Science and Mathematics Secondary Education for the 21st Century

Report of the Science and Learning Expert Group

February 2010

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

Science and Mathematics Secondary Education for the 21st Century

Report of the Science and Learning Expert Group

February 2010

Foreword

Sir Mark Walport
Gibbs Building
215 Euston Road
London NW1 2BE

The Rt. Hon. Lord Drayson
Minister for Science and Innovation
Department for Business, Innovation and Skills

Diana Johnson MP
Parliamentary Under-Secretary of State for Schools
Department for Children, Schools and Families

Dear Ministers

Here is our independent review, commissioned by Government on science and mathematics learning in schools and colleges. We believe that the timing of this review is important. Global development means that the competition and market for the products of science, engineering and technology are greater than ever before. It is a truism to state that the future of the UK depends critically on the education of future generations. Science, technology, engineering and mathematics (STEM) must be at the forefront of education in order for the UK to address some of the most important challenges facing society.

The UK does not have large stores of natural resources or a low-cost workforce. Our economy is highly dependent on our ability to add value, through scientific, engineering and technological innovation – and through advanced manufacturing skills. Our national infrastructure is ageing; our natural environment is ever more influenced by the impact of humans. We owe it to our children to prepare them for an exciting and uncertain future – and education is the most powerful tool to achieve this.

Education has had a high priority for successive governments – and we acknowledge the sustained focus on science and science education by the present government. Science education in schools has improved significantly in many respects during the last few years. We have consulted very widely in preparing this report. Many of our consultees agree that there is movement in the right direction. However, our consultation has also revealed a high degree of consensus about some key concerns. There remain important areas for improvement. We focus on these in this report and provide recommendations that we believe, if implemented effectively, will lead to substantial further improvements in education in STEM subjects.

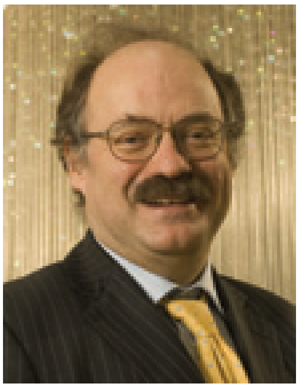
Many of us have good cause to be grateful to a single inspiring teacher that we encountered during our school education. We must ensure that teaching is a profession to which the brightest and best aspire. This can only be achieved if the teaching workforce is empowered to deliver the best education. Our overarching recommendation is that specialist teachers and their subjects need to come to the fore in the delivery of STEM education.

This requires teachers with a higher education qualification in their subject area, trained in how to teach their subject as well as in general educational skills. Experienced technicians should support teachers because practical education is an essential element of many aspects of STEM learning. Teachers and technicians should have the right and the duty to undertake first class continuous professional development throughout their careers. Subject-specific experts from relevant communities should support curriculum development and assessment. These experts should be given responsibility and accountability for the quality of their work. There should be a balance in the curriculum between subject content and context. In particular, mathematics education should be boosted – in its own right since numeracy is an exceptionally important life skill – and also as an integral element of the natural sciences, technology and engineering. At A level teachers should be empowered with the flexibility to teach some areas of the course in more depth than others, building on their own interests and aptitudes and to provide stretch and challenge for their pupils. Assessment should follow the curriculum, rather than define it. It should enable the proper testing of concept and content understanding by providing questions that enable extended responses. Even the most able teachers cannot deliver their best unless empowered by curricula and assessment that are both fit for purpose.

Science is popular amongst young people. However, it is not sufficient to assert the importance of STEM subjects at school and in colleges. It is essential that the life opportunities provided by an education in the STEM subjects are presented effectively. There needs to be an effective pull from the marketplace for young people with STEM skills; and, although society needs a STEM research workforce, it also needs young people with technical skills as part of an advanced workforce. It is vital that different pathways into STEM careers are clearly defined and laid out within schools and colleges.

There has been much focus on governance of education at a national level, through regulators such as Ofsted. However, local governance and support of expert STEM teachers is also essential. There is a sophisticated set of levers that needs to be in place to ensure the rich diversity of activities within a school or college that are needed to sustain a first class education. Responsibility and accountability for effective delivery of these diverse activities need to be provided to teachers and their local governing bodies. As one of our respondents said: "You recognise the ethos of a first class school when you go through the front door".

We would like to end by thanking all of those who have given their time and wisdom during our consultation and those who have read successive drafts of this report. We would especially like to thank our hard working secretariat, Matthew White, Rory Gallagher, Alex Morris and Heeran Buhecha. We recognise that it will take time and hard work to implement all of the recommendations in this report – but we believe that the effort is essential and will reap important dividends.



Mark Walport (Chair, Science and Learning Expert Group)
Julia Goodfellow, Frank McLoughlin, Martin Post, Joan Sjøvoll,
Martin Taylor, David Waboso

Table of Contents

Executive summary

Background and Introduction

The Science and Learning Expert Group is one of five Expert Groups set up by Government during 2009 to take forward the UK's Science and Society strategy.

We were asked to consider pre-19 science and mathematics learning in schools and colleges, to note where this is currently working well and to recommend how it could be improved. Our Terms of Reference are attached at Annex A). We were asked specifically to consider how to stretch and challenge the most able pupils and ensure that all those with the aptitudes to study the STEM subjects (sciences, technology, engineering and mathematics) at university are given the best opportunities to succeed. It is important that we make a brief taxonomic note at this point – the majority of education in schools and colleges for young people interested in STEM subjects is provided by science and mathematics teachers – and because of this we tend to refer to science and mathematics education throughout the report. In doing so, we do not neglect the importance of technology and engineering as subjects, which many young people will pursue at a higher level in HEIs and employment – and which are subjects, that, together with science and mathematics, are key to the future prosperity of the UK.

We have consulted extensively in undertaking this work. A written online consultation produced a wide range of thoughtful and constructive responses from teachers, lecturers, scientists, engineers, mathematicians, employers and others. We have also visited schools and colleges, and had a series of one-to-one meetings with key stakeholders. In November 2009 we held four workshops to 'road test' our emerging recommendations. The areas on which this report focuses represent those which came up most consistently and most strongly in this consultation. Summary reports of our consultations are provided in the annexes to this report.

Science and mathematics education has been much debated. We are not the first to look at this issue and a list of recommendations from previous reports is attached at Annex E; many of these retain contemporary relevance. We have read and taken note of these previous reports in the context of developments implemented by successive governments to address problems in science and mathematics education.

After a period in which the popularity of and attainment in these subjects declined in schools and colleges during the 1990s and into the early part of the new century, much has been achieved in recent years in reversing this decline and promoting higher take up and achievement in science and mathematics education. There has been a sustained effort by the science and education communities, the Government and many individuals who have contributed their resources, expertise, drive and commitment. The numbers of young people taking science and mathematics in school and college is once again rising and this country fares comparatively well in international studies of science and mathematics education such as the PISA and TIMMS research.

However, in spite of much good work, there are still significant problems in education in science and mathematics in schools and colleges. In particular, we have identified five important areas where there is significant scope for improvement, building on what has been achieved to date. These areas are:

- the science and mathematics education workforce in schools and colleges;
- curriculum, qualifications and assessment;
- coherent STEM programmes, pathways and enrichment;
- pull mechanisms; and
- school and college ethos.

We consider each of these priorities in turn and make recommendations to support excellent science and mathematics education in schools and colleges, and progression into higher levels of study and employment in STEM subjects and careers.

There are two overarching themes in our recommendations. The first is that the importance of the subjects themselves, ie science and mathematics, needs to be brought to the fore. There is a need to empower science and mathematics teachers as subject specialists within schools and colleges, and to engage them and other subject experts from higher education institutions (HEIs), professional bodies and employers in all aspects of delivery of education, including the design of the curriculum, assessment and progression. We make recommendations that will empower teachers and provide much stronger professional engagement by subject experts from the relevant communities in science and mathematics education within schools and colleges.

Our second overarching theme is that there needs to be much stronger local governance of the educational process within schools and colleges. This requires substantial strengthening of the capacity of the governing bodies of schools and colleges in terms of their role, composition and training. We recommend the development of a framework for support, challenge and accountability for science and mathematics education that can be applied locally within schools and colleges, working closely with the national regulators and agencies such as the Office for Standards in Education, Children's Services and Skills (Ofsted), the Office of Qualifications and Examinations Regulation (Ofqual), the Qualifications and Curriculum Development Agency (QCDA) and the Training and Development Agency (TDA).

An excellent education depends on excellent teaching, a strong curriculum, and assessment that is fit for purpose. It is therefore not surprising that our first three areas of recommendations cover each of these areas. In addition, pupils in schools and colleges have to choose which subject areas to pursue. Their choices are influenced by the quality of the education they receive, their individual aptitudes and their understanding and perceptions of potential career opportunities. Our fourth area of recommendations therefore relates to enhancement of the 'pull mechanisms' for the STEM subjects. The best education is provided in schools and colleges that have an outstanding ethos, manifested by strong leadership and governance at both an organisational and subject level. For this reason, our fifth and final area of recommendations aims to provide the levers that will enhance the leadership, ethos and governance of STEM education.

Throughout our work we have stuck to our brief, which is to look at education in science and mathematics in schools and colleges to support young people who have an interest and aptitude for the STEM subjects. However, it is impossible and inappropriate to isolate science and mathematics education from other aspects of school and college education. We believe that many of our recommendations, if adopted effectively, have broad relevance to school and college education.

In this executive summary we provide the briefest introduction to each of the five areas of our recommendations, and set out our specific recommendations. However, these recommendations make the most sense if read in the context of the detailed arguments and evidence that we set out in the body of the report.

Priority 1: The STEM workforce

In order to increase the quantity and quality of specialist teachers we will need to continue to recruit more STEM graduates into teaching, provide excellent training for them and retain excellent teachers within the profession by ensuring that their careers are rewarding in every respect. There are important sources of teachers and technicians in science and mathematics from other areas of employment. There are key opportunities in the context of the current economic environment to increase the recruitment of first class people. This has been an active area of policy for some time, and significant progress has been made in developing new ways of attracting and retaining effective teachers. Technical support staff similarly play a crucial role in delivering science with its strong practical element and we must ensure continuing expansion and development of this part of the workforce.

Teachers and technical staff must also be provided with the necessary development throughout their teaching career to enable them to teach most effectively. Continuous professional development (CPD) is central to effective career development for all teachers. Subject-specific CPD is especially important for STEM teachers who need to keep up with the latest developments in their fast-moving subject areas. Both teachers and technical staff need continuing support and updating to develop excellent practical classes and demonstrations for their pupils. New initiatives such as the License to Practice and the Masters in Teaching and Learning provide a basis for career progression rooted in excellent continuous professional development. It is essential that the highest quality CPD is valued consistently by all schools and colleges and that science and mathematics teachers and classroom support staff should be rewarded for updating their subject and teaching skills throughout their careers.

Recommendation 1: Maintain and extend programmes for recruitment of science and mathematics specialists to teaching, building on, in particular, non-standard routes such as Transition to Teaching and Teach First and take full advantage of the current 'spike' in applicants. While this situation persists, resources should be made available to TDA to ensure that no well-qualified applicant is turned away from science and mathematics teacher training.

Recommendation 2: Technicians should be recognised as essential contributors to the practical teaching of STEM subjects. Metrics should be collected on the extent of technical support within schools and further education (FE) colleges.

Recommendation 3: Schools, colleges and local authorities should make greater use of current recruitment and retention pay flexibilities to reward and retain effective science and mathematics teachers. This should be part of the accountability framework as set out in Recommendation 21.

Recommendation 4: TDA should investigate further the consistency between initial teacher training (ITT) providers in the balance between subject-specific and general pedagogical training to ensure that subject-specific pedagogical training receives a high priority.

Recommendation 5: Schools and FE colleges should collaborate in local clusters to deliver science and mathematics teaching, working wherever possible with HEIs and employers. The collaborative aspects of advanced skills teachers (AST), Specialist Schools and High Performing Schools programmes should be reinforced. Schools and FE senior executive staff should be accountable for establishing appropriate collaborative arrangements and be supported and challenged to achieve this by school and FE governing bodies and Ofsted (see Recommendation 21).

Recommendation 6: Reinforce the link between updating subject specialist skills and career development and progression for science and mathematics teachers, including:

- **more emphasis on updating subject specialist skills in TDA's Professional Standards for Teachers and the criteria for moving to advanced teacher scales;**
- **clear specifications for subject-specific teaching skills and subject knowledge should be integral to the Masters in Teaching and Learning, and the License to Practice and linked to entitlement to subject-specific CPD; accompanied by more effective**

communication to teachers of the CPD opportunities available to them;

- **more effective use of the 5 statutory school training days to improve subject teaching; and**
- **extended in-service schemes such as the second science specialism and conversion to mathematics programmes.**

Recommendation 7: Embed CPD into a clear governance framework at school level through:

- **more effective links between performance management and CPD expectations in schools; and**
- **head teachers reporting annually to the governors of their school on how staff skills are kept up to date and the use of the school's financial resources to support CPD.**
- **TDA and DCSF should establish and maintain robust quality assurance arrangements for CPD providers to support schools in choosing high quality CPD provision.**

Recommendation 8: DCSF should continue to support and fund a national network of Science Learning Centres and the National Centre for Excellence in the Teaching of Mathematics, in order to secure continuing subject leadership, building on the legacy of the National Strategies.

Priority 2: The curriculum, qualifications and assessment

The content and assessment of science and mathematics at GCSE and A level is a prime concern to many within the science and teaching communities – especially in relation to the adequacy of the mathematical content of science education, the increased scope for in-depth study within the subject, the need for accurate use of English language in science and the potential harmful impact of modular assessment on teaching and learning. We make several important proposals to address these. This is an area in which significant changes have been made very recently or are currently planned – both in relation to the design of science and mathematics qualifications and to the roles and responsibilities of the organisations which oversee the qualifications framework, so our recommendations are set in the context of the need to evaluate how far these changes have addressed the issues we identify, as well as the need for further action.

Our consultation revealed widespread concern within the science and teaching communities about the qualifications system. We believe this provides compelling evidence of a significant gap in perceptions and engagement between the specialist organisations which design and deliver qualifications, and the science and teaching communities which provide education. The teaching community depends on the availability of courses and assessment that empower teachers and maximise young people's potential for science and mathematics learning. In particular, there is a strong perception that assessment has become the 'tail that wags the dog' of the education system and that the assessment process has been inadequate in the testing of students depth of subject knowledge and understanding of key concepts.

We believe that it is crucial to ensure that the education, mathematics and science communities have much greater ownership of and engagement with the development of qualifications and assessment. We believe that this requires a culture change underpinning regular, structured engagement with these stakeholders by QCDA, Ofqual and others to develop high quality science and mathematics qualifications, which have widespread buy-in from across the range of sectors.

Recommendation 9: Ensure that the Higher Education sector and other stakeholders are engaged in the design and development of qualifications and assessment in ways that will enable them to accept accountability for and ownership of the quality of the system. In particular:

- **standing STEM expert groups should be established in each major subject to advise on the development over time of 5-19 curricula and GCSE and A level criteria in these subjects. This should be part of a process within QCDA that puts partnership and shared ownership with stakeholders at the core of its culture. QCDA must ensure that it draws transparently on the best professional, academic and employer expertise in order to develop the National Curriculum, the qualifications criteria signed-off by Ofqual, and to advise ministers; and also ensure that stakeholders are clear about how they can influence the final products;**
- **awarding bodies should engage independent subject experts from HE and business to advise on the development of specifications and examinations in these subjects; and**
- **Ofqual should include in its annual report to Parliament how it engages with the STEM community to ensure confidence in science and mathematics qualifications**

Recommendation 10: Strengthening the mathematics content of STEM pathways:

- **the mathematics content should be boosted substantially within 14-19 science education, and particularly for Chemistry and Physics A levels, drawing on input from the wider science and mathematics community on the level and types of mathematics needed for progress in STEM beyond school/college;**
- **the developments in content and criteria for the new generations of GCSEs and A levels which have yet to be examined should**

be evaluated at the earliest opportunity using the mechanisms outlined in Recommendation 9; and

- if the pilot of the GCSE Mathematics pair is successful it should be available to all students. The mathematics community supports replacing the single GCSE option with the linked pair so that all students follow both specifications at KS4, even if some do not take both examinations. We can see the attraction of this and recommend that this option should be considered in the light of the pilot outcomes.

