will feel the benefit.

But think about what you could do too - ….

we've seen record numbers of girls entering the sciences at GCSE. But it's still fewer than boys. So what could you do - how could the voice of business persuade young women engineering isn't just a job for the boys? How do you persuade girls there are careers in science, and translate that GCSE uptake into A level?

…..

[62] Design and Technology

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

> *We face a rapidly changing, newly competitive world. Improving education - especially maths and science - is essential if we are to compete.*
>
> *We are approaching the task with a sense of ambition and energy. And I urge employers to join us.*

In summary: This speech puts forward an argument that in education mathematics and science should be prioritized from the point of view of ensuring a well-qualified future workforce so that the UK is well-positioned to compete in the world economy. Students are to be encouraged to study mathematics and science using an argument that highlights the potential financial reward it may offer in future careers. As in many other speeches by government ministers key aspects of policy change in curriculum are referred to. These prioritise a curriculum that has a renewed focus on fundamental academic knowledge, particularly in mathematics, science and language. The rhetoric is based on a call for getting 'back-to-basics', suggesting that students need instant recall of fundamental knowledge if they are ever to be well-positioned to solve problems.

There is in general no emphasis on vocational education or connecting compulsory education, at both primary or secondary levels, with the world of work. This is reflected not only in the school curriculum, as evidenced in the minister's speech, but also in structures of schooling in which, in general, there is no provision of vocational schools (although exceptions are emerging and are discussed below). Indeed, the minister throughout the speech draws selectively from comparative data and highlights experiences from other countries that support the government's argument.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

3. National curriculum

The National Curriculum and what students should learn has, as the government minister's speech demonstrates, become politically contested territory in recent years. This is somewhat problematic as political timescales are much shorter than those required for large scale change in the education system[63]. The most recent curriculum framework announced by the Secretary of State for Education in September 2013 has taken over three years to produce since the election of the coalition government in 2010. Indeed, the majority of the new national curriculum won't come into force until September 2014, with the new national curriculum for English, mathematics and science having a phased start from September 2015, by which time there will be a new government.

Full details of the new curriculum can be found at:

https://www.gov.uk/government/publications/national-curriculum-in-england-secondary-curriculum

https://www.gov.uk/government/publications/national-curriculum-in-england-primary-curriculum

The mathematics curriculum document for early secondary years states that it aims to ensure that all pupils:

- become **fluent** in the fundamentals of mathematics, including through varied and frequent practice with increasingly complex problems over time, so that pupils develop conceptual understanding and the ability to recall and apply knowledge rapidly and accurately.
- **reason mathematically** by following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or proof using mathematical language
- can **solve problems** by applying their mathematics to a variety of routine and non-routine problems with increasing sophistication, including breaking down problems into a series of simpler steps and persevering in seeking solutions.

It goes on to suggest that "mathematics is an interconnected subject in which pupils need to be able to move fluently between representations of mathematical ideas. The

[63] Noyes, Wake and Drake (2013) **Time for curriculum reform: the case of mathematics, Curriculum Journal. DOI:10.1080/09585176.2013.812973**http://www.tandfonline.com/doi/full/10.1080/09585176.2013.812973#.UkFQbxYrjww

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

programme of study for key stage 3[64] is organised into apparently distinct domains[65], but pupils should build on key stage 2[66] and connections across mathematical ideas to develop fluency, mathematical reasoning and competence in solving increasingly sophisticated problems. They should also apply their mathematical knowledge in science, geography, computing and other subjects."

Experience of previous incarnations of the National Curriculum for mathematics suggest that it is likely that the list of 'content' will dominate over other processes that are identified as 'working mathematically' in the specification: working fluently, reasoning mathematically, solving problems. This is often a result of timed written assessment that is high stakes for both pupils in terms of their qualifications for progression within education and to work, and for schools and institutions that are ranked in league tables that aggregate individual students' qualifications by grade. Such assessment in mathematics has high levels of reliability in grading and has been shown to value competence in application, at an atomistic level, of rules and procedures at the expense of understanding[67].

In a similar vein the national curriculum for science aims to ensure that all pupils:

- develop **scientific knowledge and conceptual understanding** through the specific disciplines of biology, chemistry and physics
- develop understanding of the **nature, processes and methods of science** through different types of science enquiries that help them to answer scientific questions about the world around them
- are equipped with the scientific knowledge required to understand the **uses and implications** of science, today and for the future.

[64] Pupils aged 11-14
[65]Number, Algebra, Ratio, proportion and rates of change, Geometry and measures, Probability, Statistics
[66]Pupils aged 7-11
[67]https://www.gov.uk/government/publications/evaluating-mathematics-pathways-final-peport

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

By the end of Key Stage 4 it is intended that the science examination specifications enable students to

- *'develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics*
- *develop understanding of the nature, processes and methods of science, through different types of scientific enquiries that help them to answer scientific questions about the world around them*
- *develop and learn to apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory and in other learning environments*
- *develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.'*[68]

However, it has been argued that scientific practice is represented in several interrelated domains; including the real;-world contexts in which scientific questions arise and the more formal processes of critiquing established theories and models, investigating and developing explanations and solutions to problems. http://www.score-education.org/media/7316/jo.pdf.

In this framing, Osborne argues that the core set of science practices include:

- the development of models of how the world might be;
- designing experiments to test the models and hypotheses;
- analysing and interpreting data as the outcome of experiments are rarely conclusive;
- using mathematics as a tool for modelling the material world and that some ideas in science such as the notion of an electromagnetic wave and the equivalence of mass and energy are a product of mathematical modelling not of observation;

[68] http://www.education.gov.uk/schools/teachingandlearning/qualifications/gcses

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

- constructing explanations of the material world which are coherent and parsimonious;
- engaging in argument from evidence; and
- obtaining, communicating and presenting scientific information.

If it is accepted that science education should concern building learners' knowledge and understanding of:

- scientific facts and theories;
- procedural knowledge (Gott and Duggan 2010[69]) and
- scientific argumentation,

then a curriculum that emphasizes acquisition of factual knowledge alone fails to do justice to what science is and to its potential contribution to society.

4. Curriculum Materials

The UK has for many years been regarded as a hot-bed of curriculum development with many independent projects over the years having developed many innovative approaches to education in mathematics and science, as well as more widely across the curriculum. This has provided teachers with a potential rich bank of materials on which to draw, both in regards to inquiry approaches and making connections with the world of work (although the latter is less well served than the former). Notable amongst these many potential sources are the following:

http://www.nuffieldfoundation.org/education

http://www.smpmaths.org.uk

http://www.mei.org.uk

http://nrich.maths.org/frontpage

http://www.m-a.org.uk/jsp/index.jsp

http://www.atm.org.uk

[69] http://www.tandfonline.com/doi/abs/10.1080/09500690110110133#.UkFnIRYrjww

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

http://www.ase.org.uk/home/

http://www.iop.org/education/

http://www.rsc.org/education/

https://www.societyofbiology.org/education

The National STEM Centre (http://www.nationalstemcentre.org.uk) has developed an e-library that hosts thousands of excellent resources for the teaching of sciences and mathematics from the present day and carefully collected and archived from the past.

In appendix 1 we give a brief glimpse of some of the many materials that have been developed to promote connecting mathematics and science to the world of work in the UK.

The lack of connectivity between school learning in mathematics and the sciences is not due to lack of resources, rather it is because of all the other policy priorities that value academic education above all else.

5. Teacher education

5a. Initial Teacher Education (ITE)

The current diversity of school-types is mirrored in the vast array of courses of preparation to become a teacher. As the government's own website[70] setting out advice for aspiring teachers indicates:

> There are hundreds of different initial teacher training (ITT) courses available in the UK. Choosing between them is a challenge in itself, and you should be prepared to put in a lot of research.
>
> Your choice of ITT provides the foundation for your future as a teacher. As well as deciding which age group and/or subject you intend to teach, you should consider: the kind of ITT you'd like to complete
>
> ITT courses are flexible and are designed to support a wide range of individual circumstances. You can choose from:

[70] http://www.education.gov.uk/get-into-teaching/teacher-training-options/itt-routes/choose-a-course.aspx

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

- School-based training schemes, such as **school-centred initial teacher training (SCITT)**, the **School Direct Training Programme and School Direct Training Programme (salaried)**. School Direct is a great new way to gain the skills you need to become a teacher. This school-led path includes some of the country's best schools, and you could be specially selected by one of them with a job in mind just for you.
- Undergraduate and postgraduate courses, offered by universities and colleges, which include at least 18 weeks spent teaching in schools.
- Online ITT courses, in which you study from your own home. The **Open University** and **Hibernia College UK**, for example, offer such courses, which are suitable for individuals who have employment and/or family commitments.