Recommendation 11: The style of examinations should be rebalanced towards assessment of students' in-depth problem solving and deeper understanding of subject concepts; and there should be greater emphasis on the accurate use of the English language in answers to examination questions. As a first step, QCDA should evaluate the impact of the new criteria in GCSE and A level science, once the new specifications based on them have been examined for the first time, specifically in relation to the assessment of mathematics, students' in-depth problem-solving, and understanding of subject concepts. This should be undertaken according to the principles set out in Recommendation 9.

Recommendation 12: The developing regulatory framework currently being developed by Ofqual for awarding bodies should be strengthened as follows:

- in approving A level and GCSE specifications, Ofqual should ensure that the awarding body has matched the specifications to meet fully the relevant subject criteria, and that sufficient examining expertise and resources are available to the awarding body to deliver their specifications;
- the GCSE and A level awarding bodies should be regulated to prevent competition between them resulting in a lowering of examination standards;
- ensure that the governance mechanisms of the organisations that set curricula and qualifications criteria and that deliver the examinations provide the necessary executive challenge and public accountability for the quality of their work;
- the practice of awarding bodies endorsing textbooks should be stopped; and
- awarding bodies should ensure that they recruit and ensure training for a sufficient supply of examiners to improve the quality of examination question-writing across the full range of science and mathematics specifications. This will be particularly important if the call for more mathematical content in questions is to be

implemented effectively, and if we are to have better 'How Science Works' questions.

Recommendation 13: There should be a major effort to reduce the modular burden of summative assessment at A level. This should include:

- **restricting modular examination sittings to a single period during the Summer term to avoid disruption to teaching and learning at other times of the year and discourage unnecessary re-sits;**
- **making guidance, exemplar material and support available to any school which wishes to teach some or all of its A levels in linear fashion – ie with all the necessary examinations taken at the end of a continuous two year course; and**
- **the examinations at the end of the A level course should include synoptic questions aimed at ensuring that students retain an understanding of subject content and concepts across the breadth of the subject matter covered during the two year course of study.**

Recommendation 14: Scope for in-depth and exploratory learning in science and mathematics should be increased through:

- **greater flexibility to explore some elements of the course in greater depth. This will require modification of the examination system to allow a greater degree of choice in answering questions; and**
- **encouragement and guidance to schools and colleges on using the A level Extended Project to support science education programmes by providing opportunities for exploring the ways of working used by professional scientists, including working collaboratively. Completed projects should be available as a portfolio of work to support HE admissions.**

Priority 3: Coherent STEM programmes, pathways and enrichment

All young people should have access to coherent pathways in science and mathematics education so that they can achieve appropriate qualifications and gain the necessary experiences (both in the classroom and through external enrichment activities) to progress to different areas of STEM in further or higher education or employment, according to their aptitude and attainment. A variety of routes, including GCSEs, A levels, vocational qualifications, and the new Science and Engineering Diplomas provide opportunities for young people to match their choices to their preferred learning styles, aptitudes and destinations in employment and HE. It is essential that these options are differentiated clearly and communicated unambiguously. This will ensure that young people can make their choices based on the best information.

Success in STEM at higher levels requires more than specialist subject knowledge. Students must acquire more generic skills and experiences, such as the ability to use language effectively and to work on long projects, often in teams. These requirements are not always evident to young people when they are choosing their A levels, and the structure of A level programmes does not automatically mean that they will acquire this wider learning as a natural part of their programme. In particular, HE needs to do more to explain the breadth of skills and attributes it looks for in potential STEM recruits.

In this context, practical and project work, and the opportunities for enrichment of STEM education outside the classroom, are important as ways of engaging young people in science and mathematics, and delivering the experiences and skills that are needed to underpin later study and employment.

Recommendation 15: The science community and higher education institutions should provide clear information and advice to young people about the range of learning and achievement they value beyond specific science and mathematics specialisms as preparation for progress into STEM HE courses.

Recommendation 16: The niche for the Advanced Science Diploma needs to be defined clearly as an educational route for those planning to enter applied science careers. The new Advanced Science Diploma should be developed as a differentiated, rigorous and challenging pathway for applied science learning.

Recommendation 17: There should be more support, guidance and CPD for science teachers on delivering effective practical learning to enable students to participate in practical science and to provide practical demonstrations at all levels (see also Recommendation 6). Support from scientifically-qualified and experienced technicians should be available to specialist science teachers. This should be part of the accountability framework as set out in Recommendation 21.

Recommendation 18: All students following science and mathematics subjects in schools and colleges should be entitled to good quality enrichment:

- **responsibility for access to this should be locally devolved and should be an aspect of school and college performance for which school leadership should be held accountable (see Recommendation 21); and**
- **the development of consistently high-quality enrichment for all science and mathematics learners should be promoted, especially through the development and dissemination of good practice.**

Priority 4: Pull mechanisms

It is necessary but not sufficient to provide first class education in science and mathematics: it is also essential in addition to explain to young people what opportunities in life and employment are enabled, enhanced and enriched by such education. This is not a matter for schools and colleges alone; it requires the input of Higher Education Institutions (HEIs) and employers. The incentives and communication which come to young people – especially from HE, employers and careers advice – are essential in order to give young people an insight into the benefits and options open to them from careers in STEM subjects. We have considered the information, advice and guidance that young people receive currently at schools and college, and also the input that universities and employers make to pre-19 education. Some of the schemes already in place in this area are truly inspirational; however, too much of this activity is done on an *ad hoc* basis and we have considered how it can work more systematically and effectively.

Recommendation 19: All young people should receive planned systematic information, advice and guidance on STEM careers from KS2. This should be integrated into science lessons and enrichment, rather than being an 'add-on', complementing the support provided by external services and specialist careers teachers:

- **teachers, including subject specialists and other staff who provide information, advice and guidance on science progression, should receive regular, up to date training and resources on how to provide this information and specifically on what jobs and further courses exist in STEM and related subjects; and**
- **regional networks amongst schools and FE colleges should ensure that, within a locality, as many students as possible have access to high quality information, advice and guidance.**

Recommendation 20: Continue to develop HE's links with schools and colleges, through:

- **the follow up to the National Council for Educational Excellence (NCEE) recommendations and making progress with, and building on, the Goodfellow/Coyne recommendations;**
- **improving the opportunity for short-term placements and exchanges of skilled personnel in schools, FE, HE and the workplace; and**
- **developing guidance on appointing governors who have specific knowledge and experience of working with or in industry or HE in order to facilitate links between schools and these sectors.**

Priority 5: School and college ethos

In order to create a culture amongst schools and colleges that fosters a commitment to excellence in science and mathematics, accountability mechanisms and incentives are crucial. We have considered how the leadership and governance of schools and colleges can encourage and enable excellence in STEM education. Strong leadership at an institutional and subject level, held to account by supportive and challenging governance, is the best way to ensure the delivery of excellent science and mathematics education. We make recommendations to strengthen the governing bodies of schools and colleges and to improve the accountability of schools and colleges to their governing bodies for the delivery of excellent education. Strong local governance is important to support the development of local and national networks that can share good practice, support and advice to schools and colleges on the delivery of high quality science and mathematics education.

Recommendation 21: The governance mechanisms for STEM education should be transformed by:

- **strengthening the capacity of school and FE college governing bodies to provide rigorous governance combining support and challenge to the executive team, including rigorous training and wider recruitment of governors with experience of accountability systems in other environments including the commercial sector; and**
- **Ofsted, working with Government and other stakeholders, should develop a Statement of Recommended Practice (SORP) for schools as a robust framework for identifying and measuring progress against key measures of performance that should drive and challenge the executive to provide a first class education. For science specialist schools the new School Improvement Partners should be individuals with matched specialist expertise in STEM, and should work with governing bodies to support their specialist mission; schools and colleges should produce a public annual report setting out their performance in relation to these measures.**

Recommendation 22: Strengthen the capacity for well-planned, coherent science and mathematics education within schools and colleges by supporting the development of local clusters for sharing advice and support on curriculum planning and subject leadership. As part of the promotion of local clusters, reinforce the impact of specialist science and engineering colleges and schools to deliver outstanding science and engineering education; to support local curriculum leadership and collaboration; and to share expertise in the planning and delivery of STEM education in schools.

Introduction

1 We start with the non-contentious. There are three inextricably interlinked elements in the provision of education; these are teaching, curriculum, and assessment. If any of these are poor, then the educational consequences are also very likely to be poor.

2 If we were designing a system from scratch, what would we aim to achieve? Education would be provided by teachers with a level of expertise and confidence in their specialist subject appropriate for the age group that they taught. Other trained staff, such as technicians, would work with teachers to provide activities such as practical work.

3 The necessary infrastructure would be available including laboratories for practical work, library facilities, access to the internet and electronic resources. It would be a normal part of teaching culture to remain up to date, not only in the pastoral and pedagogic skills needed by all teachers, but also in subject knowledge, supported by first class continuous professional development.

4 Teachers would be supported by partnerships with external organisations, including other schools and further education colleges, higher education institutions, professional bodies and employers. There would be mechanisms for career progression that recognised increasing skill and experience of teachers, throughout their careers. This progression would be associated with increased financial reward.

5 The curriculum would be designed by subject specialists working in close partnership with those with pedagogic expertise. These individuals would come from schools, HEIs, professional and learned societies, and the workplace – and they would be both responsible and accountable for the quality of their work. Moreover, the curriculum would be designed so that there was seamless progression between the different stages of education, from primary to secondary to tertiary.

6 Assessment of progress would be achieved mainly by formative assessment, conducted by the school or college, and for the pupil and teacher. Summative assessment would be the minimum needed to provide the necessary certification for the student and those that require such certification, such as HEIs and employers. Both formative and summative assessment should be designed to assess the depth and breadth of the curriculum.

7 Aggregate summative assessment should be available for the purposes of public accountability but provided in a sophisticated context as part of a basket of school and FE college assessment measures. These need to acknowledge and reflect the complexity of the factors that determine the

collective outcomes of students in schools and FE colleges, educating young people from many different social and economic environments.

8 However, this highly simplistic attempt to boil down the essence of a good educational system hides the greatest tension in many educational systems, which is the concept that 'one size fits all'. Nevertheless, it is obvious that one size does not fit all. In the context of science and mathematics subjects, there are some obvious tensions – and these must not be ducked.

9 First, we do not all have the same aptitude for science or mathematics, or indeed for any subject in education. Second, there is an acknowledged need to provide sufficient education to all students to enable them to understand, appreciate and think about the role of science, technology and engineering in a modern society. But that is different from the education that is needed for a young person who plans to progress through the education system to become a professional scientist. Third, the curriculum and education needed for a young person for a vocational, technical training in STEM subjects is different – at least in its later stages – from that needed by a student who is aiming for a highly academic training in STEM. The content, and the learning styles and aptitudes are different for students heading along these two pathways. Fourth, it is well nigh impossible to design a single form of summative assessment that serves students of all levels of ability, particularly in science and mathematics.

10 STEM subjects are central to a thriving modern economy and because of this, are essential components of a good education. STEM learning has several important functions:

- providing knowledge and skills essential for everyday life and the ability to make well-informed decisions on a wide range of personal, family and social issues – finance, health, politics etc;
- delivering underlying knowledge and skills needed in most jobs; and
- providing pathways to specialist science, technology, engineering and mathematical careers.

11 Equity and elitism are often confused in discussions of education. We start from the principle that a key issue of equity in education is that young people of high aptitude should have access to elite education, regardless of their social background. There is nothing wrong with elite education – indeed, quite the contrary. Elite education should be available to all who have the aptitude to benefit from it.

12 This report pays particular attention to the education in science, technology, engineering and mathematics subjects of students who have the aptitude and potential to proceed to higher education. Many of our recommendations have a wider applicability in enhancing the general quality of science and mathematics in secondary education and providing a sound basis for

developing the STEM knowledge and skills needed in all sectors of the economy and for everyday life.

13 Although much of our attention focuses on STEM education at GCSE and A level, education is a continuous process and our recommendations touch earlier periods of education and other STEM pathways, such as diplomas and apprenticeships, that enable and encourage young people with aptitude for STEM subjects to choose and pursue successfully those subjects for more advanced study.

14 STEM pathways are only some amongst many educational routes available to young people. As such, they must attract young people positively, on their merits, competing with other subjects to engage and enthuse them. Of course, we – as lifelong educators, scientists, engineers and mathematicians – believe that following a STEM pathway brings significant personal reward, leading to a wide range of interesting, varied and worthwhile careers. This pathway is also financially rewarding. In 2005 a study by PricewaterhouseCoopers for the Institute of Physics and the Royal Society of Chemistry compared the financial rewards accrued by graduates in a range of subjects, and placed the earnings premiums for physics, chemistry and engineering degrees behind only those for medicine and law.[1]

15 Yet science and engineering first degree courses under-recruit and a significant number of employers continue to report difficulties in recruiting people with STEM skills. This suggests that STEM pathways in school and college need to become more effective at capturing young people's interest at school and translating it into achievement, progression and enthusiasm for STEM in choosing their HE and careers.

16 To fulfil our remit, we have first to look at the aims of a system that can give able young people the motivation and achievement to succeed.

Maximise achievement

17 Motivation is not separable from achievement. By far the biggest single factor in persuading learners to continue their interest in science and mathematics is prior success in these subjects. For instance, students of both genders and all ethnic and social backgrounds were several times more likely to choose to continue mathematics or science subjects at A level if they received an A* or A grade in the relevant subject at GCSE than if they received a B or C grade.[2]

18 We take from this the lesson that an important priority is that successful STEM pathways maximise students' achievement at each stage. All elements of the system should be geared to improving outcomes for learners. However,

1 *PricewaterhouseCoopers, The economic benefits of higher education qualifications, 2005*

2 Royal Society, *State of the Nation – science and mathematics education*, 14-19, 2008

this cannot be at the expense of devaluing grades at GCSE or A level, and we welcome the creation of the new qualifications regulator, Ofqual, as an opportunity to reinforce grading standards. Raising achievement is about ensuring that the curriculum is interesting and challenging and that the teaching matches this.

A rigorous curriculum

19 There has been much debate over the years about content (i.e. subject knowledge and conceptual understanding) versus context (i.e. learning about science in the context of examples of obvious relevance to everyday life) in science curricula. This was summarised well in Beyond 2000 (a well-researched study of the science curriculum which received wide-spread support[3]) and the report from King's College London by Paul Black and his colleagues.[4] Traditionally science education has been dominated by teaching the underpinning concepts and knowledge at the core of science. But as early as 1918 the Committee on Natural Science in Education, chaired by Sir J J Thomson, Nobel Laureate in Physics and President of the Royal Society, recommended "that more attention should be directed to those aspects of the sciences which bear directly on the objects and experience of every-day life". They also noted "....that all through the science course stress should be laid on the accurate use of the English language".[5] We will return to this point later.

20 We think that J J Thomson was correct in 1918 and that it is unproductive to argue about content versus context. The best curricula should teach the content, and illuminate the value of this by considering the context in which fundamental knowledge of STEM subjects is relevant.

Specialist teachers

21 The evidence from Ofsted is clear: teachers with specialist expertise in mathematics or the branch of science they teach achieve better outcomes in those subjects than teachers without. We need to attract talented mathematicians, physicists, chemists and biologists into schools and colleges to teach these subjects.

3 Millar, R & Osborne, J (eds) 1998 *Beyond 2000: Science education for the future*. King's College, London

4 Professor Paul Black, Dr Christine Harrison, Professor Jonathan Osborne, Professor Rick Duschl, Assessment of Science Learning 14–19, for the Royal Society, 2004

5 *Report of the Committee appointed by the prime minister to enquire into the position of natural science in the education system of Great Britain*, HMSO, 1918

Effective teaching

22 Inspiring and effective teaching of STEM subjects requires a diverse toolbox of methods and approaches. It is essential that teaching and classroom practice reflect the full range of scientific and mathematical attributes that these subjects require, including a combination of theoretical, practical, experimental and factual learning.

23 Science, mathematics and engineering may appear remote from learners' everyday experiences so learners must have opportunities to understand how STEM subjects are central to their world and gain experience of the roles of scientists, mathematicians and engineers in society. Practical engagement between schools and private industry, higher education and other STEM sectors is vital to provide young people with clear information and experience of where their learning can take them.

Recognising and rewarding achievement

24 Assessment and qualifications should match the curriculum, by testing appropriate knowledge, skills and understanding, illuminating students' progress and rewarding them fairly. But it is too easy to see assessment in terms simply of the qualifications that unlock access to HE and employment, and to neglect the importance of formative assessment in guiding students constructively through their courses.[6]

25 Qualifications themselves must provide progressive ladders of achievement, where each level leads naturally to the next without unrealistic jumps or unnecessary repetition. They must also provide recognition of different kinds of STEM learning as well as different levels of attainment. Clear pathways are needed through education to each of the different outcomes, from vocational, practical and technical STEM roles to high level theoretical research science – and the ability for learners with appropriate aptitudes and motivation to move between these.

Shaping our analysis

26 In our work, we have used the considerations above as the standards against which to analyse the performance of our current system for STEM learning pre-19. We have sought to bring together existing analysis and evidence with outcomes from our own wide-ranging stakeholder consultation. We have conducted this through a written consultation, workshops and meetings

6 Effective formative assessment has been shown to improve students' achievements, for instance: Black, P; Harrison, C; Lee, C; Marshall, B; Wiliam, D. (2004) *Working inside the Black Box: Assessment for Learning in the Classroom.* Phi Delta Kappan v86 n1 p8

with stakeholders – firstly to develop our view of the key priorities upon which our proposals should focus; and secondly, to test and to obtain feedback as our recommendations have evolved.

27 We append to this report the recommendations from certain key prior reviews of science education to point out firstly their consistency and secondly to emphasise that the time is not for more reports, but for decision and action by politicians and policy makers to build on what has already been achieved.

28 We also provide as an annex the outcomes of our consultation process, which has engaged a diverse range of stakeholders, including students, parents, teachers and academics. In our written consultation, we received about 130 responses from the key stakeholder organisations, schools, FE colleges, HEIs, employers, professional bodies and learned societies, and from those operating the system of curriculum development and assessment. We followed up our consultation with 25 meetings, including with QCDA, Ofqual and all three English awarding bodies. We held 9 focus groups with a wide range of senior stakeholders and practising scientists, teachers and students, and 4 well-attended workshops to discuss our emerging findings. We have visited schools and FE colleges and have spoken to staff and students. Our consultation has been remarkable for the consistency in the feedback that we have received about both the strengths and weaknesses of STEM education.

The context of our recommendations

29 We in the UK are not unique among the developed economies in having concerns about the scientific and technological capacity of our country and competition from other rapidly developing economies. In evidence to the US House of Representatives, Norman Augustine, Chair of the Committee on Prospering in the Global Economy of the 21st Century Committee on Science, Engineering, and Public Policy Division on Policy and Global Affairs of The National Academies, stated "Human capital—the quality of our work force—is a particularly important factor in our competitiveness. Our public school system comprises the foundation of this asset. But as it exists today, that system compares, in the aggregate, abysmally with those of other developed—and even developing—nations… particularly in the fields which underpin most innovation: science, mathematics and technology."[7]

30 However, there are positive trends in science and mathematics learning in the UK. After a long period during which take-up of science and mathematics has been declining or stagnant, there are signs that the picture is beginning to improve.

7 *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, Statement of Norman R. Augustine before the Committee on Science, U.S. House of Representatives, October 20, 2005

International comparisons of performance in science and mathematics education

Out of the 59 countries covered by the 2007 Trends in International Mathematics and Science Study (TIMSS) England's performance at year 9 was ranked 5th and 7th for science and mathematics respectively. All the countries which rank higher than England in these analyses were East Asian with the exception of Hungary which is ranked 6th for mathematics. This was a significant improvement on the 2003 results, which placed England at 18th and 20th in the two categories.

The OECD's 2006 PISA (Programme for International Student Assessment) study ranked the UK on science between 8th and 12th out of the 30 OECD countries and between 12th and 18th when compared to all 57 participating countries. In mathematics, the UK ranked between 20th and 25th among participating countries. Follow-up studies by the OECD suggested that the UK has one of the highest percentages of "Top performers" in science. 7 countries had higher percentages of top performers: Finland, New Zealand, Hong Kong, Japan, Chinese Taipei, Australia and Canada.

31 There has been sustained investment in science and mathematics education, building on the Government's Science and Innovation Investment Framework[8], and there are signs of improvement in students' participation and achievement. For instance:

- GCSE entries for separate physics, chemistry and biology are now rising strongly after a long period of decline and stagnation after the introduction of the National Curriculum and single and double science GCSEs in the early 1990s. GCSE results for 2009 show an increase of around 20% in entries for these subjects compared to 2008 and they have nearly doubled since 2002.
- The proportion of pupils achieving A*-C grades in GCSE mathematics and science has been rising steadily over the past decade. This is crucial. As the Royal Society has reported, achieving a high GCSE grade is the single most important factor in driving post-16 participation, with attitudes towards science careers being formed in early adolescence.[9, 10]
- A level entries, too, are once again rising year on year, with growth in mathematics and further mathematics particularly strong. Physics A

8 Science & Innovation Investment Framework 2004-2014, HM Treasury, 2004

9 Osborne, J., Simon, S., Tytler, R. (2009) Attitudes to Science: an update Paper presented at American Educational Research Association Conference.

10 *Taking a leading role*, a survey of 1141 scientists and engineers conducted by the Royal Society, found that 63% of them first began thinking about working in STEM by the age of 14. State of the Nation – science and mathematics education, 14-19, Royal Society, 2008

level entries are growing after a thirty year decline. AS entries in 2009 – an advance signal of A level entries in 2010 – show strong growth in mathematics and all the sciences.However, in the case of mathematics and physics, entries have only just reached the levels of a decade ago.

- Whilst trends vary between individual degree subjects, overall applications to study science and engineering at university are growing.

32 While these positive trends are likely to have multiple causes, credit must be given to the Government for systematically investing in STEM education through the Science and Innovation Investment Framework, in particular the measures to increase recruitment and retention of specialist teachers in science and mathematics and to improve the quality of CPD available to them. Specific campaigns to promote further mathematics and triple science have had striking effects. Investment to promote enhancement activities such as science clubs has been systematic and targeted. Much of this investment is in interventions with younger pupils and therefore the effects will take some years to work through.

33 However, these positive trends are at odds with the perceptions and experience of many of the people most closely engaged with science and mathematics. Throughout our consultations we have been struck by the extent to which the same concerns repeat themselves about the underlying effectiveness of the system.

34 We have given significant weight to the concerns that have been voiced to us because they point to an important gap between what is being achieved now and the potential for significantly greater success in the future. The ambition to close this gap and fully realise the potential of our young people is what motivates the recommendations in this report.

35 In particular, we have focused on five priority areas where consultations have revealed the most consistent concerns. It is these that form the basis for the remainder of this report and our detailed recommendations:

- *The STEM school and college workforce:* the supply of teachers with specialist training, continuing professional development (CPD) to promote and maintain high quality education and strong subject leadership within schools and colleges.

- *Curriculum, qualifications and assessment:* the mechanisms for determining and developing the curriculum and qualifications; ensuring that the assessment system provides tests that enable students to display a balance of breadth and depth of knowledge and understanding matched to the curriculum; and ensuring the engagement and ownership by the key stakeholders of the content and assessment of STEM learning; and the mathematics content of STEM curricula.

- *Coherent STEM programmes, pathways and enrichment:* the importance of well-defined routes for progress in STEM and of meeting the aspirations, needs and aptitudes of all learners; promoting broad and balanced programmes for STEM specialists; the role of Advanced Diplomas; the importance of practical and project work; and the opportunities for enrichment of STEM education outside the classroom.
- *Market pull:* how effectively industry and HEIs interact with schools and FE colleges, for example to communicate the nature and value of STEM careers, to communicate the value placed on different qualifications and to strengthen links between the various sectors. This chapter also considers delivery of information, advice and guidance (IAG).
- *School and college ethos:* ensuring that leadership and governance arrangements are in place to allow schools and colleges to foster a commitment to excellence in science and mathematics; developing local and regional networks of excellence in STEM education.

The Science and Mathematics Workforce in Schools and Colleges

36 It is widely acknowledged that "no education system can be better than the quality of its teachers".[11] Additionally, the quality of teaching has been shown to be a major determinant of pupils' interest and achievement in science, pointing to the importance of the quality of initial teacher education and professional development.[12, 13] Evidence from our stakeholder consultation, including from young people themselves, has underlined that the best science and mathematics teachers are subject specialists with excellent teaching skills.[14]

37 Pupils and teachers have told us that the starting point for inspirational teaching is teachers who know and love their subject; biology is best taught by a biology graduate, chemistry by a chemist and physics by a physicist. Specialist knowledge and experience enables teachers to explore and illuminate their subject, bringing it alive for students through personal experience and knowledge of current research and debate. Deep and inspiring subject knowledge also allows teachers to respond knowledgably to students' interests and provide stretch and challenge for the most able students. GCSE students at one school told us that they could easily distinguish teachers with subject specialisation by their ability to answer their questions in a confident and satisfactory fashion.

38 This feedback is reinforced by academic studies and evidence such as that from Ofsted, which shows a strong correlation between subject expertise and teaching quality in schools (see figure 1.1 below).

39 Given this strong link between subject specialism and teaching quality, the acute shortage of specialist teachers in mathematics, chemistry and physics is a major concern. The government has recognised the need to tackle this problem and has set a number of ambitious targets so that by 2014 25% of science teachers in maintained schools will have a physics specialism; 31% will have a chemistry specialism; and 95% of mathematics lessons will be delivered by a mathematics specialist.

11 Barber for McKinsey.

12 Osborne, J., Simon, S & Collins,S, (2003) *Attitudes towards science: A review of the literature and its implications. International Journal of Science Education*, 25 1049-1079

13 Wiliam, D (2006) *Assessment: Learning Communities Can Use It to Engineer a Bridge Connecting Teaching and Learning.* Journal of Staff Development 27, 1, 16-20. Research shows students who get the best teachers learn at twice the rate of students taught by average teachers; shows that a focus on assessment "for" learning is the most powerful, and yet most neglected, aspect of teacher practice

14 As the Royal Society's 2007 State of the Nation report on "the UK's science and mathematics teaching workforce" notes, there is no universally accepted definition of a "specialist teacher", but for the purpose of this report, we will use NFER's definition of: "holding 'university qualifications in the subject [s/he is teaching], either at degree level or above or for their ITT [initial teacher training]'" (NFER 2006).

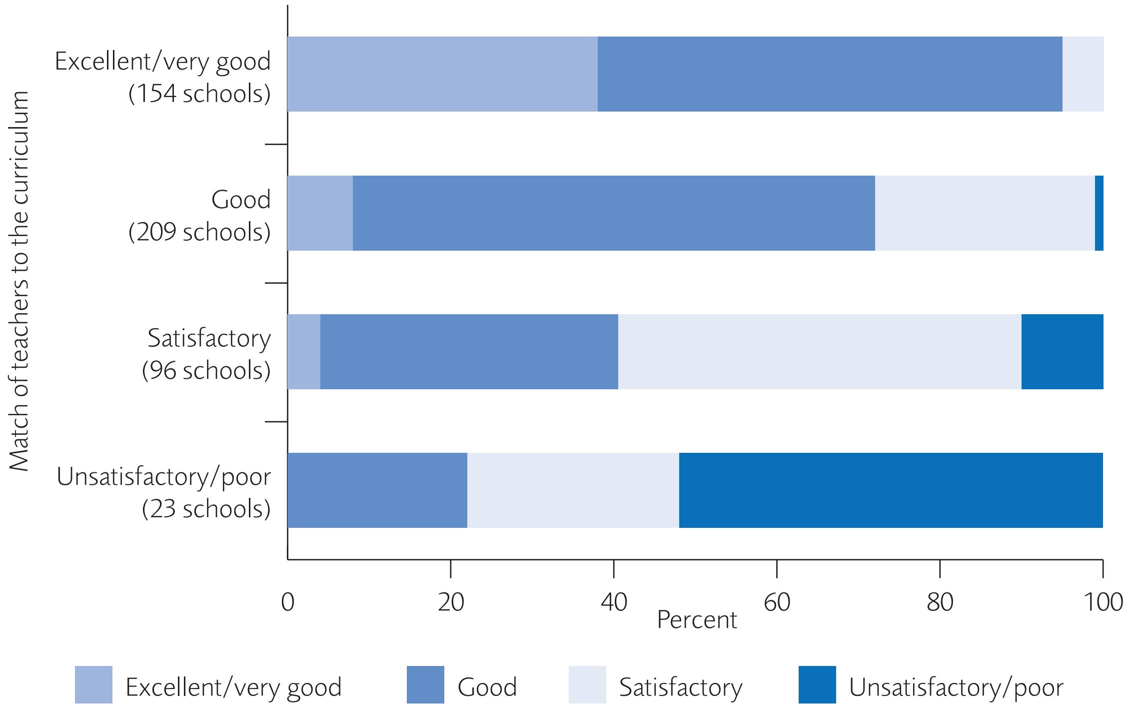


Fig 1.1 Relationship between the quality of teaching and match of teachers to the curriculum in secondary schools (% of secondary schools) (source: Ofsted)

40 There are essentially four ways to meet these targets, which this chapter will consider in turn: recruiting more physics, chemistry and mathematics specialists into teaching; improving the retention rate of these teachers; encouraging people who have left teaching to return; and training more existing or prospective teachers to teach effectively outside their primary specialism.

41 Recruiting people with a strong subject background in STEM subjects is only the first step in ensuring a first class teaching workforce. Their initial teacher training (ITT) needs to be fit for purpose, providing subject-specific as well as general pedagogical training. Throughout their career they need high quality continuous professional development (CPD) to keep both their subject knowledge and teaching skills fresh and up to date.

42 Because practical demonstrations and practical classes are a key element of the STEM subjects, teachers in these subjects need laboratory infrastructure and technical support to deliver practical classes effectively. Finally they need to be empowered to deliver a curriculum that has sufficient flexibility and challenge to provide fulfilment to both teachers and pupils. In this chapter we make recommendations to strengthen initial teacher training, to enhance CPD uptake, and to enhance technical support. In subsequent chapters we deal with curricula for STEM subjects.

Priority 1.1 – Improve the quantity and quality of supply of specialist STEM teachers and technical support staff.

Recruitment

43 Recruitment of specialist teachers into science and mathematics is an area where there is good evidence of impact from current initiatives. We are impressed with the variety and coverage of initiatives and the intensity of effort and resources devoted to maximising the numbers coming into the profession from a wide variety of sources and backgrounds. These initiatives include shortage subject bursaries, Golden Hellos, the Graduate Training Programme, Transition to Teaching, Teach First, Student Associate Scheme and pre-ITT subject enhancement courses.

44 Whilst there is a strong link between initial subject specialism and teaching quality, increasing STEM recruitment from non-standard routes needs to be part of a sustainable set of policies. Early evidence from TDA suggests that courses that train non-specialists, such as the Science Additional Specialism Programme (SASP), have a positive impact on raising the quality of learning and teaching in STEM subjects. The recruitment of both specialists (from traditional and non-traditional routes) and non-specialists need to be analysed together, drawing on as wide a base as possible, in order to set targets and develop coherent policy.