As a trainee, you will gain classroom experience by spending time teaching in at least two schools. Other than employment-based programmes, all routes include some training in schools as well as at your chosen university or higher education institution (HEI).

Trainee teachers will typically spend at least the following amounts of time being trained in schools:

- 160 days (32 weeks) on a four-year undergraduate programme
- 120 days (24 weeks) on a two- or three-year undergraduate programme
- 120 days (24 weeks) on a secondary programme for graduate trainees
- 90 days (18 weeks) on a primary programme for graduate trainees

The duration of employment-based schemes will be determined by the training programme.

As a graduate trainee, you are expected to have a good understanding of the subject or subjects you are training to teach before you start your ITT programme. Some subject training courses are available to help you improve your **subject knowledge and understanding**

The current coalition government has made many changes to the structures of Initial Teacher Education, with a strong belief that there is a need for training that is school-led. This is a major change from well-established practices that have for many years seen the

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

vast majority of entrants to the teaching profession taking part in Post-Graduate Certificate Education courses in Higher Education Institutions (HEIs).

This shift in policy direction is evidenced in the Secretary of State's speech of September 2013[71] when he put forward his view of the importance of teaching.

Extracts here highlight the current policy direction, although it is too soon to come to any considered judgment about the success or otherwise of such a shift:

> *Take, for example, the whole practice of teacher training.*
>
> *The evidence shows the best teacher training is led by teachers; that the skills which define great teaching - managing behaviour, constructing compelling narratives, asking the right questions, setting appropriate tasks - are best learnt from great teachers; that the classroom is the best place for teachers to learn as well as to teach.*
>
> *The work of Doug Lemov in the United States - teacher, founder of a charter school, author of 'Teach Like a Champion', which has transformed the debate around teacher training and won followers all over the world - has found support right across the American political spectrum.*
>
> *In this country, schools play a central role in all of the ITT providers judged to be outstanding under Ofsted[72]'s tough new regime.*
>
> *We have already taken a number of steps to put teachers and schools in charge of recruitment and training.*
>
> *Brand new teaching schools have become centres of excellence in training and development - and we will be expanding the number of teaching school alliances beyond the planned 500. The first group of teaching schools have now been operating for 3 years and I can now confirm that their funding will continue beyond the planned 4 years into a fifth year.*
>
> *While our new teacher training scheme, School Direct, gives aspiring teachers the opportunity to work in a great school from day one, just like student medics in*

[71] https://www.gov.uk/government/speeches/michael-gove-speaks-about-the-importance-of-teaching

[72] Ofsted is the Office for Standards in Education which is a government agency that inspects the quality of education in schools as well as the provision of ITE courses across sectors

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

hospitals - learning from more experienced colleagues and immediately putting their new skills into practice.

In this speech the Minister goes on to speak of how the chronic shortage of mathematics and science teachers is being tackled. Although there are concerns that the move to school-based initial teacher training is leading to even greater shortfalls in recruitment. Recent research suggests that on the two routes (salaried and unsalaried)in which new recruits follow training directly in schools (known as School Direct). Data in the Parliamentary briefing note of August 2013[73] shows that:

- For physics, 75% of salaried trainee places were still empty at the start of August, as were 77% of unsalaried places.
- In chemistry, some 63% of salaried places were unfilled and 57% of unsalaried places.
- For maths, the figures were 56% and 61% respectively. Recruitment for trainee biology teachers was stronger, with 71% of salaried places filled but only 43% of unsalaried places.

The Briefing note reports July 2013 in the report of their research[74] Professor John Howson and co-author Chris Waterman argue that recent reforms to the ITT system, combined with other demographic and economic factors, risked creating teacher shortages in future years.

Prof Howson says this amounts to more than 800 unfilled training places for Stem teachers on School Direct.

His analysis indicates that the shortfall is compounded by fewer Stem trainees on PGCE courses where between 40% and 50% of places remain unfilled.

"Shortfalls of this magnitude in Stem subjects cannot be glossed over as insignificant" said Prof Howson.

In the Secretary of State's speech of September 2013 he goes on to suggest that the government is addressing this problem, although as the data suggests the measures being taken are at present insufficient:

[73] http://www.parliament.uk/briefing-papers/SN06710
[74] Howson, J., and Waterman, C., *Teacher training places in England: September 2013,* June 2013.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

We've also done a lot to deal with the systematic shortages of specialist maths and physics teachers that we inherited. We've collaborated with the Institute of Physics and the Institute of Mathematics to introduce prestigious new scholarships worth £20,000 and brought in new training bursaries of up to £20,000 to attract the brightest graduates into these core subjects, more if trainees go to schools with a high proportion of pupils on FSM.

But we've got to go even further. So we will soon be announcing even greater incentives in shortage subjects, where recruitment has historically been most difficult, and we will do even more to encourage would-be teachers to study maths and physics at A level and beyond. And we've ensured that - at least in maths and physics - there will no longer be any cap on the number of teachers recruited each year, no published target for ITT places; on the contrary, we want to recruit as many new teachers in these subjects as we can.

Schools can now also use their new powers to attract and reward great teachers in specialist subjects, in particular - giving them the power to pay great physics and maths teachers more, right from day one.

The strength of the Secretary of State's belief that the well-established route into teaching through universities should be replaced by new school-centred training is strong as his speech goes on to demonstrate suggesting that in the next few years, over the duration of the lifetime of MaSciL, there will be much change in this particular area.

As schools take more control over training the next generation of teachers, many of the best academy chains and teaching school alliances are now playing an even greater role in training the next generation of teachers as accredited SCITTs, school-centred initial teacher training providers.

We want to see their numbers increase, enabling more aspiring teachers than ever before to benefit from the expertise and experience of some of the best in the business - so we will be bringing forward proposals to support this later in the year.

The best higher education institutions welcome our changes because they know that discriminating schools will increasingly choose partners in HE who deliver the best quality training and development.

Many have in fact been working hand in glove with schools for many years, and School Direct is just an extension of what they already do. Oxford University, for

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

example, has collaborated with local secondary schools on an internship programme called Oxford City Learning for many years now, and School Direct places have simply been incorporated within that successful scheme.

But sadly, there are some vested interests within some universities that oppose the shift towards school-centred teacher training by SCITTs or through School Direct; those, perhaps, which have long relied on an effective monopoly of teacher training to sustain their finances.

So it's vital for the future of the profession that we defend teachers from self-interested attacks - and stand up for the principle of teachers teaching teachers.

For those wishing to become teachers there have traditionally been two routes into teaching in terms of the way aspiring teachers structure their own education and obtain qualifications. Put simply, they may either study initially for a first degree in a specific discipline such as mathematics or science or follow a degree course that is situated in education as a discipline itself. The preparation of Secondary teachers is predominantly of the former type, with over 90%[75] following this route which until recently in most cases involved an additional year of university-based study leading to a Post Graduate Certificate in Education (PGCE), whereas in the Primary sector over 40% of entrants follow the latter route which provides a broader range of subject knowledge appropriate to teaching as well as study related to teaching and learning more broadly.

Although the design of the training / education is in the hands of ITE providers, be they HEI or school based, all new entrants to the teaching profession must have met a range of statements of competence defined nationally:

New Teachers' Standards were introduced in September 2012 and set a clear baseline of expectations for the professional practice and conduct of teachers, from the point of qualification. They replace previous standards leading to Qualified Teacher Status (QTS) and are used to assess all trainees working towards QTS, and all those completing their statutory induction period[76]. They should also be used to assess the performance of all

[75]Data from DCSF: School Workforce in England (including Local Authority level figures), January 2009 (Revised) (Appendix A Table A1)
http://webarchive.nationalarchives.gov.uk/20100210151716/http://dcsf.gov.uk/rsgateway/DB/SFR/s000874/index.shtml

[76] A period equivalent to a year of full-time teaching in school during which new teachers must show that they can cope with what is almost a full workload of teaching.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

teachers subject to the Education (School Teachers' Appraisal) (England) Regulations 2012.

These "standards"are organised around two themes: (1) Teaching, (2) Personal and professional conduct.

The majority of new entrants to teaching currently still follow one-year courses with a substantial HEI input although these are very much school focused with students spending at least 18 weeks in schools that work closely in partnership with a local HEI practising teaching under the guidance of a school-based mentor.