Teach First

Teach First is a business-led Government initiative to attract, train and support high achieving graduates to teach mainly priority subjects in disadvantaged schools. It was launched in London in 2003, and has since extended to Manchester, the Midlands, Liverpool and Yorkshire. Participants sign up for the two years of the programme, but around half have opted to remain in teaching, many in challenging schools. Ofsted has praised the Teach First programme and said that it has produced some of the best trainee teachers ever. 470 participants have been recruited for the 2009 cohort and more may be added, nearly 40% per cent of whom are teaching mathematics and science.

Transition to Teaching

The Transition to Teaching programme is designed to capture the talent of people leaving industry, whether for early retirement, restructuring or career change reasons, and encourage them to train to be mathematics, science or ICT teachers. The programme is directed at employers and offers them support to communicate to their staff the benefits of career change into teaching. For the staff it offers tailored support to help with making the decision, and some support while they train on existing TDA teacher training routes. There are currently about 450 private employers who have agreed to support the programme. After only just over a year of operation, there are already over 370 people being helped to consider teaching including some 70 in teacher training.

45 Whilst over the past decade recruitment has consistently undershot the TDA's annual targets for science and mathematics specialist entry to initial teacher training, in 2009/10 the targets are being met for the first time and the early prospects for 2010/11 are encouraging. The latest published figures from the Graduate Teacher Training Registry show that applicants to ITT for 2009/10 courses in STEM subjects increased by 30% compared to the previous year. Physics applicants made up 26% of the science applicants and Chemistry applicants made up another 30%. All entrant targets for 2009/10 are expected to have been met by July 2010 in mathematics and science.

46 Current economic and labour market conditions have played a significant role in this improvement, and we welcome the money that has been made available by the Government to TDA to support over-recruitment of science and mathematics specialists – qualified both educationally and with the personal attributes needed to motivate and inspire young people – against the current initial teacher training targets for schools and maximise the impact of this one-off opportunity to boost supply.

47 Given the prospective squeeze on public finances, it is therefore timely to underline how vital this investment in future teachers is to giving young people exactly the skills that the country needs for a secure economic future.

48 Our first two recommendations build on the work that has already been undertaken to enhance the recruitment of specialist teachers to the STEM subjects. These are that there should be no let-up on the initiatives that are bearing fruit in enhancing recruitment of STEM specialists to teaching. The 2014 targets that will enable widespread access to STEM specialist teachers are challenging and will only be met if there is no let-up on current recruitment mechanisms.

Recommendation 1: Maintain and extend programmes for recruitment of science and mathematics specialists to teaching, building on, in particular, non-standard routes such as Transition to Teaching and Teach First and take full advantage of the current 'spike' in applicants. Whilst this situation persists, resources should be made available to TDA to ensure that no well-qualified applicant is turned away from science and mathematics teacher training.

49 Teachers are not the sole contributor to the science and mathematics workforce in schools and colleges. Well-qualified and experienced technicians play a vital role in supporting teachers to deliver engaging science lessons. The importance of technicians is reflected in the dramatic rise in their numbers in schools, which has almost doubled since 1997 from 12,700 to 24,300 in January 2009. Teachers stressed that technicians provide invaluable assistance in preparing and managing the resources required for practical work and demonstrations, reducing their workload and allowing them to focus on teaching and learning. Technical staff provide particularly crucial support and guidance for newly qualified teachers and those teaching outside their specialism, who might otherwise avoid practical work due to a lack of confidence or experience. The best practice has technicians integrated fully into science departments and fully involved in the life of the school. For example, they are involved in discussions on how practical lessons can be integrated into the curriculum and schemes of work and their CPD is addressed in a strategic way. This maximises impact as well as retention.

50 The scale and quality of technician resource varies enormously between schools and colleges. We spoke with several technicians who held scientific PhDs, whilst others had no background or training in science. Many schools and colleges reported that they had difficulties recruiting quality technical staff, suggesting scope for targeted initiatives to address this issue. Our second recommendation recognises the importance of well-qualified technical support in the delivery of strong STEM education.

Recommendation 2: Technicians should be recognised as essential contributors to the practical teaching of STEM subjects. Metrics should be collected on the extent of technical support within schools and FE colleges.

Retention

51 It is costly and futile to recruit and train specialist teachers and technicians if they cannot be retained. DCSF data cited by the Royal Society in 2007 suggest that in science and mathematics subjects, more than 40% of people

who qualified as teachers in 1999 were not practising teaching five years later.[15]

52 Nationally the evidence suggests that the drop-out rate for science and mathematics teachers leaving the profession is similar to other subjects.[16] However, variations in mobility and retention mean that local retention patterns vary.

53 As Ofsted has highlighted, the high demand for mathematics and science teachers makes it relatively easy for them to move between schools, and the shortages are worse in some places than others. Challenging areas and schools are particularly affected. There is also evidence that there is a significant drop-out amongst those in their first few years of teaching. Stakeholders felt that the provision of mentoring, coaching and support for newly qualified science and mathematics teachers was especially important. Encouragingly, the Government has recently established a pilot scheme along these lines. Evaluation of the success of this scheme is just beginning, so no evidence is available at this stage on its impact.

54 Our consultation also suggested that one of the most important factors for improving retention would be greater empowerment and flexibility to teach an engaging curriculum, as well as input into its design, recommendations for which will be discussed in the following chapter. Access to high-quality CPD, including opportunities to spend time and increase links with HEIs and employers was also felt to be an important lever to improve retention.[17]

55 Financial incentives are a powerful lever for retention. Schools need to reflect the realities of the marketplace in teacher salaries. Teachers remain on a universal salary scale despite the shortage of specialist physics, chemistry and mathematics teachers, and science and mathematics graduates can often earn substantially more elsewhere than arts and humanities graduates. Many schools seem reluctant to use existing pay flexibilities to support recruitment and retention of effective science and mathematics teachers. Although it is unrealistic for teaching salaries to compete with many of those available in the corporate sectors, it is a testable hypothesis that relatively small amounts of additional salary could be influential in persuading teachers in shortage subjects to stay in the school, college or profession. We therefore welcome planned DCSF evaluation of the impact of recruitment and retention bonuses.

15 Royal Society, *State of the Nation report – the UK's science and mathematics teaching workforce*, 2007

16 For example, evidence collected by the Local Government Association suggests that turnover rates for physics, chemistry and biology teachers was actually below the average for all subjects, with mathematics above average.

17 The most recent Chartered Institute of Personnel and Development annual survey of HR professional lists a lack of training opportunities as a major reason for voluntary staff turnover *Recruitment, retention and turnover survey report*,(2008)

Recommendation 3: Schools, colleges and local authorities should make greater use of current recruitment and retention pay flexibilities to reward and retain effective science and mathematics teachers. This should be part of the accountability framework as set out in Recommendation 21.

Initial Teacher Training

56 There was a consistent message from stakeholders that Initial Teacher Training (ITT) varies significantly in focus and quality between providers. Much of this training takes place in schools and concerns were raised over the availability of high-calibre placements. Several stakeholders suggested that more could be done to co-ordinate and quality assure placements, and incentivise high-performing science schools and colleges to take on trainee teachers. Of perhaps greater significance is the reported lack of consistency between ITT providers in terms of general pedagogical and subject-specific learning, with many stakeholders arguing that the balance is too often weighted towards the former. The two are not incompatible of course, but subject-based pedagogical training was felt to comprise the most effective form of training. We recommend that this is an issue that merits further investigation and action.

Recommendation 4: TDA should investigate further the consistency between ITT providers in the balance between subject-specific and general pedagogical training to ensure that subject-specific pedagogical training receives a high priority.

Collaboration

57 It is widely agreed that improving the recruitment and retention of specialist teachers will take time and therefore in the short-term greater collaboration amongst and between schools, FE colleges and HEIs will be needed to improve science and mathematics education. Our consultations revealed a number of excellent examples of schools and colleges working together (and with HE institutions and employers) to share expertise, facilities, students and resources.

58 The Government's recent white paper highlighted that partnerships are at the heart of their vision of a world class education system. The Group believes that this collaborative model should be developed to improve the skills and deployment of the science and mathematics education workforce in particular.

Further Mathematics Support Programme

The Further Mathematics Support Programme (FMSP) was established in September 2009, building on the successful Further Mathematics Network. Its primary aim is to increase the number of young people studying Further Mathematics at AS and A level. It is funded by the Government and is managed by MEI (Mathematics in Education and Industry) and has had real success, with the number of A level Further Mathematics entries rising from 5,192 in 2005, when government funding started, to 9,443 in 2009.

FMSP's provision of free resources and expert advice enables some schools and colleges who were not teaching Further Mathematics to start teaching the subject. Other schools and colleges can arrange for their students to receive Further Mathematics tuition through the FMSP. This year over 200 schools and colleges have students receiving tuition, enabling over 900 students to study for Further Mathematics qualifications who would not otherwise be able to do so.

The FMSP also encourages and supports schools and colleges to work together in consortia to provide Further Mathematics tuition. This can enable neighbouring schools and colleges to teach their Further Mathematics students together, forming viable teaching groups and sharing teaching expertise, particularly for smaller schools and colleges. As a result of this initiative, every sixth form Mathematics student in England has the opportunity to study for AS/A level Further Mathematics qualifications, even if their school or college is unable to offer them tuition directly.

59 A variety of initiatives that encourage collaboration already exist, for example accreditation for both specialist school status and the Advanced Skills Teacher scheme requires outreach and collaboration with other institutions. However, it is widely argued that this duty to collaborate is not monitored or regulated as effectively as it could be.

60 Throughout this report our recommendations are aimed at empowering teachers, schools and FE colleges at the level of the community and our key recommendations on the governance to achieve this are set out in paragraphs 158 to 165. Recommendation 5 needs to be read in this context.

Recommendation 5: Schools and FE colleges should collaborate in local clusters to deliver science and mathematics teaching, working wherever possible with HEIs and employers. The collaborative aspects of the AST, Specialist Schools and High Performing Schools programmes should be reinforced. Schools and FE senior executive staff should be accountable for establishing appropriate collaborative arrangements and be supported and challenged to achieve this by school and FE governing bodies and Ofsted (see Recommendation 21).

Priority 1.2 – Ensure that science and mathematics CPD is valued consistently by all schools and colleges. Science and mathematics teachers and classroom support staff should be rewarded for updating their subject and teaching skills throughout their careers.

Continuing Professional Development

61 CPD is central to effective career development for all teachers. Subject-specific CPD is especially important for STEM teachers who need to keep up with the latest developments in their fast-moving subject areas, and who need continuing support and updating to develop excellent practical classes and demonstrations for their pupils.[18] Indeed, this is so central to good science teaching, that we strongly recommend that subject-specific CPD in science and related subjects is treated as a special case for targeted support.

62 The Group welcomes the focus on the importance of CPD both in the follow-up to the 2006 FE White Paper[19] and the Government's recent schools white paper, which aims *"to ensure that as highly-valued professionals, teachers have the right to access effective professional development throughout their career"*. We would add to this that teachers should have the right *and the duty* to access effective professional development throughout their career.

63 Feedback from stakeholders has underlined the importance and value of subject-specific CPD in particular. Given the current shortage of physics and chemistry specialists, it is clear that biologists will be required to teach these subjects for the foreseeable future, particularly at lower levels in the schools, so CPD for teaching outside a specialism is vital. There are a

18 Osborne, J & Dillon, J (2008) *Science Education in Europe: Critical Reflections. Report to the Nuffield Foundation*

19 DFES, *Further Education: Raising Skills, Improving Life Chances*; 2006

number of initiatives in existence that appear to be having a positive impact in this area. For example, the National Foundation for Education Research (NFER) conducted an independent evaluation of chemistry for non-specialists courses, funded by GSK, DIUS and the Royal Society of Chemistry (RSC) and delivered through the network of Regional Science Learning Centres. They found that nearly 80% of participants felt it had 'quite a lot' or a 'great effect' on their professional practice, whilst over half of pupils agreed that their teachers seemed to know more about the subject, could answer questions better and were using more resources and equipment in lessons.[20]

64 Deepening subject knowledge and skills through CPD is also essential within a teacher's specialism, yet it was felt that there are not yet sufficient levers or mechanisms to incentivise this, with many stakeholders arguing that it should be linked to career progression. For example, the TDA's Professional Standards for Teachers stipulate only that teachers, 'evaluate their performance and be committed to improving their practice through appropriate professional development.' The Group believes that this should be revised to set out an explicit link between subject-specific CPD and career progression for science and mathematics teachers in schools and the FE sector.

65 The introduction of the Masters in Teaching and Learning course and the Licence to Practice also provides an opportunity to support and incentivise subject-specific CPD. It was also felt that statutory school training days are often dedicated to whole-school issues or general pedagogy, rather than being used to deepen subject skills and knowledge.

Recommendation 6: Reinforce the link between updating subject specialist skills and career development and progression for science and mathematics teachers, including:

- **more emphasis on updating subject specialist skills in TDA's Professional Standards for Teachers and the criteria for moving to advanced teacher scales;**
- **clear specifications for subject-specific teaching skills and subject knowledge should be integral to the Masters in Teaching and Learning, and the License to Practice, and linked to entitlement to subject-specific CPD; accompanied by more effective communication to teachers of the CPD opportunities available to them;**

20 Jones *et al.* 2008. *Evaluation of the Chemistry for Non-Specialists Training Programme: Final Report.* Slough: NFER.

- **more effective use of the 5 statutory school training days to improve subject teaching; and**
- **extended in-service schemes such as the second science specialism and conversion to mathematics programmes.**

66 Secondary education is currently part way through an important culture change embedding the link between rigorous performance management to high quality, well-planned professional and career development, TDA has been working on embedding the links and support for CPD leaders, which help schools to make stronger links between performance management and CPD.

67 We believe strongly that this trend should be supported and encouraged. However, incentives and levers should not only be at an individual teacher level however. We understand the temptation in practice to neglect CPD when it costs the school money and means releasing valued teachers from the classroom periodically. Schools and colleges need clear incentives to prioritise professional development and should be accountable for keeping staff skills (including technicians and support staff) up to date and the impact of this on pupil outcomes.

68 Currently, funding for CPD comes both from general school and college budgets and ring-fenced funding and central subsidies, including in FE, the Learning and Skills Improvement Service (LSIS) STEM Programme. In a period when all public budgets are under pressure, there is a clear risk that CPD will be seen as discretionary and non-essential spending. This would be an historic misjudgement. We recognise that ring-fencing CPD budgets either nationally or locally is inconsistent with the current drive towards greater budgetary delegation to schools. Nevertheless it is vital that commitment to science and mathematics CPD is reinforced through clear incentives and expectations. We believe that including this amongst the metrics included in a report to governors (outlined in the Introduction, and in more detail in Section 5) and in the annual report of schools and FE colleges is the best and most implementable way of incentivising schools to provide adequate CPD.

69 There are a wide range of CPD opportunities available to science and mathematics teachers, yet take-up and quality are often reported to be uneven. A notable exception is the national network of Science Learning Centres which in 2008/09 reached 79% of secondary schools and 17% of primary schools in England, with 98% of participants rating their experiences as good or very good. Good impact of this CPD is now evident in classroom practice.[21] Schools, colleges and individual teachers are frequently unaware of available CPD activities and of sources of support in meeting the costs of,

21 SQW (2009) *External evaluation of National Network of Science Learning Centres Interim report*

for example, providing supply cover. It was widely felt that participation in CPD is highest in school or colleges with excellence in these subjects and that such self-selection bypasses those schools where CPD might add most value. Indeed, challenging schools were thought to be particularly reluctant to release their teachers for external training.

70 Whilst we support the value of externally delivered CPD courses, we are also aware that it can be difficult for teachers to secure release from their school or college, due to the resource and timetabling issues involved in ensuring supply cover. This problem was reported to have become more acute since the 'rarely cover' agreement came into effect at the start of this academic year.

71 In this context, CPD that takes place in-school will become increasingly important as we move forward. Ofsted have stressed that in-school CPD can be extremely effective, since teachers can work collaboratively, supported by coaches, continuously learning from each other by watching each other's lessons and reflecting on the effectiveness of practice. Effective CPD can therefore take place through teachers learning from other schools and observing other effective teachers. This collaborative model of CPD is still in its relative infancy, but has the potential to play a more prominent role in the future, although it has limitations in terms of development of subject knowledge.

72 The National Strategies currently delivers science and mathematics CPD in schools to raise attainment in these subjects, but given that this organisation will cease in March 2011, the legacy of experience and good practice in science teaching developed by the Strategies must be captured and preserved to inform ongoing improvement and the development of new approaches to delivering in-school CPD. With the loss of the National Strategies, it is ever more important that the network of Science Learning Centres continues to receive a high level of support, in order to assure continued subject leadership in science. The external evaluation of the network has found 'the Science Learning Centres are important players; users and partners want to see them continue in the future'.[22] The same applies for mathematics with the need for continuing support for the National Centre for Excellence in the Teaching of Mathematics (NCETM).

73 The other major issue that came out of our consultation in relation to CPD is the urgent necessity for science and mathematics teachers to improve their industry and sector knowledge in relation to STEM subjects. This is especially important in the context of applied qualifications and to provide appropriate and effective careers advice to learners (as will be explored in greater detail in Section 4). Indeed, building on the collaborative networks that are beginning to be developed through Diplomas, stakeholders suggested that schools

22 *ibid*

could work with, and draw on, FE colleges' links with local employers and industry to improve the sector-knowledge of their teachers.

74 Finally, given the increasing heterogeneity in the types and providers of CPD, many stakeholders agreed that it would be helpful for greater quality assurance of CPD, with the Government and the TDA providing a kite-mark.

Recommendation 7: Embed CPD into a clear governance framework at school level through:

- **more effective links between performance management and CPD expectations in schools; and**
- **head teachers reporting annually to the governors of their school on how staff skills are kept up to date and the use of the school's financial resources to support CPD.**
- **TDA and DCSF should establish and maintain robust quality assurance arrangements for CPD providers to support schools in choosing high quality CPD provision.**

Recommendation 8: DCSF should continue to support and fund a national network of Science Learning Centres and the National Centre for Excellence in the Teaching of Mathematics, in order to secure continuing subject leadership, building on the legacy of the National Strategies.

The Curriculum, Qualifications and Assessment

75 Developing and delivering an excellent curriculum and assessing students' progress are key components of any successful education system. We have not set out to undertake a detailed analysis of the coverage of the curriculum and qualifications in science and mathematics. Rather, we have sought the views of those with expertise in designing and delivering science and mathematics education in schools to develop a picture of where practitioners themselves see the strengths and weaknesses of the current system, and where improvements can be targeted to best effect, taking into account the significant changes currently in process within the qualifications framework.

76 We welcome the division of the responsibilities of the former Qualifications and Curriculum Authority between the new Qualifications and Curriculum Development Agency (QCDA) – supporting the development of the curriculum and related qualifications – and the Office of the Qualifications and Examinations Regulator (Ofqual) – which will regulate and monitor standards.

77 Specialists in individual subjects and disciplines often feel that their own discipline is under-represented. However, with some important exceptions, noted later in this chapter, we have not found consistent concerns with the high-level aspects of the subject construction of either the National Curriculum programmes of study or the subject coverage provided by GCSEs and A levels in science and mathematics.

78 However, the consultation process revealed some major concerns about the specifications and examinations associated with the major public qualifications and in particular, the process of developing GCSE and A level criteria and specifications. There was a strong and consistent message that this has become disconnected from its key stakeholders in schools, FE colleges and HEIs. Professional and learned bodies and employers are also largely disengaged from the curriculum and qualifications development. As we set out below, the creation of QCDA provides a good opportunity to address this issue.

79 One of the major challenges in education is that there are powerful incentives that mean that the examination system readily becomes the 'tail that wags' the whole education system. Thus broad subjects are narrowed into individual specifications which, in turn, define what is taught and how it is assessed. It is then almost inevitable that it is the specification that drives the content of learning in the classroom, because, if it is not in the specification, it will not be examined. This link between subject content and examination is exemplified by the example from a guide to students in the box below.

Extract from the Salters-Nuffield Advanced Biology website

"Know what you need to know!

You can only be examined on what is in the specification. The whole specification can be downloaded from the Edexcel website but even for teachers it is hard-going. Students will find it much better to use the 'Check your notes' activities. These are 'student-speak' versions of the specification and are cross-referenced to the learning activities available on www.newsnab.com and to the Checkpoint questions in the SNAB textbook. The 'Check your notes' activity sheet for each topic is always the last activity number in any SNAB topic. For example, for Topic 1 Lifestyle, health and risk it is Activity 1.26. The specification material is covered in the textbook, which along with your own work and notes, should be your first revision resource. The textbooks may also include information that is useful or interesting, but you can only be examined on what is specified."

from: http://www.advancedbiology.org/resources/snab-revision-tips,1430,NA.html (accessed 30 Dec 2009)

80 This connection between what is assessed and what is taught is absolutely central to the quality of students' educational experience. It is an area where a very high proportion of stakeholders expressed concerns and offered suggestions on ways of improving the science and mathematics offer made to young people in schools and colleges.

Priority 2.1 – Reconnect the design and delivery of science and mathematics qualifications with HE and other stakeholders, to support consistent development of specifications and examinations which meet their needs and the needs of students progressing to STEM HE or employment

81 In highlighting, later in this chapter, widespread concerns about the assessment system, it is also apparent to us that they are linked by a common theme: that teachers, lecturers and other STEM professionals feel disengaged from the design and delivery of the examination system, and disempowered from influencing it.

82 It has been put to us repeatedly that the best teachers who are active in schools, FE colleges and HEIs no longer participate in the design of qualifications or examination processes. Whilst QCDA and Ofqual consult widely, neither they nor the awarding bodies currently have the culture or mechanisms which should underpin a permanent, in-depth role for subject

professionals in shaping rather than responding to, solutions. The creation of QCDA provides a valuable opportunity to improve the engagement of stakeholders, and their ownership of curriculum and qualifications development, and we urge that this opportunity is taken.

83 Within the regulatory framework set by Ofqual and its partner regulatory bodies in Wales and Northern Ireland, and the subject criteria set out by QCDA, the design of individual A level and GCSE STEM specifications rests in the hands of the awarding bodies and is led largely from within by professional examiners with specialist subject experience, rather than subject specialists who have experience of examining. We believe that a more balanced approach is needed: one in which – at all levels in the process – people with expertise in the design and delivery of examinations are brought together with those who have the expertise and up to date subject knowledge which comes from being working scientists, mathematicians, engineers and teachers.

84 Establishing this balance would give the wider STEM community a clear voice, and ownership of the qualifications and assessment about which they currently express their concern. Given the vigour with which these concerns are often expressed, it is incumbent on them to grasp the opportunity to influence the future direction of the system assuming that our recommendations are accepted.

Recommendation 9: Ensure that the higher education sector and other stakeholders are engaged in the design and development of qualifications and assessment in ways that will enable them to accept accountability and ownership for the quality of the system. In particular:

- **standing STEM expert groups should be established in each major subject to advise on the development over time of 5-19 curricula and GCSE and A level criteria in these subjects. This should be part of a process within QCDA that puts partnership and shared ownership with stakeholders at the core of its culture. QCDA must ensure that it draws transparently on the best professional, academic and employer expertise in order to develop the National Curriculum, and the qualifications criteria signed-off by Ofqual, and to advise ministers; and also ensure that stakeholders are clear about how they can influence the final products;**

- **awarding bodies should engage independent subject experts from HE and employers to advise on the development of specifications and examinations in these subjects; and**
- **Ofqual should include in its annual report to Parliament how it engages with the STEM community to ensure confidence in science and mathematics qualifications**

Priority 2.2 – Strengthen the regulation and subject content of STEM qualifications, assessments and examinations

Assessment for qualifications

85 Effective, fit-for-purpose assessment is central to the outcomes and reputation of high quality education. Responses to our consultation and discussions in workshops and other events have been dominated by comments on the role and impact of the summative, external assessment associated with GCSEs and A levels in shaping science and mathematics learning in schools and colleges.

86 It is not surprising that so much attention should focus on these examinations. The stakes are high for teachers and schools/colleges, as well as individual learners. But there is an inherent danger that assessment becomes 'the tail that wags the dog' – *i.e.* that learning becomes directed solely at ensuring the best examination results.[23]

87 Ideally, the drive for good results would happen within the context of broad, exploratory learning to ensure that the learner's experience of the subject goes beyond what is needed to achieve a good grade. Many teachers accomplish this very effectively. But it is unrealistic to hope that, when time and other resources are limited, learning will not be directed towards the most visible outcome and that the consequence is teaching to the test.

88 This is a difficult incentive to remove. It therefore becomes paramount that the nature of GCSE and A level assessment in STEM subjects is driven by, and reinforces the incentive to acquire, the skills, knowledge and understanding, and the balance between breadth and depth, that students will need to progress further in these and related subjects.

23 Harlen, W et al (1994) *Assessment and the improvement of education.* In Moon & Shelton Mayes (Eds) *Teaching and Learning in the Secondary School*, (O.U.P.) p 274 – 'There is an unavoidable backwash on the curriculum from the content and procedures of assessment. The higher the stakes of the assessment, the greater this will be.'

Examination consistency in A levels and GCSEs

89 The perceptions of many stakeholders is that the quality and consistency of examination questions within the assessment framework set by the regulators is variable and not always well-suited to the subject matter and skills being tested. This has especially been an issue in the first generation of the new GCSE How Science Works content – where Ofqual and the Government have recently acted.[24] But concern about the variability in the quality of question-setting appears to go wider, and is often linked to concerns about the resources available to the awarding bodies to maintain consistent quality of examinations across a wide range of different mathematics and science specifications.

Examination question styles

90 GCSEs, A levels and their predecessors have always made use of a mixture of different kinds of question, including multiple choice, short answer and essays/long problems, which allow the examiner to test both the breadth of the student's knowledge of the subject and more in-depth critical and conceptual understanding.

91 A significant strand of perception among stakeholders is that the wholly legitimate drive for consistent standards of assessment has tipped examination methods too far towards short answer and multiple-choice tests. These are useful to test the breadth of subject knowledge, and they can be marked simply and reliably but over-reliance on them constrains a student's ability to demonstrate conceptual understanding of the subject. Longer answers and essays test a depth of subject knowledge and understanding that, although more subjective to mark, provide much better insight into a student's conceptual grasp of a subject.

92 Multiple choice and short answer questions are a long standing feature of examinations in STEM subjects. Over time, these modes of examination have become the dominant examination style in GCSEs and A levels, at the expense of long answer and essay-style questions. There is a widespread perception that this trend has gone too far, with the outcome that students in the STEM subjects are no longer educated to produce written work in the form of essays, with the depth of rigour and analysis demanded by the essay form – a concern which has been reflected in various analyses of our examination system over the past decade – both generally and specifically in

24 Ofqual, March 2009, *The new GCSE science examinations: findings from the monitoring of the new GCSE science specifications:2007 to 2008*

relation to assessment in science and mathematics.[25] There is a closely related concern that students are less able to use the English language accurately to express clearly their understanding of scientific concepts (see para 122 below).

93 This trend towards shorter questions and evenly spread coverage of the course content is readily acknowledged by those involved in the design and setting of examinations. It is harder to establish a direct causal link between the trend and the widespread perceptions that the in-depth knowledge and conceptual skills of students are insufficiently developed when they start their HE courses. What matters most is how to improve those skills to the right level in the future. We believe that rebalancing the style of examinations towards longer analytical problems would be influential in ensuring that young people develop those skills more consistently.

94 We are pleased therefore that the new A level science criteria demand a wider range of question styles, a requirement for extended writing and more questions requiring a synoptic overview of the subject and offer the possibility of a new A* grade to recognise high achievement. We believe that in evaluating the impact of these changes, it is essential to harness at the earliest stage the expertise of the science and teaching communities through the arrangements set out in Recommendation 9, above.

Increasing mathematics

95 One of the most consistent messages we received on science content was the insufficient levels of mathematics that it now contains. Many stakeholders felt that the level of mathematics in science has been reduced over the past decade, especially at A level, though also at GCSE.

96 There are concerns that increasing the level of mathematics in science may reduce take-up. We acknowledge that some students can find mathematics daunting, but if the material is taught and assessed well, demanding mathematics content can be made accessible to a wider audience and rather than providing a blockage, should enhance science learning and motivate learners through a deeper grasp of the subject.

97 These concerns are neither new nor unrecognised. The new generation of science A levels introduced in 2008 introduce additional levels of demand into the examinations. Ofqual also recently announced that the new GCSE criteria, due to come into effect in 2011, will also promote greater stretch and challenge and be accompanied by documentation setting out the specific mathematical knowledge, skills and understanding associated with each of

25 For instance: DfES, 2004, *Final Report of the Working Group on 14-19 Reform*; and Professor Paul Black, Dr Christine Harrison, Professor Jonathan Osborne, Professor Rick Duschl, 2004, *Assessment of Science Learning 14–19, for the Royal Society*

the six GCSE science titles. At both levels, these changes are intended to address the concerns we have highlighted, and are strongly welcomed by the Group as a move in the right direction. These developments in GCSE and A level should be monitored and evaluated using the mechanisms outlined in Recommendation 9.

98 HE stakeholders have also highlighted that in order to study physics, chemistry and engineering (and increasingly biology too) in higher education, studying mathematics post-16 is a significant advantage. We therefore very much welcome the recent significant increases in the number of young people following mathematics and further mathematics at A level. Much credit is due to the government-funded Further Mathematics Support Programme [See page 33] which has clearly had a direct influence on this growth. Some stakeholders have suggested that increasing competition for students between HEIs had meant that A level mathematics has become less prevalent as an entry requirement for some STEM degrees.

99 The need to extend the range of specific mathematics options for secondary students has been recognised. The recent introduction of "functional mathematics" has been a major development, widely welcomed by HE and employers. We welcome the current pilot of a linked pair of mathematics GCSEs, building on the Smith Report's conclusions that the workload and difficulty involved in mathematics at GCSE merited a twin award. The two GCSEs are designed to be complementary: one emphasising the use and interpretation of mathematics, mainly, but not exclusively, related to everyday life and problems about the real world; and the other treating the subject in a more formal manner with particular emphasis on reasoning and symbolisation. The pair is intended to provide better learning and appreciation of mathematics and to reduce the conceptual gap between GCSE and embarking on A level. It should also help address the concerns of employers about use and application of mathematical skills.

100 Unlike the core/additional GCSE science specifications, the mathematics pair is not nested to offer a single GCSE option which covers the whole of the national curriculum programme of study accompanied by a second GCSE which goes beyond the minimum curriculum. Rather, the national curriculum mathematics requirements are shared between the two GCSEs, and in order to meet the curriculum requirements students would have to follow both specifications, or follow a separate single mathematics GCSE covering the whole national curriculum requirement as they do now.

Recommendation 10: Strengthening the mathematics content of STEM pathways:

- **the mathematics content should be boosted substantially within 14-19 science education, and particularly for Chemistry and Physics A level, drawing on input from the wider science and mathematics community on the level and types of mathematics needed for progress in STEM beyond school/college.**
- **The developments in content and criteria for the new generations of GCSEs and A levels which have yet to be examined should be evaluated at the earliest opportunity using the mechanisms outlined in Recommendation 9.**
- **if the pilot of the GCSE Mathematics pair is successful it should be available to all students. The mathematics community supports replacing the single GCSE option with the linked pair so that all students follow both specifications at KS4, even if some do not take both examinations. We can see the attraction of this and recommend that this option should be considered in the light of the pilot outcomes.**

Recommendation 11: The style of examinations should be rebalanced towards assessment of students' in-depth problem solving and deeper understanding of subject concepts; and there should be greater emphasis on the accurate use of the English language in answers to examination questions. As a first step, QCDA should evaluate the impact of the new criteria in GCSE and A level science, once the new specifications based on them have been examined for the first time, specifically in relation to the assessment of mathematics, students' in-depth problem-solving, and understanding of subject concepts. This should be undertaken according to the principles set out in Recommendation 9.