Consequently for "trainee teachers" the focus is very much on day-to-day classroom practice and the school as a work place. In an ethnographic study Hodkinson and Hodkinson (1999, 275) found that the predominant focus of school experience for trainee teachers concerned the pragmatics of 'teaching and implementation of national policies rather than those aspects of pedagogy, reflection and critical analysis' traditionally encouraged by the HEIs. The different priorities are perhaps encapsulated in the tension often experienced in the use of the words "education" and "training" which are often used interchangeably in this context but with very different underlying philosophies. This subtlety is recognized in the HEIs as they struggle to provide a wider base of professional knowledge to underpin practice. As Spendlove and colleagues (Spendlove, Howes and Wake 2010[77]) conclude in a study that explored the role of school based mentors who support trainee teachers working in schools during their PGCE year,

> *"It appears that interpretation and implementation of 'the standards' by the mentors in our case study legitimises an impoverished view of what it is to be a professional, omitting as they do reference to pedagogical understanding of a scholarly or theoretical kind (Shulman 1998). We fear that this narrow view of 'the standards', focused exclusively as they are on the ability to perform in classroom settings, is likely to ultimately lead to the recalibrating of the professional ability of teachers to a community that increasingly lacks the capacity to critically reflect on its own practice."*

5b. In-service teacher education or continuing professional development

Professional development work in the recent past was criticized as being more concerned with introducing new initiatives (such as the National Numeracy and Mathematics

[77] http://www.tandfonline.com/doi/abs/10.1080/02619760903414116?journalCode=cete20#preview

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

Strategies or revisions to examinations and assessment regimes), rather than enabling teachers to reflect on their own teaching in a sustained and systematic manner.

In 2004, the Smith report recognized that "a large-scale programme of subject specific continuing professional development (CPD) for teachers of mathematics in England, Northern Ireland and Wales is an urgent priority". In response to this, in 2006, The Researching Effective CPD in Mathematics Education (RECME) project was set up under the auspices of the National Centre for Excellence in the Teaching of Mathematics (NCETM[78]) in order to characterize different types of professional development and to investigate the evidence for, and interrelated factors that contribute to, making CPD effective; and to establish the roles of research in CPD[79].

The report defines professional development (PD) for teachers as follows:

"CPD for mathematics teachers should stimulate teachers to re-think, to experiment, to make fresh distinctions and to probe those distinctions to explore how they are informative in enabling choices related to teaching and learning."

The project reviewed 30 different professional development initiatives across England and this revealed something of the complex patchwork of such provision that exists. (including courses, within-school initiatives and network events). Of particular interest to MaSciL, their conclusions recommended that developers and providers of CPD should:

- take into account the experience and expertise of teachers and build on these as opposed to adopting a 'deficit model'
- encourage teachers to try out new ideas in the classroom by giving them 'permission' to do so
- build adequate time into the programme for teachers to try out new ideas and reflect on their learning
- consider the support, both intellectual and emotional, that teachers need in order to cope with adjusting to learning that challenges them intellectually and professionally

[78] https://www.ncetm.org.uk
[79] The full report may be downloaded from: https://www.ncetm.org.uk/enquiry/9251

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

- include stimulating and challenging mathematical activities within the CPD programme
- include opportunities for teachers to develop knowledge about mathematics and ways of teaching mathematics within the CPD programme. This should include focusing on theoretical concepts when appropriate
- pay explicit attention to students' mathematical learning, acknowledge that this is not easy and build in time and opportunities within the CPD for teachers to develop their capabilities to recognise and talk about mathematical learning. This could involve the dissemination of relevant supporting research findings
- take into account a combination of factors, including teacher learning, change in teacher attitudes, the extent to which engagement in the CPD seems to evoke passion, changes in teachers' practice and changes in student learning within processes of self-evaluation
- be explicit about research underpinning the design of the CPD and the ways in which changes in classroom practice are likely to influence student learning.

"*Importantly, changes should be sustained and ongoing and the argument in the literature is that, without change in teacher knowledge and beliefs, any change in classroom practice is unlikely to be sustained*." (Recme Report: Joubert & Sutherland, 2009).

National Centres in Excellence

The important role that mathematics and science have to play in national priorities has resulted in the provision of two important focal points, national centres focused on the teaching of science and mathematics. Although both organizations have the same aims of supporting the professional development in the teaching of their respective subjects they operate quite differently. The National Science Learning Centre[80] (NSLC) under the same roof as the National SREM Centre is geographically situated in the North of England and has facilities to host professional development courses as well as an administrative centre which coordinates the work of five regional Science Learning Centres funded by the government, managed by Myscience.co Ltd and run by various organisations centres:

[80] https://www.sciencelearningcentres.org.uk/

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

- regional Science Learning Centre Consortium London and the South East. The University of Hertfordshire
- regional Science Learning Consortium Central England: The University of Hertfordshire
- regional Science Learning Centre Consortium South West: Myscience.co Ltd
- regional Science Learning Centre Consortium Derbyshire,Yorkshire, the Humber and the North East: Sheffield Hallam University
- regional Science Learning Centre Consortium North West: Myscience.co Ltd

Together this network provides a range of opportunities for science teachers to engage with professional development in science teaching with funding that facilitates schools releasing staff to attend. In contrast the National Centre for Excellence in Teaching Mathematics (NCETM[81]) is a "virtual" centre with a web-based portal providing an on-line a focal point for mathematics teachers to find materials/resources and CPD opportunities made available by charter-marked providers. This is coordinated by a small group of staff with regional coordinators providing a point of contact for schools and colleges. In contrast to the NSLC and its regional network the NCETM has no dedicated buildings operating entirely on-line with staff either visiting schools / colleges or organising meetings at premises it hires for the occasion. The NCETM also funds research into effective teaching of mathematics with this mainly small-scale and carried out by collaborative networks of teachers often working with HEI staff.

The developing role of the NCERTM is perhaps best elicited by their own statements regarding current and future priorities:

> **The NCETM - present**
>
> The NCETM supports teaching schools and other improvement agents in their work with schools, colleges and teachers across England. The new NCETM is a consortium managed by Tribal Education in partnership with Myscience, Mathematics in Education and Industry (MEI), and the Institute of Education, University of London (IOE); it is funded by the Department for Education (DfE).
>
> It provides and signposts high quality CPD resources to teachers, mathematics education networks, HEIs and CPD providers throughout England. At the same

[81] www.ncetm.org.uk

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

time, the National Centre encourages schools and colleges to learn from their own best practice through collaboration among staff and by sharing good practice locally, regionally and nationally. It liaises with both the Further Mathematics Support Programme (A Level) and the LSIS STEM Support Service to ensure a coherent offer across the FE sector.

This collaboration takes place virtually through the NCETM portal and face-to-face through a regional network of established CPD network meetings that are now self-sustaining, but facilitated by the NCETM.

The Centre funds and publishes research into effective mathematics teaching practices and CPD. Teacher Enquiry in the classroom is supported by the Centre and findings are shared via the portal. Research both informs the NCETM's strategy and acts as a form of CPD in its own right.

Many of the aspects of the old NCETM continue. The highly recognisable NCETM brand will be seen at the forefront of its work, as will many of its features such as:

- online support for professional development provided through the Personal Learning Space and tools
- the portal resources such as the sector magazines
- online development modules
- support for providers of CPD through the CPD Standard and the directories of provision.

The NCETM – future

In supporting teaching schools and other improvement agents with their work the NCETM will, in particular, be providing:

- modules of online support for specialist leaders in education
- a programme of events for improvement agents (from teaching schools and other CPD providers), focusing on providing professional development, with separate programmes for primary and secondary mathematics. These programmes will consist of a 24-hour residential event, followed by an interim task to be completed in-school, and ending with another 24-hour residential event. Those completing the programme will be accredited and will be qualified to provide their own training to

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

schools directly. The first cohort will take place in May/June 2012 and it is intended that at least 300 delegates will benefit from this programme in 2012-13

- support for head teachers of teaching schools
- support for mathematics lead schools
- exemplification of the new teaching standards with respect to teaching mathematics
- aid in the consultations regarding the new National Curriculum
- amending the Self-evaluation Tools to take into account potential changes to the National Curriculum
- Teacher Enquiry funded projects to continue, with a specific emphasis on supporting the work of teaching schools, and with arithmetic, algebraic and geometric proficiency.

Both centres of excellence through their web presence support e-communities of teachers providing space for discussion across the full range of teaching issues in the different disciplines.

Of general and emerging concern in relation to the new emerging models of diversity in school types and governance is the lack of coherent provision of professional development and with the lack of the communities that Local Authority management of schools provided the potential lack of collaboration between schools. To some extent the latter is being redeveloped through new alliances that are being developed but there is still an issue of lack of strategic funding for professional development. Due to the disbursement of funds directly to schools each school is able to control its own

6. Classroom implementation

6a. Policy direction of travel

Many of the proposed policy directions and changes that are identified above have, at the classroom level, had little impact on the day-to-day experience of school students, mainly because of the timescales required for enactment of policy changes across large systems such as education. However, day-to-day teaching is often slow to change and the current Secretary of State for education repeatedly argues that teachers should be in charge of all aspects of the curriculum (see for example a speech devoted to this at

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

https://www.gov.uk/government/speeches/michael-gove-speech-to-teachers-and-headteachers-at-the-national-college-for-teaching-and-leadership).

This is somewhat at odds, however, with his speech of September 2013[82], in which he argues strongly against discovery/inquiry teaching methods and those who attempt to make learning have relevance to students' lives:

> *… there has also been an emphasis on teachers having to put their own learning aside so that work is 'relevant' to the students. This has resulted in the dumbing of educational material down to the level of the child - with GCSE English papers that ask students about Tinie Tempah, or Simon Cowell - rather than encouraging the child to thirst after the knowledge of the teacher.*
>
> *I believe that we need to move away from these approaches to education - I would call them pedagogies but they don't leave much place for the pedagogue - towards an education system which believes, right from the early years, in the importance of teaching.*
>
> *Because schools are - above all - academic institutions. We need teachers to actively pass on knowledge, organised in academic disciplines such as physics and history - to introduce children to precisely those areas of human thought and achievement which they are most unlikely to discover or understand on their own.*
>
> *Children naturally learn to talk; they do not naturally learn to read, or to play the violin, or to carry out long division.*
>
> *The most impressive scientific evidence on how children learn - from experts like Paul Kirschner, Richard E Clark and John Sweller - all points towards the importance of direct instruction. Their work on 'why minimally guided teaching techniques do not work' is hugely powerful.*

Perhaps most telling of the Secretary of State's view of the ideal in teaching is his statement that…."*We need teachers to actively pass on knowledge, organised in academic disciplines"*. Of course, this is somewhat problematic in terms of the value that MaSciL places on inquiry that builds on the work of PRIMAS and which it defines in the following way:

[82] https://www.gov.uk/government/speeches/michael-gove-speaks-about-the-importance-of-teaching

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

Inquiry-based learning aims to develop the inquiring minds and attitudes that are required to cope with an uncertain future. Fundamentally, IBL is based on students adopting an active, questioning approach. Students inquire and pose questions, explore and evaluate, and the problems they address are relevant to them. Learning is driven by open questions and multiple solution strategies. Teachers are proactive, supporting struggling students and extending those that are succeeding through the use of carefully chosen strategic questions. They value students' contributions, including their mistakes, and scaffold learning using students' reasoning and experience. In the classroom there is a shared sense of purpose and ownership.

6b. Classroom practice: Inquiry

In analysing TIMSS videos of lessons researchers (Stigler and Hiebert, 1999) pointed to how lessons in different countries can be characterised by reference to a 'cultural script' (Wierzbicka, 1999) that sets out the cultural expectations of what one might expect a lesson to be in a certain country. Students, teachers and indeed parents and the wider community have some expectations of the form of a mathematics or science lesson: whilst there are some expectations about school lessons in general there are also expectations about lessons in different subjects. The work of Stigler and Hiebert and colleagues points to differences between mathematics lessons in America and Japan identifying a "typical' lesson structure in each country. Particularly pertinent here are their observations that the American script typically involves an acquisition followed by application phase, in other words teacher exposition followed by student practise of skills and techniques they have just observed. In contrast they point to Japanese lessons typically involving students being engaged in working in a sustained way on one or two problems specifically designed to address the understanding of specific mathematical content. Periods of student work (either as individuals or in pairs / small groups) are interspersed with whole-class discussion of emerging understanding). They carefully frame their descriptions by pointing out that of course every lesson is individual, but lessons on the whole tend to follow such an identifiable cultural script. As Brousseau (1997) suggests, over time such scripts result in what he terms the didactical contract, which sets implicit expectations about what it means to take part in a mathematics or science lesson. Attempting to vary this contract, for example by introducing new or innovative pedagogies, can prove difficult for teachers particularly for individuals if they

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

are running counter to expectations that have become embedded in the day-to-day practice of a school.

What then, are the cultural scripts of mathematics and science lessons in England? Again, warning that it is dangerous to characterise all lessons by all teachers as being similar, or indeed as having certain common characteristics it is possible to identify a cultural script for both mathematics and science lessons in English classrooms.

Mathematics lessons in Primary schools have been greatly influenced by the National Numeracy Strategy which from 1996 onwards developed, as the National Numeracy Project, support for teachers in Primary schools with their teaching of mathematics especially in the domain of number. Following what was perceived as a successful intervention in the Primary school sector by setting out clear expectations and supporting lessons down to the detail of lesson plans the Key Stage 3 strategy took a less directive approach in supporting Secondary School teachers in acknowledgement of their more secure subject knowledge. In Primary Schools in mathematics therefore, as Ofsted (2008a) identifies, lessons are now often structured in three or four phases. Following an introductory phase where the teacher outlines to the whole class the intention of the lesson, pupils often work in groups organized by attainment with tasks differentiated accordingly. After working on maybe one or two tasks in groups the whole class often reconvened to summarise what had been learnt.

In primary science, there has been no equivalent standardizing pedagogy as there has been in mathematics, although the National Curriculum documents provide non-statutory guidance. For many primary schools the first appearance of science as a separately identifiable subject came with the introduction of the National Curriculum in 1989. A feature of this curriculum was its emphasis on the enquiry-based nature of science. The Statutory Orders of the National Curriculum (DES,1989) expected 45% of science curriculum time devoted to ‘exploration of science’ and 55% devoted to acquiring ‘knowledge and understanding’. Subsequent National Curriculum documents have renamed the ‘exploration’ component ‘investigations’ and ‘scientific enquiry’. The pedagogical requirements of teaching the exploration of science, and indeed the knowledge and understanding components, placed severe demands on many primary teachers, and since this time there has been a strong and fairly coherent effort to improve the scientific understanding and pedagogical content knowledge base of primary teachers in science. In the 1990s all 4 year initial teacher education courses were required to contain no less than100 hours of science pedagogy, and at the same time the government

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

funded a series of 20 day secondments onto a science course for one teacher from every primary school in England. Other initiatives followed. A recent review by Ofsted found that science lessons in primary schools are rarely 'unsatisfactory' and in a good proportion of lessons there is a strong focus on enquiry as a central pedagogical strategy.

Science will be found as an identifiable subject within the curriculum of most primary schools. Typically it will be one session per week of 1.5h to 2h, occupying around 10% of curriculum time. Lessons would almost always begin with some sharing of the learning outcomes and these are often revisited at the end of the learning episode. The science teaching is likely to be set within what teachers would call 'meaningful contexts', which might include 'family', 'our locality' or 'keeping healthy'. Practical activity would be a strong feature of the curriculum experience with most lessons being 'hands-on' and many lessons engaging pupils in collecting, sorting, observing, measuring and recording. Much of this work would be under the close direction of the teacher who would provide structured guidance on how to carry out the task and how it should be recorded. Writing frames are often used to provide structure to the pupils writing. Teachers are often likely to draw connections with other curriculum areas when the opportunity arises through science lessons.

A major impact made by the National Strategy in mathematics in influencing the cultural script for Secondary school lessons was formalising the idea of the "three-part lesson". That is, a brief "starter" activity that mobilises students in mathematical thinking (often involving mental mathematical activity), followed by a main part of the lesson which is often of the form acquisition followed by application as in the typical US lesson, with a final plenary activity in which the whole-class might make a quick if not superficial assessment of their progress against the objectives of the lesson. In the spirit of promoting a reform agenda the inspectorate criticise this prevalent script, but are keen to recognise when and where in implementation it works well:

"When this approach was used well, teachers developed pupils' understanding of why the method worked through explanations and activities. They selected a suitable range of questions so that pupils developed the necessary breadth of skills and understanding of the applicability of the method" (Ofsted 2008a, p. 16).

On the other hand, Ofsted mathematics reports often express concerns about how exposition often denigrates to the transmission of rules and procedures that students are expected to remember and apply without relational understanding (Skemp, 1976), which

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

militates against students having the skills necessary to take their learning of mathematics forward effectively.

At secondary level, enquiry in science has a long pedigree in England, though it has never been adopted on a wide scale. Science curriculum development before the National Curriculum sought to privilege an inquiry focus in order to break the mould of transmissive science teaching prevalent in the 1960s. Chief among these initiatives were the Nuffield Science projects[83] which had a powerful influence on the discourse of science education in schools, and on subsequent curriculum development initiatives.

However, in the context of high-stakes assessment, enquiry has been more latterly introduced and practised as a narrow strategy, an activity where the purpose is directed away from the practise of science by pupils, towards the consolidation of material didactically introduced. 'In some schools, practical work is too heavily directed by teachers and there is too much reliance on work sheets. In these circumstances, practical activities are often used to illustrate points rather than to give pupils the opportunity to plan and conduct their own investigations'. (Ofsted, 2008b)

More specifically, at KS4, recent developments in the cultural script involve a formulaic and narrow understanding of science as enquiry. "GCSE science has presented a view of scientific method based around planning, obtaining evidence, analysing/drawing conclusions and evaluating". Science in the form of this 'procedural knowledge' in relation to enquiry / scientific method is reduced to pupils' ability to 'jump through a series of pre-determined hoops and to do so in an ever narrowing range of contexts' – most commonly, 'investigating the rate of reaction between marble chips and acid'. This gives rise to a hypothesis: that many pupils disengage from science because 'they are not given an opportunity to see it as a creative and exciting subject' (Myths about Science, National Strategies).