Regulation

101 There is a widespread perception from teachers and others that awarding bodies compete not simply on the quality or variety of their offer but to some extent on grading standards, and that pressure on the education system to deliver higher participation and grades is partially responsible for insufficient mathematics content in most science courses and assessment.

Previous reports, such as those from Mike Tomlinson and the Royal Society, have highlighted the need for strong regulation to assure continuity and consistency of standards.[26, 27] We should emphasise that we do not have proof that competition between the awarding bodies has affected grading standards, but the potential incentive for it to do so was acknowledged by at least some of the representatives we met of the awarding bodies, who noted that one of the intentions of qualifications reform has been to improve students' chances of passing and achieving higher grades.

102 In response to these widespread concerns, we considered whether to recommend a reduction in the number of awarding bodies – but recognising that the availability of choice is in principle, important – we decided to recommend instead that the planned stronger regulation by Ofqual, the new regulator, is given a chance. Effective, rigorous regulation is necessary to maintain consistent quality and standards and to build stakeholders' confidence. Division between Ofqual and QCDA of the QCA's previous combined responsibility for specifying qualifications and regulating them is a welcome, necessary first step in establishing a regulatory system with the necessary independence to promote public and professional confidence – but the proof will be 'in the pudding'. We also welcome Ofqual's current consultation on how its regulatory duties should be implemented. If stronger regulation by Ofqual does not work as a means of strengthening the quality of examinations, we would recommend that there is a closer examination of whether it is appropriate to continue with competing awarding bodies.

103 A second problem is that each of the awarding bodies produces textbooks aligned closely to their examination specifications. A number of our consultees indicated that they felt these were directed at helping candidates to pass exams, rather than to understand the subject in depth and felt that the alignment of an examination with a textbook business represented a conflict of interests.

104 Effective implementation of our recommendations to strengthen qualifications and assessment will require more effective governance of the bodies responsible for implementing them. The establishment of separate roles for Ofqual and QCDA could provide the framework to achieve this organisational governance. Our challenge to these newly formed bodies is to prove their effectiveness by implementing our recommendations. There is much to achieve and changed ways of working are needed to make the necessary improvements.

26 Mike Tomlinson, 2002, *Inquiry into A Level Standards: Final Report*, DfES

27 Royal Society, 2008, *State of the Nation – science and mathematics education, 14-19*

Recommendation 12: The regulatory framework currently being developed by Ofqual for awarding bodies should be strengthened as follows:

- **in approving A level and GCSE specifications, Ofqual should ensure that the awarding body has matched the specifications to meet fully the relevant subject criteria, and that sufficient examining expertise and resources are available to the awarding body to deliver their specifications;**
- **the GCSE and A level awarding bodies should be regulated to prevent competition between them resulting in a lowering of examination standards;**
- **ensure that the governance mechanisms of the organisations that set curricula and examination criteria and that provide the examinations provide the necessary executive challenge and public accountability for the quality of their work;**
- **the practice of awarding bodies endorsing textbooks should be stopped; and**
- **awarding bodies should ensure that they recruit and ensure training for a sufficient supply of examiners to improve the quality of examination question-writing across the full range of science and mathematics specifications. This will be particularly important if the call for more mathematical content in questions is to be implemented effectively, and if we are to have better 'How Science Works' questions.**

Science GCSEs

105 The qualifications that have attracted perhaps the most comment and controversy are the science GCSEs introduced in 2006. The previous double award was replaced by core and additional science, triple science (ie separate biology, chemistry and physics), and applied science. The rationale for this change was to provide a greater flexibility and a better balance between theory and application, whilst retaining the breadth and depth of the previous curriculum. A major driver behind this was the demand to make the curriculum more engaging and related to real life contexts, as well as the desire to improve the scientific literacy of all young people.[28] This resulted

28 Scientific literacy is taken to mean an understanding of both concepts of science and of processes and practices of science.

in the development of 'How Science Works', which aims to ensure that all young people understand the methods scientists use to gain new knowledge and understanding, and appreciate the impact of science and technology on everyday life.

106 Whilst these new GCSEs have been criticised, for example in recent reports by Ofqual[29] and SCORE,[30] many of the problems highlighted relate to assessment, and we welcome the steps taken by Ofqual to address the problems and provide a sound basis for 'How Science Works'. The Group supports the idea of teaching 'use of science' providing that content, process and context are properly balanced in the curriculum and specifications; and we equally support the flexibility provided by building up the content of science GCSEs through the nested core, additional and triple sciences.

107 However, our consultation highlighted concerns over the relative lack of effective communication and CPD that accompanied these changes, which meant that the courses are often not being taught as intended. External evaluation of the pilot Twenty First Century Science GCSE showed that teachers needed at least one cycle of teaching the course, with good support for their understanding of the course intentions, in order to engage learners effectively.[31] There remains confusion over the efficacy of teaching core and additional in a linear manner or in parallel, and triple science is currently delivered in a variety of ways, for example as a GCSE option, in the allocated double GCSE time, after-school or beginning in Year 9. The Group would welcome an evaluation of the effectiveness and impact of these different delivery models on pupil engagement and attainment.

108 There was broad consensus that triple science at GCSE provided the best grounding at Key Stage 4 for studying science at a higher level, yet this is still not available in all schools and only 11% of GCSE pupils in maintained schools took the qualifications in 2009, although we recognise that this figure is an improvement on previous years. The Government has set a target of increasing this figure to 17% by 2014, which would mean over 100,000 pupils taking triple science. The Group fully supports this ambitious target and the Triple Science Programme, which helps schools deliver this qualification. Recruiting more specialist teachers and providing high-quality CPD will be vital to achieving this target, as well as better marketing of STEM subjects and careers.

29 Ofqual, March 2009, *The new GCSE science examinations: Findings from the monitoring of the new GCSE science specifications: 2007 to 2008*

30 SCORE (2008) *GCSE Science 2008 Examinations*

31 Ratcliffe, M & Millar, R (2009) *Teaching for understanding of science in context: evidence from the pilot trials of the Twenty First Century Science courses.* Journal of Research in Science Teaching 46, 8, 945-959

Flexibility and in-depth learning

109 Whilst there was often conflicting feedback from stakeholders about the level of content in science and mathematics qualifications, there was widespread support for creating greater flexibility for teachers in delivering GCSE and A level courses. The current assessment framework's focus on comparability and consistency means that there is a drive to cover the breadth of the course, with relatively little choice in terms of topics to teach and exam questions to answer. Consequently, teachers have relatively little time and few incentives to teach individual topics in greater depth, which may help engage students and prepare them for the demands of HE. This is compounded by regular modular assessment, which encourages teachers to focus on preparing their students for the next set of examinations, rather than delving into additional detail for aspects of the subject in which they or the learners are interested.

The burden of assessment

110 The growth in modular examinations also has an impact on flexibility in teaching and learning. There is no doubt that the trend towards modular courses was driven by the popularity of the format with teachers and students. For many, the regular reinforcement of progress that comes with success part way through a course is motivating and confidence-building.

111 At the same time, the growth of modular programmes has been accompanied by persistent concerns about the overall burden of examinations over the 14-19 phase and its impact on students' learning experience[32] – concerns which have also featured strongly in our consultations and discussions, and which have been reflected in the restrictions on the number of units introduced for the new generation of A level specifications. Partly these concerns stem from the volume of public examinations at Key Stage 4, which is unusually high compared to the education systems in other similar countries. It also results from the impact which modular assessment of GCSEs and A levels has on the flexibility of teachers to design and deliver teaching programmes which allow scope for more exploratory, in-depth and discretionary learning. This problem is not one of the total amount of time spent in examinations. This is little different now from the examination time associated with previous generations of non-modular qualifications.

112 Rather, the division of courses into smaller teaching units makes it harder to teach and learn flexibly across the internal boundaries between units; and more numerous and more frequent examinations mean that teachers and students have few periods when they do not feel the close proximity of – and need to focus on – the next set of examinations. In practical terms, more

32 For instance: DfES, 2004, *Final Report of the Working Group on 14-19 Reform*; and Tony Ashmore & Malcolm Trobe, 2010, *Assessing assessment – Politics or progress?*, National Education Trust

time in total is spent revising and less time spent learning for frequent smaller examinations than for fewer large ones, even if the total subject coverage and time in the examination room is the same over the course as a whole. The division and fragmentation of A level courses into modules also reduces the opportunity for synoptic assessment of the whole two years of the A level course.

113 One of the major drivers that has been increasing the pressure on young people to take ever more summative examinations is the need for HEIs to make provisional entrance decisions before a high proportion of students have taken their A level examinations. Whilst schools and colleges have flexibility in shaping the assessment burden on their students (e.g. by limiting the number of GCSEs they take) competition for HE places creates two pressures that operate in the direction of more rather than less assessment.

114 The first of these is the pressure to take more and more GCSE subjects and to increase the number of A and A* grades as a means to help students stand out in subsequent HE applications before full A level results are available. The second pressure is on schools and students to enter AS examinations during the first year of the A level course. Because A level grades are based on a sum of modular examinations, there is tremendous pressure on students to take modules at the earliest opportunity and to repeat these to improve examination grades.

115 These perverse incentives reduce time for education and increase time devoted to preparation and revision for examinations. One solution would be for HEIs to change their policies for admissions. It has been recommended previously that HEIs offer places after A level results have been provided.[33] This recommendation was considered carefully and rejected by both the HEI and school/college communities on practical grounds, specifically that there is insufficient time between completion of A levels and the start of HEI courses to undertake a satisfactory admission process. Furthermore it is impractical to move A levels significantly earlier in the year or to postpone HEI admissions without creating a new set of problems. Indeed HEIs currently operate their admissions processes to deal with both modular and linear assessment systems. The International Baccalaureate, for example, does not have modules and is assessed wholly at the end of the course.

33 For instance, Admissions to HE Steering Group, 2004, *Fair Admissions to Higher education: recommendations for good practice*, DfES

Recommendation 13: There should be a major effort to reduce the modular burden of summative assessment at A level. This should include:

- **restricting modular examination sittings to a single period during the Summer term to avoid disruption to teaching and learning at other times of the year and discourage unnecessary re-sits;**
- **making guidance, exemplar material and support available to any school which wishes to teach some or all of its A levels in linear fashion – i.e. with all the necessary examinations taken at the end of a continuous two year course; and**
- **the examinations at the end of the A level course should include synoptic questions aimed at ensuring that students retain an understanding of subject content and concepts across the breadth of the subject matter covered during the two year course of study.**

Extended Projects

116 One potential way of exploring a subject in significant detail in the current curriculum framework is the Extended Project, a new level 3 qualification equivalent in size to half an A level which forms a compulsory element of Diplomas and can also be taken as a free-standing qualification as part of an A level programme. The Group are particularly excited by the possibility of learners undertaking Extended Projects as an integral part of their STEM education, since this has the potential to provide students with an opportunity to work on substantial scientific projects, which would be highly valued by both HE and employers. These projects could be multi-disciplinary, investigating issues that span the STEM subjects, and can be collaborative – giving learners a taste of structured research and projects in the sector.

117 Undertaking an Extended Project would provide young people with the research and independent study skills needed for a smooth transition into any higher education institution. The Group believes that it could form part of a portfolio, similar in concept to those used to exhibit the work of students applying for art courses, and which could be used as a basis for university applications – preferably through discussion at interview or, less satisfactorily, through description in personal statements.

118 There were 5,947 Extended Project entries in the 2008/09 exam season in England, the first full year of the qualification following a successful pilot. The qualification is still therefore very much in its infancy, and the Group

believes that guidance and support should be developed to encourage schools and learners to undertake Extended Projects in STEM topics. The Group also recognises the risk that this qualification becomes the preserve of independent and high-achieving schools, but strongly believes that steps must be taken to ensure that all schools and colleges are able to offer it. If the Extended Project does prove successful over the next two years, the Government should consider how to make the Extended Project an entitlement for all students studying at level 3.

Recommendation 14: Scope for in-depth and exploratory learning in science and mathematics should be increased through:

- **greater flexibility to explore some elements of the course in greater depth. This will require modification of the examination system to allow a greater degree of choice in answering questions; and**
- **encouragement and guidance to schools and colleges on using the Extended Project to support science education programmes by providing opportunities for exploring the ways of working used by professional scientists, including working collaboratively. Completed projects should be available as a portfolio of work to support HE admissions.**

Coherent STEM Programmes, Pathways and Enrichment

Priority 3.1 – Ensure high quality science, engineering and mathematics pathways to suit all learners

119 Successful progress into STEM at higher levels is not simply a matter of picking the right GCSE and A level subjects. Our remit focuses on GCSEs and A levels, however, we are very conscious that alongside these qualifications there are a wide range of highly successful applied and vocational qualifications and work-based training opportunities in STEM subjects. These lead to an equally wide range of destinations in HE, FE and employment. These options make a vital contribution to the national supply of economically essential professional and technical STEM skills. Qualifications such as the proprietary qualifications offered by the awarding bodies provide long-standing alternatives to GCSEs and A levels, and entry data indicate that they are an increasingly popular option.

120 Whilst our terms of reference did not require us to look at the existing range of applied and vocational qualifications in any detail, it is worth noting that many stakeholders were strongly supportive of the range of options currently available and of the education that they provide. We did not encounter problems or pressure for major reform of the framework for progress in STEM outside the framework of GCSEs, A levels and the new Science and Engineering Diplomas.

121 The whole programme of learning matters. Students need to acquire not just the right science or mathematics qualifications but also the more rounded core of knowledge and experience that enables them to communicate ideas effectively, work collaboratively with their peers and manage their time and their work.

122 The new Advanced Diplomas are designed on this principle to bring together a coherent mixture of specialist and generic learning, including relevant GCSEs and A/AS levels, within a single award, but the GCSE/A level route currently has no similar organising principle to guide students towards greater breadth of learning. Students need to be encouraged not just to pick the right science and mathematics subject at A level but to construct a coherent programme of learning which provides an excellent all-round preparation for STEM HE and careers. For example, J J Thomson, in his previously cited report noted "that all through the science course stress should be laid on the accurate use of the English language."[34] There are strong arguments that

34 Thompson *et al*, *op it*

both English and Mathematics are subjects that all students should pursue throughout their entire school and college education.

123 There is a real issue here about how to encourage students to follow coherent programmes within a system of free-standing qualifications in individual subjects – especially when preferences and signals from HE institutions vary widely about the combinations of courses and subjects they most value.

124 There is no magic bullet to solve this problem, and of course different HEIs will always ask for different levels of achievement and mixtures of subjects. Nevertheless, we think that HEIs and the academic science community must collectively take the lead in communicating earlier and more effectively with schools, colleges and young people about the range of learning and achievement which will provide an excellent basis for progression to STEM in HE, to influence the choices made by STEM specialists before they embark on post-16 learning.

Recommendation 15: The science community and HE institutions should provide clear information and advice to young people about the range of learning and achievement they value beyond specific science and mathematics specialisms as preparation for progress into STEM HE courses.

Diplomas

125 Since last year young people have been able to study for Diplomas, a new qualification that combines theoretical study with practical experience. The Group supports the concept of the Diploma programme, and believes that valuable lessons can be learned from schools working together in consortia and with employers to deliver qualifications. We also recognise that GCSEs and A levels in science and mathematics are not suitable for all young people – especially those whose aptitudes and preferences are more for applied and practical aspects of STEM learning.

126 The Group fully supports the Engineering Diploma, which has filled an important vacant niche in the current qualification framework and has been widely welcomed by HEIs and employers. The Advanced Science Diploma needs to have the same clarity of role so that its purpose and audience can be clearly communicated. We do not believe that a single Advanced Science Diploma can successfully deliver against multiple expectations. It is essential that the current policy debate about the Diploma is resolved quickly to establish the necessary clarity.