The introduction of the Assessment of Pupil Progress at KS3 has influenced teachers' priorities in the classroom, with more time given to work aimed directly at the 'five skills' as they are often understood; Thinking scientifically, Understanding the applications and implications of science, Communicating and collaborating in science, Using investigative approaches and Working critically with evidence. This re-focusing of the assessment

[83]See http://www.kcl.ac.uk/depsta/iss/archives/collect/1nu30-0.html for a list of useful sources

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

criteria, as in KS4, has had the effect of moving teachers away from learning activity concerned with obtaining scientific data from experiments to more critical evaluation of scientific evidence and consideration of the 'institutions of science'.

In mathematics and science, therefore, common pedagogies in secondary schools often exclude student enquiry of the type that PRIMAS advocates as providing important experiences for students to support both understanding for learning and positive dispositions towards mathematics and science. On the other hand whilst pedagogies in primary schools at first sight seem better able to support such learning here teacher subject knowledge is less well developed to be able to sustain and direct effective student enquiry. The inspection evidence therefore points to a need for the development of Primary school teachers' mathematical knowledge and the pedagogic practices of secondary teachers.

6c. Vocational education

Vocational education might be considered deeply problematic and with a troubled history in England. In discussion of this it is important to distinguish between vocational and pre-vocational courses. During compulsory schooling pupils have little opportunity to be involved in any courses that are vocational. Above all study of academic subjects is highly prized and as the extracts of the speech of the Secretary State for Education above elicit this is considered at a political level it is best to maintain this focus. Vocational courses are almost without exception not available in pre-16 education and there are no vocational schools. Post-16 vocational education is available in Further Education Colleges: MaSciL is not concerned with education in this non-compulsory phase.

Fundamental to problems with pre-vocational education courses that have over the years seeped into compulsory school provision is the issue of parity of esteem for (pre-)vocational qualifications when considered alongside traditional academic qualifications. Again, the Secretary of State for Education, made his views clear on such issues in a speech in which he tackled the question, "What does it mean to be an educated person?" in May 2013[84].

> But the central problem with vocational education was never addressed. Many vocational qualifications were not respected because they were not as rigorous as academic qualifications. Genuinely high quality technical and vocational courses –

[84] https://www.gov.uk/government/speeches/what-does-it-mean-to-be-an-educated-person

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

such as the apprenticeships offered by organisations such as BAE or Rolls-Royce – have always been over-subscribed. Colleges which offer genuinely demanding courses in areas which the economy needs such as cooking or construction enjoy no shortage of applications. Sadly, however, there have been far too many qualifications which were badged as vocational which were of marginal value to the students who acquired them. As Alison Wolf pointed out in her ground-breaking report on vocational education[85] – far and away the best thing ever written on the subject – under the last Government hundreds of thousands of students received little or no benefit from vocational qualifications which had little or no labour market value.

The last Government lied to students. It told them the courses they were studying would prepare them for the world of work. It congratulated itself on the number securing passes. But the truth, as Professor Wolf pointed out, was that. "Many of England's 14-19 year olds" did not "progress successfully into secure employment or higher level education" because they had been denied "the skills that will enable them to progress". Many of these qualifications were judged as "worth" two or more GCSEs but they had no proper, rigorous, external assessment and required no demonstration of mastery of any skill directly applicable to the workplace. The only way to rescue vocational education from its devaluation has been to make vocational qualifications more rigorous. That is what we have done – following Professor Wolf's lead by counting only rigorous vocational qualifications in school performance tables, making apprenticeships more demanding and introducing a new – explicitly aspirational – measure of vocational accomplishment: the technical baccalaureate. I apply to vocational education the same principles I apply to academic education – we should be setting expectations higher, demanding greater rigour, applauding genuine effort.

These passages need some careful contextualization. First of all, almost throughout the reference is to vocation education and qualifications in the main pre-vocational qualifications are being referred to. These focus more on underpinning knowledge, ideas and understanding rather than work place specific competence. Over the last 10 years or more such qualifications, although primarily and initially designed for use with post-16 students have increasingly been used alongside traditional academic qualifications

[85] https://www.gov.uk/government/publications/review-of-vocational-education-the-wolf-report

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

(GCSEs) in the last years of compulsory schooling. Because of this 'equivalence' in points scores (in comparison with academic qualifications) allocated to school performance measures were established and this had the effect of increasing their popularity with schools as they sought ways by which to improve their points scores that contribute to school league tables. It is this issue to which the Secretary of State refers here. Schools in pursuit of ever higher league table positions increasingly turned to these qualifications for use with students, often promoting them at the expense of concern about individual students' needs.

In the government's response[86] to the Wolf Report on vocational education, of relevance to the pre-16 compulsory school sector are the following statements (again referring to pre-vocational rather than vocational qualifications):

> Young people aged 14-16 must have a broad and balanced education that provides the foundation for further learning. We want the vast majority of 14- 16 year olds to be taught an academic core, which can then be supplemented by a vocational element. We agree with Professor Wolf that allowing young people to specialise too soon narrows their choices and limits their chance to secure further learning and employment in the longer term.
>
> Pupils must be offered vocational qualifications that are valuable, respected and support progression to further learning and skilled jobs. We therefore agree with Professor Wolf that we should clearly and simply recognise through performance tables those vocational qualifications which are most appropriate for the vast majority of 14-16 year olds, and which are comparable in terms of rigour of content and assessment to other qualifications that will count in the tables.
>
> We want 14-16 year olds to do vocational qualifications that are comparable with the best academic qualifications in terms of content, assessment, and opportunities to progress. We will identify the best vocational qualifications for this age group and will recognise them in performance tables. In this way we will break free from the old equivalency based performance tables and include only a set of clearly defined vocational qualifications which have the greatest benefit for this age group. Preferred qualifications for this age group will:
>
> ◦ Have rigorous assessment, including a percentage of external assessment;

[86] https://www.gov.uk/government/news/government-publishes-response-to-the-wolf-review-of-vocational-education

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

- Provide good progression opportunities to Level 3;
- Be in subjects which are recognised by employers and higher education;
- Offer rigour, breadth and depth;
- Be of an appropriate size to complement the academic core for the majority of students.

Thus the government's intentions are again clear: that in compulsory schooling most pupils will follow primarily academic courses: the use of vocationally oriented courses and qualifications in schools is to be restricted. In doing so the stated intention is to attempt to provide higher status to pre-vocational qualifications by restricting them in number and exercising more in the way of quality control than previously. They go on to provide details of their course of action:

> We will consult with employers, schools, colleges, higher education, and other experts …. in order to refine the attributes of the best vocational qualifications for 14-16 year olds. At the same time as incentivising take up of these key vocational qualifications, we are clear that young people must take the qualifications that are right for them. We want schools and colleges to be free to choose whatever qualifications they identify as most appropriate for particular students and will enable them to progress, whether they are recognised in the performance tables or not. This may be appropriate where a student has a particular commitment to a specialisation like drama or music, or for those young people who may not be able to complete a full GCSE programme immediately (for example those with English as a Second Language). The most important thing is that the choice of course or qualifications is driven by what is best for the pupil, not the performance table score.

In recognition that young people are often not well-prepared for entering the world of work and may lack many skills the government, whilst prioritizing academic qualifications, does recognize that there is a need to strengthen what vocational education there is in schools. One way of doing this has been a relaxation of rules about who can teach and the qualifications that are required of them. This allows the possibility of schools employing experts directly from a desired field of employment.

The earlier mentioned different new school types are also part of the current government's policy priorities in support of promoting school-industry/business links.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

We believe that it is right for young people to have a choice as to where they take their education. That is why we are supporting the creation of University Technical Colleges (UTCs), which offer full-time technically-orientated courses, with clear progression routes into higher education or further learning in work, including apprenticeships. Studying in UTCs provides opportunities for young people to integrate academic study with practical learning, studying core GCSEs alongside technical qualifications. UTCs specialise in subjects which need modern, technical, industry-standard equipment, such as engineering and construction, and teach these disciplines alongside business skills and the use of ICT. In the March 2011 Budget, Government committed to establishing at least 24 UTCs by 2014.

We are also keen to see many more Studio Schools across the country, an innovative new model of 14-19 provision delivering project-based, practical learning alongside mainstream academic study. Students work with local employers and a personal coach and follow a curriculum designed to give them the employability skills and qualifications they need for work or further education.