127 There is an important potential niche for the Advanced Science Diploma as an educational route for those entering applied science careers, for example providing direct entry to technical jobs directly from school or college, or providing the entry qualification to pursue a degree qualification in an applied science at an HEI. This route should be distinct from that for a young person committed to undertaking further studies in the natural sciences, engineering or medicine. However, it is also important that educational pathways do not have 'fossilised' outcomes – if an Advanced Science Diploma is developed with a clearly differentiated applied science niche, then it should be possible for a student who has done sufficiently well in such a diploma to progress to a STEM degree course in any HEI.

Recommendation 16: The niche for the Advanced Science Diploma needs to be defined clearly as an educational route for those planning to enter applied science careers. The new Advanced Science Diploma should be developed as a differentiated, rigorous and challenging pathway for applied science learning.

Priority 3.2 – Improve the availability and consistency of enhancement and enrichment

128 What young people learn in schools and colleges is not simply defined by programmes of study and subject criteria. The key determinant is *how* teachers and lecturers deliver the curriculum in schools and colleges. Subject coverage is only one aspect of effective learning, how young people are taught is at least as important in determining what they learn.

129 There was a general consensus amongst stakeholders that far more could be done to engage and enthuse young people, both within and outside science lessons – primarily through practical work and extra-curricular enrichment.

Practical work in science

130 Practical work is one of the defining features of scientific observation and enquiry. There is consistent evidence that the extent and quality of practical activity is an important factor affecting students' attitudes to science.[35] Stakeholders universally agreed the value of high-quality practical work, and stressed that it plays a vital role in increasing the engagement and motivation

35 This reinforces the findings of several studies that have suggested that learners would like more discussions, practical work and collaborative group work in their lessons (e.g. Francis *et al.*, 2004 in Lord *et al*, 2006).

of learners. This was strongly reinforced by the young people with whom we spoke, who described how practical work helped to bring science to life. However, practical work is not just about making science fun and enthusing students, it also promotes attainment, by developing learners' scientific skills, knowledge and conceptual understanding, as well as helping to root science in the 'real world' and show how scientific theory might be used in a laboratory or university. This is reinforced by findings from Ofsted, who have concluded that those schools "with the highest or most rapidly improving standards ensured that scientific enquiry was at the core of their work in science. Pupils were given the opportunity to pose questions and design and carry out investigations for themselves."[36]

131 International comparisons indicate that students in the UK spend more time on practical activities than do students in most other countries. However, some stakeholders expressed concerns that the amount of practical work has declined and, perhaps more importantly, that its quality varies significantly. This supports the finding of SCORE's report on practical work in science[37], which highlighted that although there is a wide range of practical work in science taking place across the UK, quality is uneven. This report identifies the following factors as affecting the quality of practical work in science: well-planned and effectively implemented teaching; confidence levels of teachers; shortcomings of equipment; perceptions of restrictions imposed by health and safety; pupils' behaviour; and lack of technical support.

132 Our consultation with stakeholders supports these findings, and suggests that the first two factors have the strongest influence. Indeed both teachers and learners believed that specialist teachers provided the most stimulating, original and developmental practical work, and were more able to link theory and practice effectively. As noted in the previous chapter, as well as the recruitment of specialist teachers, CPD and support from technicians were seen as vital for improving the confidence of teachers and quality of practical work. A range of CPD and resources is currently available, but the Group believes that this could be communicated and delivered in a more joined-up way than at present.

36 Ofsted, June 2008, *Success In Science*

37 SCORE; December 2008, *Practical Work In Science: A Report And Proposal For A Strategic Framework*

Recommendation 17: There should be more support, guidance and CPD for science teachers on delivering effective practical learning to enable students to participate in practical science and to provide practical demonstrations at all levels (see also Recommendation 6). Support from scientifically-qualified and experienced technicians should be available to specialist science teachers. This should be part of the accountability framework as set out in Recommendation 21.

Macclesfield College – Engineering: girls can do it too project

Macclesfield College is leading a national innovation project entitled *Engineering: girls can do it too*. The major aims of the project are to promote science and engineering to girls in primary and secondary schools in East Cheshire as sectors offering exciting, rewarding and appropriate career choices for women and to increase the number of girls/young women undertaking a range of science and engineering courses post-14. The project has gained excellent, active participation from employers including: Airbus, Astra Zeneca, BAE SYSTEMS, Haden Freeman, Siemens and Vauxhall Motors, and developed partnerships with a range of institutions, such as SEMTA, North West Aerospace Alliance, University of Manchester, Women In Science and Engineering, STEMNET and the local Education Business Partnership.

The project participants are 53 girls drawn from Years 2, 5, 8 and 10 in two East Cheshire high schools and a primary school. Parents have also been engaged so that they are fully committed and involved in the project. The project is based upon planned and sustained intervention to promote science and engineering as exciting areas of study and rewarding career choices for women. Project activities have included: building and racing a hovercraft; after school clubs in which the Year 5, 8 and 10 girls built and programmed a robot and took part in the North West regional competition; an after school science experiments club for Year 2; visits to employers; and BAE SYSTEMS organised a week of science and engineering activities for the girls including a theatre production, design, building and programming activities and a visit to see the Typhoon combat aircraft production.

The project is now in its second year and has expanded to include two further schools, bringing the total number of students to over 70.

Enrichment and enhancement

133 There is increasing recognition of the benefits of cross-curricular learning, at both primary and secondary phases. During consultation with stakeholders, the Group learned of innovative examples of off-timetable, cross-curricular projects in science, which had a powerful effect in motivating students and allowing them to link science with other subjects and real-world contexts, and helping overcome traditional weaknesses in engagement with STEM subjects, such as under-representation by girls.

134 Stakeholders identified extra-curricular activities as crucial to the engagement and enthusiasm of young people in science and mathematics and there appears to be a greater emphasis on providing out of school science activities in England than other OECD countries.[38] Similarly to practical work however, the quality and impact of these activities was felt to vary significantly across the country.[39] The Group is keenly aware that whilst there are a multitude of excellent STEM enhancement and enrichment activities taking place across the country, they are less common in challenging schools and areas, where they are needed most. The Group believes that access to these activities should not be limited by socio-economic or geographical determinants, and that all young people should be entitled to benefit from STEM enrichment and enhancement.

38 For example 75% of headteachers in England who responded to the OECD's PISA survey indicated that their school had a science club, compared to the OECD average of 30%. In addition, a third had science fairs, more than two-thirds also had science competitions (67% compared to the OECD average of 53%) and 59% had extracurricular science projects (including research); while the OECD average was 45%.

39 An evaluation of the impact of Science and Engineering Clubs indicates largely positive results on learners' engagement, attainment and progression (Mannion and Coldwell, 2008). The research found that there was a positive impact of attending the club on pupils' skills and attitudes in STEM subjects. For example, the vast majority (over 85%) of club leaders and other staff saw improvements in pupils' practical skills, self confidence and thinking skills. Club members were also more interested in future science and engineering careers compared with reference group pupils. However, there was mixed evidence about whether pupils' understanding of STEM careers has increased as a result of attending the clubs. Whilst most pupils thought that they had developed their understanding of what engineers and scientists do (65% and 75%) the discussions with pupils during the case study visits revealed a lot of ongoing misconceptions.

STEMNET (the Science, Technology, Engineering and Mathematics Network)

STEMNET works with thousands of schools and colleges – primary, secondary and FE – to help teachers and lecturers inspire their students in STEM. It coordinates innovative programmes nationally on behalf of government, including the STEM Clubs Network and the STEM Ambassadors Programme. It also has a role in co-ordinating STEM enhancement & enrichment as part of the Government's STEM Cohesion Programme.

STEMNET and its local partners support teachers in understanding what enhancement & enrichment activities are available in their area, and how participation in these opportunities can benefit them and their students. STEMNET can advise teachers on which enhancement & enrichment activities may best suit their students' needs – be it stretch and challenge for the most able, or engagement through practical involvement for those requiring additional motivation.

The STEM enhancement & enrichment available to schools and colleges includes a wide range of activities, such as those featured in the STEM Directories. Teachers and students work with STEM Ambassadors as part of these activities or within the classroom, including raising awareness of careers using STEM. Alongside these activities, schools and colleges can affiliate free-of-charge to the STEM Clubs Network to access resources and support to establish and develop STEM Club activities.

"The STEM Club has increased students' enjoyment and participation in normal science lessons, and they have a greater scientific knowledge and understanding of subjects outside the National Curriculum." Science Teacher, Larkmead School

For further information, please see: www.stemnet.org.uk

135 The Group supports the work of the STEM Cohesion Programme in attempting to bring together the multitude of enrichment activities available and believes that best practice examples of STEM enrichment should be collated and disseminated to schools, colleges and other institutions in order to improve consistency.

Recommendation 18: All students following science and mathematics subjects in schools and colleges should be entitled to good quality enrichment:

- **responsibility for access to this should be locally devolved and should be an aspect of school and college performance for which school leadership should be held accountable (see Recommendation 21).**
- **the development of consistently high-quality enrichment for all science and mathematics learners should be promoted, especially through the development and dissemination of good practice.**

Market Pull

136 It would be impossible and undesirable simply to "push" students through science and mathematics education if there is no "pull" on young people's motivation and choices from attractive opportunities in HEIs and, most importantly, the workplace. Science, engineering and mathematics are high quality, strategically important subjects but they are not intrinsically 'better' than French, history or any other subject. It is misleading to talk about a 'STEM pipeline', which implies that those young people who do not carry on with science subjects post-16 are simply 'leakage'. This is not the case and those students with the aptitude to study sciences further but who instead choose humanities or arts subjects are not making a bad or illegitimate choice.

137 STEM must thus compete effectively for the attention and choices of young people, particularly through three areas of activity. First is information, advice and guidance (IAG) delivered in secondary schools and FE colleges, second is specialist advisory services such as local Connexions services and third is through interactions between schools, FE colleges, HEIs and the workplace. This section will consider the evidence before making recommendations for how improvements can be made in both these areas

138 Given current projections on the future demand for science, engineering and mathematics graduates in the UK workforce it is clear that it is in the economic interests of the UK that an adequate number of young people leave the education system qualified to work in these areas. Papers published by DIUS in January 2009 (*The Demand for STEM*) and Warwick IER (*The Demand for STEM Graduates*) highlight this need.[40]

139 Even under very conservative estimations it is believed that the demand for STEM graduates will increase and the Warwick study states:

"Growth in employment is expected to be fastest for those qualified at the highest levels, while the number of those in employment with no or few formal qualifications is projected to decline. With the main exception of medicine, the results generally suggest that the "demand" for those qualified in most STEM subjects will grow significantly faster than the average for all subject groups."[41]

140 This demand will be further exacerbated by the aging nature of the current STEM workforce.

141 Clearly, given these projections it is an economic necessity that the UK has access to an adequate supply of STEM graduates both in terms of quality and quantity. With a stretching curriculum that is well taught and rigorously

40 DIUS, 2009, *The Demand for STEM*; Warwick IER/CIHE, 2009, *The Demand for STEM Graduates*
41 ibid.

assessed we expect that enough young people will be able to take science further. In order to ensure that they want to, we must provide sufficient IAG and better experience, through links with universities and the workplace. We must also ensure that this advice is given consistently to all young people. Those who provide it must themselves possess accurate, up to date information about the range of educational and career opportunities in STEM subjects.

142 The onus should not be solely on schools, colleges and the Connexions service. Universities and employers must also do all they can to ensure that young people are enthused and informed about science and the possibilities that it offers post-16 and post-18. We make recommendations around how this interaction can best be achieved.

143 In both of these areas a range of activities already exist at a national and, in many cases, local level. This is to be welcomed but we must also consider how maximum value can be realised from these existing schemes going forward.

Priority 4.1 – Provide all young people with high quality, consistent information, advice and guidance about STEM subjects and careers.

144 Over recent years much work has been undertaken on ensuring that high quality information, advice and guidance is provided to young people at schools and colleges to encourage uptake of science, engineering and mathematics post-16. The June 2009 21st Century Schools White Paper and the IAG strategy published by DCSF in October 2009 sets out an 'IAG Guarantee' to all young people that they will be provided with high quality information, advice and guidance. We would support this general progress but believe that there are issues which are specific to the sciences and which require specific IAG.

145 Our evidence suggests that young people begin thinking about jobs very early in their school careers and young people we spoke to in Years 9 and 10 had clear ideas. Indeed recent research commissioned by DCSF suggests that, as early as Year 7, 85% of young people feel they know the job they want to do in the future and 65% of these pupils have held these views for over 2 years. These jobs are drawn from narrow parts of the occupational structure and over 80% are 'higher status positions'.[42] However, this research also indicates that the majority of these young people do not have a good knowledge of which post-14 choices will enable them to realise their goals. Although we

42 Atherton, Cymbir, Roberts, Page, Remedios, 2009, *How young people formulate their views about the future: Exploratory Research*, Westminster

may question how realistic are career choices at this stage, this is a crucial time for young people as it is now that they are making GCSE choices. However, there is also evidence that it is at this stage or earlier in Key Stage 3 that young people are 'turned off' science subjects and this was cited by around half of the teachers who responded to our written consultation.

146 It was also noted in written responses that making science relevant to jobs and the 'real world' helped to engage pupils at all levels. STEM-specific information, advice and guidance should be integrated into science lessons and enrichment. It is a core activity and not an 'add-on' or a matter that should be devolved to Personal, Social,Health and Economic education lessons. Similar conclusions have emerged from other studies such as those emerging from the STEM Careers Timeline project run by Warwick University Centre for Education and Industry on behalf of the DCSF.[43]

147 A large scale survey of students' choices of their A/AS level subjects conducted in 2006 (Vidal Rodeiro, 2007), found that 80% of young people acknowledged that they received advice, whereas 20% stated that they were solely responsible for their own decisions. Parents were the most common source of advice about subject choice (mentioned by 43% of students), followed by teachers at secondary schools (38%) and other students/friends (21%) and siblings (16%). The study also highlights the impact of parents' background (including ethnicity, class and profession), and the impact of their perceptions of science and mathematics as 'hard' subjects.

IAG Sheffield Hallam Case study

Sheffield Hallam University's Centre for Science Education in association with VT Enterprise (and funded by the Government) are working to deliver a wide range of resources to enable teachers to deliver IAG to students. This involves a series of eight 15 minute programmes for TeachersTV on STEM careers; a programme of CPD modules to support a range of delivery methods; and IAG professional support packs to improve knowledge and understanding of STEM career pathways. A website www.futuremorph.org has also been developed and contains a number of these resources.

It is critical that teachers are provided with this sort of support so that they feel able to provide STEM specific IAG, and that this support is provided through a variety of media to suit all teachers. Increasing teachers' and lecturers' awareness of STEM information sources is a high priority for the government's STEM Cohesion Programme for the next two years.

148 During our consultation a number of young people and teachers expressed concerns about the capacity of subject teachers to offer accurate, up to date

43 STEM Careers Awareness Timeline Pilot, 2009, *Lengthening Ladders, Shortening Snakes: Embedding Stem Careers Awareness in Secondary Schools, Report arising from five stakeholder conferences*

advice on science careers which are constantly evolving and developing and may be quite alien to a teacher's own experience, if any, of industry. STEM degrees and careers are constantly evolving and today's 15 year olds will likely be working in branches of STEM that have not yet been imagined. However, it is also important for more general careers advice on science to be provided; for example one respondent to our written consultation said, "Financial and job security rewards of progression in these subjects could be made more explicit".

149 There is a wealth of information available but it is not widely used by teachers and lecturers. In the evaluation of the STEM Cohesion Programme undertaken by the National Foundation for Educational Research (NFER), 78% of teachers and lecturers surveyed were aware of only five (or fewer) sources of information on STEM careers and 45% used no external sources of information on STEM careers at all. Furthermore, only 10% of teachers surveyed 'often engaged' with STEM careers-related CPD and training.