In addition to providing opportunities for a very restricted proportion of the school population to enroll in these schools that have very clear and distinctive links with industry and business the government also has promoted the practice of some 14-16 year-olds being able to take some pre-vocational courses based in local FE Colleges alongside the traditional academic programmes in school.

For some young people at age 14, college will offer a better learning option than schools, subject to ensuring that appropriate safeguards are in place. This will enable them to access good quality vocational provision, alongside the core academic Key Stage 4 programme. Students are currently able to enrol in colleges pre-16 and we want to see more young people being offered this opportunity. We will communicate this to all schools and colleges directly.

In September 2012 the statutory requirement that every young person aged 14-16 had a brief period of ‘work experience’ by attending a workplace to gain experience of day-to-day aspects of work place activity was withdrawn, in line with the recommendations in the Wolf Report. The Report also recommended that post-compulsory education students

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

should have an improved experience of work experience in ways that might improve their employability skills[87]:

PART 2: EMERGING ISSUES FOR REFLECTION

In this section we explore briefly some issues that are important in relation to achieving widespread uptake of inquiry-based mathematics and science learning: promoting equity in relation to gender, the scope of students' achievement and the promotion of entrepreneurship. These themes are intricately interwoven across policies that have been discussed in the first section of this report although often not explicit. Outcomes due to policy implementation and enactment in relation to themes such as these may, of course, be uncertain in relation to any one particular policy. However, as policies interact, becoming part of the fabric of education at different times and with different time-scales, consequences, often unintended, are almost certainly likely to be unknown and unforeseen.

In England, these particular issues currently have a relatively low profile in policy circles, although they remain of interest to educators, educationalists and researchers.

i. Gender equity

It is well-known that certain areas of study in the sciences and technology prove more attractive to males than females. Stark evidence is provided of this by scrutiny of participation data at A-Level (post-compulsory qualifications often taken at age 18/19 just prior to university entrance).

Subject	Male	Female
Biology	26988	36951
Chemistry	26988	24830
Physics	28190	7379
Mathematics	53435	34625
Computing	3513	245

Participation in science subjects by gender (source: http://www.jcq.org.uk/examination-results/a-levels/a-as-and-aea-results-summer-2013)

[87] http://www.education.gov.uk/schools/teachingandlearning/qualifications/b00223495/post-16-work-exp-enterprise-educ

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

Although there are clearly gender-stereotyped patterns of participation achievement rates are less problematic. According to the Eurydice report[88], there is a gender gap with girls outperforming boys. In maths, which was traditionally a subject where boys performed slightly better than girls, this trend has now been reversed. Girls perform slightly better than boys in maths throughout compulsory education. The gender gap in the sciences has traditionally been very small.

In contrast, the PISA report states that 'In mathematics .. the gap in favour of boys in the United Kingdom, is second highest after Chile among OECD countries (OECD average gap is 12 score points)…. In science, boys outscore girls by 9 score points.'[89] This issue is not a policy concern at present.

The National Curriculum in England suggests that teachers should take account of their duties under equal opportunities legislation that covers disability, race, religion or belief, sex and sexual orientation.[90]

National policies for tackling gender issues fall under the Sex Discrimination Act. Section 22 of the Sex Discrimination Act 1975 states that it is unlawful for the 'responsible body' of an educational establishment to discriminate on grounds of sex.

Specific guidance is given in terms of careers advice to teachers. For example, the Equality Advisory Support Service offers a toolkit for teachers, which is 'A set of free online education resources to help deliver careers and equality-related learning to Key Stage 2 students in England, developed with the help of careers experts and teachers and tested in primary schools.] [91]

The areas of focus for teachers' professional development tends to be decided at the school, departmental or individual level. It could be that gender issues is a topic that is chosen to focus on. The need to challenge gender stereotypes in subject choice and careers advice is recognised as a key issue. Guidance for schools on the gender equality duty includes advice on the challenges in the provision of Information, Advice and Guidance (IAG) and the role of schools in IAG delivery. Other initiatives provide support to encourage women into science careers, such as the UK-wide Women into Science and

---

88 http://www.nfer.ac.uk/shadomx/apps/fms/fmsdownload.cfm?file_uuid=67EB886D-C29E-AD4D-00A3-6752B523AE2E&siteName=nfer

89 http://www.oecd.org/pisa/pisa2009keyfindings.htm#Country_notes

90 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210969/NC_framework_document_-_FINAL.pdf

91 http://www.equalityhumanrights.com/advice-and-guidance/a-free-primary-careers-education-resource/

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

Engineering (WISE) campaign. The WISE campaign collaborates with industry and education to encourage UK girls of school age to value and pursue STEM or construction related courses in school or college, and to move on into related careers. There is no specific training in IBL offered to combat inequities in participation due to gender.

ii. Student achievement

In general, it seems that UK students perform poorly in international tests such as PISA. According to the PISA report, 'Viewing the United Kingdom school system through the prism of PISA'[92]

In mathematics, 20.2% of students do not reach the baseline of Level 2 and are thus only capable of answering questions involving familiar contexts and where all relevant information is present and the3questions are clearly defined (OECD average is 22.0%). In science, the proportion of students below Level 2 on the PISA science scale is at, 15%, below the OECD average of 18% and in fact has declined slightly from 17% in 2006 (Table V.3.5 in the PISA 2009 report). (p.4). It goes on to say that 'socio-economic disadvantage has a strong impact on student performance in the United Kingdom: 14% of the variation in student performance is explained by students' socio-economic background (OECD average 14%) (p. 5).

These results are also reported in, for example, the report by Jerrim and Choi 'The mathematics skills of school children : How does England compare to the high performing East Asian jurisdictions?.[93]

These scores in international tests have a major impact on policy rhetoric. As a result over years there has been an increasing emphasis and focus on improving pupil achievement. This has led to a climate in which schools, teachers and pupils are constantly measured, monitored and set targets. Fundamental to the performativity culture in which education is now immersed is national testing and assessment.

Although not introduced alongside the National Curriculum it was not long before students were assessed in the core subjects at the end of each key-stage, that is at ages 7, 11 and 14 (for the first time in 1991, 1995 and 1998 respectively). These assessments against National Curriculum statements of attainment allowed student progress to be measured towards the traditional end-of-compulsory schooling assessment known as the

[92] http://www.oecd.org/pisa/pisa2009keyfindings.htm#Country_notes
[93] http://repec.ioe.ac.uk/REPEc/pdf/qsswp1303.pdf

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

General Certificate of Secondary Education (GCSE) at age 16. The GCSE examinations lead to qualifications for students in a wide range of subjects: this is in contrast to national tests that whilst ostensibly measuring pupil attainment are in reality used as measures of school performance. GCSE qualifications are used to support progression to either further study or employment. Although students receive the results of their national tests and they influence within-school setting[94] for different subjects, perhaps more importantly students' levels introduce an element of accountability into the school system with aggregated data being made public, purportedly to inform parental choice of schools which in reality is heavily circumscribed by the location of where families live. From the outset the publication of such data has been used by local press/media to inform "league-tables" of performance with GCSE results in secondary schools being used to provide a single headline figure of performance. Without explaining here the intricacies of test performance data made public it is important to note that mathematics (alongside English) has since 2006 been given an enhanced role to play in the secondary school's headline figure. Put simply, only those pupils who gain a high GCSE grade in mathematics and English plus three others are counted as being successful. The consequence of this has been to put increased pressure on schools to ensure their pupils achieve a high grade in mathematics (in many schools more pupils gain a high grade in GCSE English than mathematics so that mathematics can be seen as a limiting factor on school performance). Although science[95] is not in such a high profile position this is non-the-less considered an important high status GCSE (or in the case of most pupils a double award GCSE) to obtain.

Assessment at age 7 is now carried out by the pupils' teachers, and has been withdrawn altogether at age 14.

[94] Although students attend a comprehensive primary or secondary school there is an element of differential education either by group work in primary school or pupils being timetabled in classes that are based on ability in secondary school.

[95] In England with the introduction of a National Curriculum an integrated approach to science was introduced with the expectation that students would follow a balanced science curriculum that brought together the separate disciplines of physics, chemistry and biology with scientific method as a focal and integrating feature. In secondary schools therefore the vast majority of students follow courses leading to a double award in GCSE science taught by science teachers who will themselves have specialised in one of the separate disciplines in their own education post-16.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

Schools are under intense pressure to make sure they have increasingly high scores in key measures of performance and inspection and this would be considered by policy-makers as the single most effective way of driving up standards.

A wide range of pupils have special educational needs, many of whom also have disabilities. Lessons should be planned to ensure that there are no barriers to every pupil achieving. In many cases, such planning will mean that these pupils will be able to study the full national curriculum.
(Department for Education, 2013, p. 8)

The areas of focus for teachers' professional development tends to be decided at the school, departmental or individual level. It could be that low achievement is a topic that is chosen to focus on, but this is very likely to be framed in terms of 'making the grade' rather than how to support the pupil as learner. IBL would most likely not be considered as the most effective way of improving achievement, particularly as we move to a curriculum that is knowledge based. There is therefore no specific training in IBL, and is often low-priority except where it is valued by individual teachers.

iii. Promotion of entrepreneurship

Entrepreneurship does not sit comfortably in a curriculum that is focussed on acquisition of knowledge organised around traditional academic subjects. However aspects of Enterprise Education are taught as part of Personal, Social and Health and Economic Education. This subject is not itself compulsory for schools to teach, but is taught in most schools and is then compulsory for pupils.[96]

To support enterprise in schools the government is enhancing online resources for teachers at the Enterprise Village and promoting the recruitment of 2 500 local enterprise champions through the Inspiring the Future website.[97]

A Guide to Enterprise Education for Enterprise Coordinators, Teachers and Leaders at Schools, published in March 2010, provides examples of the way in which enterprise capability and entrepreneurial thinking may be incorporated into the ethos and operation of schools.[98]. There is no specific training in IBL in relation to teaching this.

[96] http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/135EN.pdf
[97] See footnote 7
[98] See footnote 7

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

Implications for Mascil (England)

As this report highlights there is much policy change at present, across all aspects of the governance of education: school systems, structures and governance, curriculum and qualifications, initial teacher and continuing teacher education. Policy change in any one of these areas might provide sufficient challenge for the implementation of a project such as MaSciL that seeks to bring about change in the learning experiences of pupils in mathematics and science. With change across all areas at the same time the challenge is potentially immense. On the other hand at a time when everything 'is up in the air' there is also the potential to find new ways of working that exploit as far as possible new potentials for change and improvement. The team at Nottingham is well positioned to take advantage of change as they are active across many of the areas we have identified. To provide two brief examples: the team has contributed substantially to the new formulation of the National Curriculum in mathematics providing expertise in the specification of problem solving; the team has funding to run in parallel a project that will explore the sustainability and scalability of a new model of professional learning through high quality lesson study informed through collaborative work with colleagues in Japan.

The table below indicates the major areas of policy change as identified and elaborated in this report and identifies how the MaSciL team might tackle the issues. In attempting to consider how best to tackle the challenges that each policy initiative provides attempts have been made to seek synergies across work in the project and with other initiatives the team is working on in this period as well as considering staff expertise and the networks of support on which they can call.

Issue	MaSciL response
School systems and structures New systems of school governance support a wide range of school types with policy promoting the development of academies and in favour of chains or consortia of academies focused on schools judged to be outstanding. A small number of schools designated as University Technology Colleges and	There are opportunities to develop new partnerships with alliances of schools. This is already underway in relation to other projects we work on. For example, in researching curriculum innovation in projects such as MAP, Bowland/Nuffield and FasMed.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

Studio Schools have innovative features and curricula that are supportive of students working in ways that support links with the world of work and maybe less so support inquiry learning. New models of collaboration are being initiated by those charged with oversight of professional development in mathematics and science. For example, the NCETM is developing Mathematics Education Strategic Hubs that are based in	Some of these partnerships provide the potential for working with new communities focused on professional learning that can be supported by the MaSciL professional learning toolkit alongside the toolkit that will be developed in the Nuffield Lesson Study project

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

National Curriculum and assessment The new specification of the curriculum in general is aimed to develop basic knowledge across all subjects. There is much policy rhetoric that favours a back-to-basics approach and which decries inquiry methods and attempts to connect learning with the reality of the worlds that students inhabit. This is often spoken of as 'dumbing down.' However, in the detail the new curriculum and particularly important the specification of assessment at age 16 (GCSE) which is acknowledged to drive the system due to it being key to the performance measures that rank schools in league tables, there are aspects that are supportive of inquiry approaches.	Curriculum change always provides the potential to 'sell' professional development as providing appropriate up-skilling towards implementation. At a policy level it will be important to continue to promote problem solving and modeling in mathematics with awarding Bodies and pursue the work we have been doing in informing potential improvements in assessment in ths regard. The Nuffield Lesson Study project that supports the professional learning in the teaching of problem solving provides a parallel development and it will be important to look for overlap and synergies in work between the two projects.
Initial Teacher Education Initial teacher education is shifting from its long-time and well-established base in the universities to schools. There are many implications of such a change in provision, not least of which is the proliferation of those now involved in provision: leading to potential challenges of the 'reach' of innovation of projects such as MaSciL. Also of concern is the potential for the profession to stagnate in terms of development with an apprenticeship	It will be important that the adaptability of the proposed professional learning toolkit of MaSciL will prove attractive through ease of use and appropriateness of content and approaches to the wide range of providers of ITE. This needs to be considered carefully at the design stage.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

model emerging where new entrants to the profession mimic 'old hands' who are considered expert. Schools are not necessarily sites of innovation.	The e-learning version of the materials (WP5) may prove particularly helpful in this regard.
Continuing professional development (cpd) With the allocation of funding direct to schools it is not clear how in the future schools will prioritise cpd in general and in mathematics in particular. Local Authority (LA) networks of subject teachers have been affected by the curtailment of LA activity. Many schools are now directly funded by central government and the LA does not have sufficient funding for the support activities it used to run. It is not only funding that is at issue but the lack of infrastructure to support cpd at a local level. New models of community and partnership are merging often focused around newly designated national Teaching schools. A new network of Mathematics Education Strategic Hubs (MESH) is being initiated and supported by the NCETM. The Science Learning Centres continue to provide cpd in science.	This area is particularly unclear at the initial stages of MaSciL. However, the Nottingham team has been active in working with newly emerging communities of mathematics educators as supported by NCETM. It is important that these network connections are maintained. The funding that MaSciL will have available to support professional development activity will be most helpful given the likely squeeze on funding.
Classroom practice: inquiry	

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

The curriculum in its implementation does not in general prioritise inquiry teaching. Reasons for this are deep-seated and firmly rooted in the didactical contract or cultural script for lessons in mathematics and science. Teaching approaches are not specified by curriculum documents but there is much rhetoric that inquiry methods are not appropriate in a knowledge rich curriculum. The inspection service Ofsted that regularly inspects and grades schools, on the other hand is supportive of active approaches to learning that promote conceptual understanding and active engagement.	MaSciL has much expertise on which to draw and a national (and international) reputation on which to build. Most recently in relation to inquiry learning the PRIMAS project ahs successfully worked with over a hundred teachers who act as ambassadors/multipliers using the PRIMAS materials to work locally with colleagues in introducing inquiry learning in their classrooms.
Classroom practice: vocational education There is little, if any, expectation for mathematics and science in compulsory school education to connect with the world of work. There are no vocational schools. An academic curriculum for almost all students is favoured. There are emergent new models of schools and curricula that for proportionately very few students prioritise connections with business	Early inquiries have identified interest from teachers who wish to motivate the learning of mathematics and science for those pupils who seek some utility of purpose and application of knowledge when they learn what can often be quite abstract ideas. There is a wide range of materials from which teachers can draw if and when they adopt the MaSciL approach.

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

and industry and favour thematic and project approaches to learning.	Our current and developing networks and partnerships should ensure adequate 'reach' during the project.

Resources from the UK that link mathematics and science to the world of work

The Inspired Bus Company

This resource from Siemens encourages students to explore the challenges facing bus designers when producing a bus for an urban environment and investigate how different solutions can be identified and evaluated

http://www.nationalstemcentre.org.uk/elibrary/resource/9501/topic-1-the-inspired-bus-company

I Can See Clearly Now

This resource looks at the effective use of low energy light bulbs and how they have enabled the waterfront at Durban in South Africa to be transformed. The first activity sets the scene by showing how lighting is not only a technical process but has a social impact too. It then presents students with the challenge of finding the best way of producing cheap and even illumination over an area.
Students use the supporting information sheets to compare and contrast filament light bulbs and low energy light bulbs They then investigate energy transfer by using a power meter and a light meter to compare energy consumption and effect, displaying their data quantitatively using Sankey diagrams.
Finally, students work in groups, generating ideas and using materials to devise a practical solution to design a reflector for a bulb that will produce most even illumination over a stipulated area with the bulb at a stipulated height

http://www.nationalstemcentre.org.uk/elibrary/resource/9504/topic-4-i-can-see-clearly-now

Picture This

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

This resource from Siemens encourages students to think about medical diagnosis and how information can assist the doctor in being effective and accurate. Students are asked to suggest ideas about the characteristics of a useful image to support a medical diagnosis. They then look at the properties of sound, how sound is made and how sound travels as a wave.
After exploring the idea that humans can hear sound within a certain range of frequencies and that other sounds (ultrasound) exist at higher frequencies, students then carry out a research task into how bats use high frequency sounds. Finally, they apply their knowledge to explain how ultrasound images are formed of the inside of the body.
http://www.nationalstemcentre.org.uk/elibrary/resource/9509/topic-9-picture-this

Go with the Industrial Flow

This Mathematics Matters case study looks at how mathematicians can help industry to manage their use of fluids. Many industrial processes involve the complex movement of fluids, but predicting fluid behaviour can often be difficult. Mathematical models of fluid flow can help to improve manufacturing efficiency and reduce costs, whilst also enabling new applications of fluids within industry. The resource can be used by teachers to guide their students or shared directly with students to inform them about careers using mathematics.
http://www.nationalstemcentre.org.uk/elibrary/resource/3755/go-with-the-industrial-flow

Faster Formula One

This Mathematics Matters case study looks at how Formula One teams use mathematical methods such as fluid mechanics and Navier-Stokes equations to improve performance. Every second counts in the fast-paced world of Formula One, so race teams use advanced mathematics to squeeze the best performance out of their cars. Computational fluid dynamics lets car designers quickly test out new ideas before deploying them on the racetrack.The resource can be used by teachers to guide their students or shared directly with students to inform them about careers using mathematics.
http://stem.org.uk/rx5pa

Pod 2: Waste

In this Nuffield Foundation resource students investigate whether recycling alone can mitigate the wastefulness of current industrial processes. They categorize waste into two main categories - natural materials which can be recycled through natural systems, and

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

processed technical materials which cannot. Students learn that in order for technical materials to be reclaimed products need to be designed so that they can be easily recycled and dismantled. Groups of students are set the challenge of designing a 'cradle to cradle' version of a familiar product.
URL: http://stem.org.uk/rx4ao

STEM Choices: Industry Focus
This set of four profiles of UK industries give an overview of each one and is designed for students to gain an insight into careers available to people who have studied STEM subjects. The industries featured are the nuclear power, pharmaceutical, renewable energy and maritime industry.
Each profile includes an overview of the main activities of the industry, including mythbusters; a number of case studies in which workers describe their roles and career paths; details of qualifications for entry to the industry such as apprenticeships and degree level study (including details of which universities offer appropriate courses); examples of specialisms; and websites and links to classroom resources.
http://stem.org.uk/rx4hk

An Energy Evolution
This Mathematics Matters case study describes how mathematicians help to boost efficiency in the energy industry by mapping buried oil reserves. As oil supplies become harder and more expensive to reach, it's essential that we maximise the yield from available reservoirs in any way possible. Mathematicians are contributing with a tool inspired by biological evolution that seeks out the best way to extract the oil. The resource can be used by teachers to guide their students or shared directly with students to inform them about careers using mathematics.
URL: http://stem.org.uk/rx5p7

Julian Ma: Pharmaceuticals from Plants Researcher
Produced by Science & Plants for Schools (SAPS), these materials look at the work of the plant biologist, Julian Ma. Through seeing how natural and genetically-modified plants can produce medicines, students gain a greater understanding of the career opportunities available in plant biology.
Julian is Professor of Molecular Immunology and joint head of the Infection and Immunity Research Centre at St George's Hospital Medical School in London. He

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

specialises in ‘pharming’; the production of medicines by plants.
The materials include full teacher guidance and student information sheets. These cover:

- careers case study and questions
- testing herbs for antimicrobial properties
- questions on antimicrobial molecules
- comparing the antimicrobial properties of different herbs
- considering the potential for using medicines from plants

URL: http://stem.org.uk/rx935

Protecting Your Head

Protecting Your Head, from the Centre for Science Education, is a set of teaching materials which offer a cross-curricular approach to learning about engineering. The context for the activities is the design of head protection for snowboarders where the risk of injury is significant but personal image is also important.
Teachers' notes and the starter activity are included at the start of the file called 'Protecting your head pack'.

Starter activity

- Which helmet is best?

Technology

- Wind tunnels
- Designing a helmet

Science

- Investigating polymorph
- Materials testing

Mathematics

- Tesselations
- Market research

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.

Cross-curricular activities
• Dangerous sports?
• Injury and recovery
• Marketing 'safety'
• Should helmets be compulsory?
URL: http://stem.org.uk/rx885

Want to Do Something Different?
Produced by the Gender Equality and Race Inclusion (GERI) project, this teacher guidance and classroom activities outline a process that encourages young people to explore, in a comprehensive and constructive way, those jobs usually done by members of the opposite sex. Case studies and activities look at various sectors including engineering and healthcare.
URL: http://stem.org.uk/rx3nw

Industrial Encounters: Good Practice for School Links
From CIEC Promoting Science, this guide aims to help schools and science-based companies make the best use of their opportunities to liaise together. It concentrates upon using link activities to enrich aspects of the school science curriculum but there are many principles in the guide, with a more general application.
There is extensive coverage of a range of topics and these include:
• Site visits
• Work experience
• Teacher secondment
• Competitions
• Careers conventions and evenings
• Mock interviews
• Financial support
• Enterprise schemes
• Agencies who may help to set up links
• Industry days
• Lectures and presentations
• Industrialists in the classroom
URL: http://stem.org.uk/rx8h9

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

Perfect pylons
Published by the Royal Academy of Engineering, this activity sheet looks at electricity and its distribution in the 21st century. Most UK households consume large amounts of energy. As more renewable sources of energy are used and the use of fossil fuels is reduced, it is important to ensure that electricity is supplied to consumers in an easy but efficient way. This activity should encouage students to think about these subjects. During the activity the student group will apply their knowledge of materials, forces and structures to their model pylons and test them to see how strong they are. The sheet also contains two energy supply industry case studies.
URL: http://stem.org.uk/rx57v

Polar Bears in Trouble
In this Science upd8 activity students take on the role of a trainee documentary producer working for an environmental channel. The television programme scenario, 'Bears in Trouble', explores how rising temperatures in the Arctic could be endangering the survival of polar bears. Polar bears seem perfectly adapted to the Arctic environment, but students reveal a different story when they study the bear's feeding strategy.
URL: http://stem.org.uk/rxop

Packaging Design
This resource from the Department for Education develops the 3-D thinking required to move between solid objects and their 2-D nets. The activities are placed in the context of packaging. Students flatten out a packaging box to show the flat 2-D 'net' that made up the whole pack and investigate how the net could be adapted to fit a different sized product. They then work in small "design teams" to produce viable solutions to a real-world 3-D problem - designing eye-catching and well-fitting packaging for a designer ball. The design teams then 'pitch' their ideas to the class.
URL: http://stem.org.uk/rxwz

Introduction to science in the workplace
Careers work with young people can consist of many different parts. The traditional one-to-one interview for advice and guidance is only a very small part of how pupils will make choices about their future career path. Science teachers should take opportunities to

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

relate their subject to potential future learning pathways and show pupils where the subject sits in the world of work.
There is great potential in being able to integrate practical work with a careers element within science lessons, and this set of resources exemplifies some of the ways in which this can be done.
Six sections provide information on specific areas essential to using the science in the workplace approach successfully.
1. Why integrate careers information into lessons?
2. The role of teachers as sources of careers information
3. Features of the resources
4. Transferring the model and designing your own resources
5. Involving others and developing longer term strategies
6. Route map
References for the introduction to science in the workplace
http://www.nuffieldfoundation.org/practical-work-learning/introduction-science-workplace

The Travelling Salesman
It's a common problem, and applies as much to travelling salesmen as to paper rounds! The salesman has a widely spread number of calls to make, but wishes to do so by covering as little ground as possible. Should he travel in a closed shape like an irregular polygon, or would it be better to criss cross the area to shorten his journey? In times of high fuel costs and concerns over carbon emissions, this is more than just an intellectual puzzle!
http://www.ima.org.uk//viewitem.cfm?cit_id=384133

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.
SEVENTH FRAMEWORK PROGRAMME

mascil
mathematics and science for life

Project Information
Project no. 320693
Project acronym: mascil
Start date of project: 01/01/2013
Duration: 48 months
Project title:

mathematics and science for life

Dissemination level
Thematic Priority: Science in Society
Funding scheme: FP7

Information about the deliverable
Deliverable N° 2.1
Due date of deliverable: Month 9
Actual submission date: 04/10/2014
Deliverable title:

Analysis of the British policy context

Excerpt from the Deliverable No. 2.1 "National working papers on analysis of policy context"

Contact Information
Coordinator: University of Education Freiburg, Prof. Dr. Katja Maaß
Lead partner for this deliverable: Foundation for Research and Technology, Dr. Kathy Kikis-Papadakis
Website: www.mascil-project.eu

The project mascil has received funding from the European Union
Seventh Framework Programme (FP7/2013-2017) under grant agreement n° 320693.