Recommendation 19: All young people should receive planned systematic information, advice and guidance on STEM careers from KS2. This should be integrated into science lessons and enrichment, rather than being an 'add-on', complementing the support provided by external services and specialist careers teachers:

- **teachers, including subject specialists, and other staff who provide information, advice and guidance on science progression should receive regular, up to date training and resources on how to provide this information and specifically on what jobs and further courses exist in STEM and related subjects; and**
- **regional networks amongst schools and FE colleges should ensure that, within a locality, as many students as possible have access to high quality information, advice and guidance.**

Priority 4.2 – Maximise the contribution which HE and employers can make to science, engineering and mathematics education in schools and colleges

150 There has been increasing recognition that education must become more collaborative and several facets of that collaboration have been explored elsewhere in this report. One important collaboration is between schools and colleges working with higher education and industry in the delivery of STEM

curricula. This is important because the HE sector and employers are well placed to lend physical and intellectual support to schools and colleges in their provision of science learning.

Lewisham A* Academy

Lewisham A* Academy aims to raise aspirations and encourage gifted and talented students at three London schools in challenging circumstances to excel academically in the priority subjects of English, mathematics and science.

The scheme is part of the Government's School Higher Education Links in London (SHELL) project, which seeks to ensure every secondary school in London has a link with a Higher Education Institution with a view to increase the proportion of young Londoners going to university.

Twenty Year 10 students from each of the three schools taking part have been selected by their teachers because they have demonstrated both academic potential and the personal desire to strive for excellence.

Undergraduates from a spectrum of London universities, including Trinity College of Music, Queen Mary's, the School of African and Oriental Studies, King's College, and Goldsmiths will work closely with the young people involved. They will provide guidance on academic matters and snapshots of university culture, designed to enthuse students and galvanize their efforts to succeed educationally – aiming for A*s rather than just crossing the C grade threshold.

151 There are a number of examples of good practice within the HE sector of sharing both physical and intellectual resources with schools and FE colleges and, in terms of HE this has been the subject of a substantial report by Professors Julia Goodfellow and John Coyne and recommendations from the National Council for Educational Excellence (NCEE).[44, 45]

152 High quality secondments in any direction between these sectors may have lasting effects on the participants. A teacher who has had a secondment to an industry in the STEM sector will bring back to his/her teaching a much deeper understanding of the opportunities in the workplace, coupled with the enhanced ability to teach the practical applications and possibilities of STEM. Interchange of teaching and technical staff between school, FE and HE sectors has the opportunity to enhance the mechanisms for progression between these sectors. Work secondments from industry to education will build relationships between employers and the educational communities that serve their needs to mutual benefit.

44 Professors Julia Goodfellow and John Coyne, 2008, *Universities' Links With Schools in STEM Subjects*, DIUS, (web document)

45 National Council for Educational Excellence: Recommendations, October 2008

STEPs at Work

The Royal Academy of Engineering in partnership with the Institute for Education Business Excellence (IEBE) currently run STEPs at Work (Science, Technology and Engineering Placements), a national programme of work placement opportunities for teacher and careers staff. This scheme provides opportunities for over 1100 teachers of STEM subjects from primary, secondary and FE institutions to enter the work place for short periods to improve their knowledge of recent developments in the science world.

Feedback from these events has been positive, with one Leicestershire careers advisor commenting, "This experience will ensure that our students get the best advice on their future career choices".

153 Greater collaboration between schools and colleges, and universities and industry has long been suggested as a means of delivering better enrichment and exposure to science. Most people will find little to disagree with in the report by Professors Goodfellow and Coyne mentioned above, or indeed in preceding paragraphs of this report. The difficulty lies in how schools should best be helped and encouraged to develop these links. As will be discussed in detail in Priority 5 of this report, local leadership, supported and challenged by strong governance, is a key driver of outstanding school performance (Recommendation 21). One area where this could have particular impact is in improving links between local schools, colleges, HEIs and employers.

Simon Langton Star Centre

The Langton Star Centre is based at the Simon Langton Grammar School in Canterbury. Its aim is to develop projects where students can work alongside scientists and engineers, making a real contribution to new physics. For example, the Langton Ultimate Cosmic ray Intensity Detector (LUCID) is a project to put a new style cosmic ray detector into space in 2011. The school is using detector technology from the Large Hadron Collider at CERN, and working with Surrey Satellite Technology Limited on satellite design. Alongside this project they are developing a global school-based project to detect cosmic rays called "CERN@school". The school uses the Faulkes telescopes in Hawaii and Chile to involve students throughout the school in live observing, taking part in the search for Near Earth Objects and observations on exoplanets.

This research based approach has led to enormous uptake in the sciences, for example this year there are 170 students taking A level physics, whilst 30 have applied to physics and engineering degree courses and over 50% have applied to STEM university courses.

The school has developed partnerships with universities in the UK and overseas, and works collaboratively with other schools to share good practice and to enthuse physics teachers and students locally and nationally.

For further information about the Langton Star Centre, please see: www.thelangtonstarcentre.org

The school has a similar approach to bioscience – for details, please see: Myelin Basic Protein Project http://mbp-squared.org/

154 Governing bodies have a significant role to play in facilitating links between schools, colleges and the wider community. It is a theme of this report that governing bodies should be more active in overseeing schools' performance in relation to STEM. A potential obstacle to both of these goals is difficulty in recruiting governors who have experience of STEM in HE or industry to complement the range of other experience represented within the governing body as a whole.

Recommendation 20: Continue to develop HE's links with schools and colleges, through:

- **the follow up to the NCEE recommendations and making progress with, and building on, the Goodfellow/Coyne recommendations;**
- **improving the opportunity for short-term placements and exchanges of skilled personnel in schools, FE, HE and the workplace; and**
- **developing guidance on appointing governors who have specific knowledge and experience of working with or in industry or HE in order to facilitate links between schools and these sectors.**

School and College Ethos

155 So far, we have considered the range of individual factors that can influence and strengthen students' enthusiasm for STEM subjects. The theme that integrates these factors is a strong commitment of schools and colleges to STEM education. Successful schools and colleges devote their energy, expertise and resources to delivering the best possible outcomes in STEM subjects. It is a commitment to excellence in education, bringing together the character, spirit and attitudes of the leadership, staff, pupils and parents that comprises the ethos of successful schools and colleges.

156 Ethos may seem nebulous and difficult to capture; what is it that gives some schools and colleges a better ethos than others? As one respondent to our consultation put it, 'you know it the moment you walk through the door'. Ethos is to a very large extent about leadership. In the case of STEM education it is about leadership at two levels; firstly, strong and inspiring school and college leadership that is sympathetic to STEM subjects, and secondly, strong STEM subject leadership enthusiastically committed to providing the best possible outcomes for students in STEM subjects. Strong leadership infects staff, pupils and parents – and is the key to first class education.

157 Excellent, knowledgeable and dedicated science and mathematics teachers deliver the curriculum in engaging and innovative ways that suit the needs of their pupils. They have the imagination and energy to forge collaborations with other schools and colleges, and with universities and industry.

Priority 5.1 – Ensure that accountability measures and incentives support all schools' and colleges' commitment to participation and achievement in science and mathematics

158 As we have discussed earlier in this report the majority of our recommendations have been made, in different guises, at regular intervals during the last 150 years. But they have not been implemented effectively on a widespread scale. The formula is simple in essence: i) teachers, knowledgeable about their subject and empowered to teach in creative ways; ii) a challenging and interesting curriculum agreed by subject and pedagogic experts; and iii) a balance of formative assessment, to help learner and teacher, and summative assessment, carefully linked to the curriculum, to provide certification. The consistent message that came from our consultation was that a strong framework of accountability is the key to achieving

improved performance. This is the case in any field of human endeavour. Good governance is a key enabler of good performance.

159 There is no shortage of accountability in the education system – schools and colleges are held accountable through their governing bodies; they have financial accountabilities; schools' educational accountabilities are largely measured by and therefore defined by their position in comparative league tables; Ofsted provides an external accountability mechanism; and the School Report Card, currently under development, will be based on a wider basket of measures, and thus has the potential to broaden the base for schools' public accountability. But are these the right accountabilities?

160 We believe that they could be – but that there are ways to make them substantially better. First and foremost is the need to ensure that the governing bodies of schools and colleges are strengthened to ensure that they can provide the non-executive challenge and support that is vital to the effective running of any institution. Three things are needed to achieve this – firstly an appropriate balance of expertise and input amongst the membership of governing bodies, secondly effective chairmanship, and thirdly training for board members and chairs.

161 The second improvement that is needed is a code of practice to drive schools' and colleges' accountability to their governing bodies, and through the governing bodies to the public. Models exist in other sectors such as the City Combined Code for businesses or the Statement of Recommended Practice (SORP) for charities. These codes provide sophisticated baskets of performance measures that, in combination, provide a framework against which a governing body, be it a board of directors, charity trustees, or as we propose here, a school or college governing body, can support and challenge an executive team. A strong code of practice also provides a framework for external accountability through annual reporting mechanisms and a regulator, in this case Ofsted. Good governance is not a replacement for good leadership, which is essential – but effective governance provides the support and challenge to good leaders to enable and reward their best performance.

162 FE colleges recognise the importance of this too and are already considering development of a code of practice for the statutory FE college sector. As exempt charities, they already comply with the charity SORP and will be subject to oversight by a statutory Principal Regulator. It was noticeable that governance and accountability issues arose in our consultations more frequently in relation to schools than to FE colleges.

163 A particular concern is that the accountability measures for secondary education are far too crude. Indeed there was much comment in our consultative work that the majority of efforts are too focused on performance tables, which can potentially lead to a driving down of standards. As one respondent put it, "there is too much emphasis on 'raw' results rather

than quality of courses offered. League tables seriously damage delivery of subjects." As we were told elsewhere, "The emphasis on passing examinations and scoring points for league tables puts pressure on teachers and students to concentrate on those aspects of education which will receive recognition in the performance tables. The things which engage some students are not in the examination and so they can be missed out with a consequent impoverishment of the curriculum that students experience". The key is to ensure that, through a carefully constructed 'basket' of accountability measures, all important aspects of a school or college's performance are accounted for adequately and publicly.

164 Within this report, we have emphasised the importance of career development for teachers, coupled with first class uptake of CPD. We have advocated for collaborative links between schools, FE colleges, HEIs and the workplace. We have emphasised the importance of subject enrichment. We are pragmatic – none of this will happen, particularly in the schools and colleges where it is most needed, unless there are proper accountability mechanisms in place.

165 With this preamble we make what we believe to be one of our most important recommendations.

Recommendation 21: The governance mechanisms for STEM education should be transformed by:

- **strengthening the capacity of school and FE college governing bodies to provide rigorous governance combining support and challenge to the executive team, including rigorous training and wider recruitment of governors with experience of accountability systems in other environments including the commercial sector; and**
- **Ofsted, working with Government and other stakeholders, should develop a Statement of Recommended Practice (SORP) for schools as a robust framework for identifying and measuring progress against key measures of performance that should drive and challenge the executive to provide a first class education. For science specialist schools the new School Improvement Partners should be individuals with matched specialist expertise in STEM, and should work with governing bodies to support their specialist mission. Schools and colleges should produce a public annual report setting out their performance in relation to these measures.**

Priority 5.2 – Develop national and local level subject leadership and expertise in strategic planning and delivery of science and mathematics within and across schools and colleges

166 As we have emphasised throughout this report, there is presently a skills shortage of specialist STEM teachers within the school and FE college system, so sharing of skills is essential. Collaboration is essential to providing the best education, amongst schools and FE colleges and between schools, FE colleges, HEIs, professional bodies and employers.

Local Partnerships

Science Excellence and Innovation Partnerships: an integrated approach

The North East has formally recognised the importance of taking a long-term strategic approach to increase, and sustain, the supply of skilled individuals to support its STEM base. Studies commissioned by the Regional Development Agency (One North East) led to the creation of region-wide STEM integrated education framework, at the heart of which is a commitment to a collaborative approach through the establishment of Science Excellence and Innovation Partnerships (SEIPs).

Each SEIP is organised around a single local authority area, with an identified lead school which acts as a coordination hub working closely with partner, or spoke, schools to address 4 key areas: enquiry based approach to learning (EBL); Continuing Professional Development; careers; and an enrichment entitlement.

For example, the County Durham hubs have worked closely with the local authority advisory service, the Regional Science Learning Centre and university specialists to develop new approaches to enquiry-based, practical and contextualised learning. In addition, the SEIP operating in Newcastle upon Tyne has integrated its planning to take advantage of the Science City Strategy, which has led to particular opportunities and enhanced enrichment programme linked to HE and local employers.

The strength of the SEIP model lies in the establishment, on behalf of the partnership, of clear relationships with FE, HE and industry partners, combined with targeted funding to provide hubs with capacity to take a more strategic approach to STEM, which can then be disseminated to partner schools.

167 The concept of specialist science schools and colleges is not new. As early as 1872 Recommendation XVIII of *The Second Report of the Royal Commission on Scientific Instruction and the Advancement of Science* stated, 'We recommend that whenever the arrangements for scientific teaching in any institution shall have attained a considerable degree of completeness and efficiency, such institution be recognized as a Science School, and be so organized as to become the centre of a group of elementary science classes'. It took 122 years for this recommendation to be implemented starting with Specialist Technology Colleges in 1994!

168 Amongst the 94 per cent of secondary schools that now have specialist status, there are 342 specialist Science Colleges and 59 specialist Engineering Colleges. We believe that the expertise of these Science and Engineering Colleges could be harnessed more effectively to lead and support good practice on a local and regional basis. In theory this already happens and in return for additional funding, specialist schools are expected to spread good practice to others and share one third of their annual grant with other schools and colleges and their local communities. However the impact of that requirement is not always evident in perceptions of how the scheme works in practice. Nor are schools labelled as specialist Science and Engineering Colleges, excellent in education of these subjects by virtue of the title alone. specialist schools need to live up to their specialist status.

Recommendation 22: Strengthen the capacity for well-planned, coherent science and mathematics education within schools and colleges by supporting the development of local clusters for sharing advice and support on curriculum planning and subject leadership. As part of the promotion of local clusters, reinforce the impact of specialist science and engineering colleges and schools to deliver outstanding science and engineering education; to support local curriculum leadership and collaboration; and to share expertise in the planning and delivery of STEM education in schools.

List of Annexes

Science and Learning Expert Group Terms of Reference

In relation to science learning up to the age of 19, the Group should initially consider and make recommendations to Ministers and relevant independent bodies for action on the following:

- How to build on the existing DIUS (now BIS)-DCSF STEM programme and planned developments to enhance the coherence, reach and impact of programmes to:
  - improve quality, take-up and achievement in science learning;
  - further mobilise and engage the scientific community to support and enrich teaching and learning;

  focusing in particular on how to extend availability and take-up of opportunities for stretch and challenge of the most able learners.
- How HE should engage with developments in school science curricula, qualifications and teaching to encourage smoother progression into HE STEM courses.
- How to increase the numbers doing science A levels from the range of existing progression routes, including core and additional as well as triple science at GCSE.
- How far the four qualifications routes for 14-19 (GCSE/A level; Diplomas; Apprenticeships; Foundation Learning Tier) will support appropriate learning and assessment opportunities for all on the knowledge, skills and understanding needed to support appropriate progression from each route into further learning, HE and careers in science-related fields. This work would identify any gaps to inform JACQA's biennial review of 14-19 qualifications in 2011, and be informed by the development of the science Diploma.

In preparing its advice, the Group should:

- Engage widely with key stakeholders, including learners, schools, colleges and the scientific community to establish a wide consensus on the relevance, impact and manageability of its proposals.
- Take account of the full range of existing statutory roles and responsibilities for the delivery of science learning; and work closely with Ofqual, QCA and the Science Diploma Development Partnership to ensure that any proposed content changes to relevant GSCE/AS/A level and Diploma programmes are feasible and consistent with the framework of current and planned qualifications, the competing demands on the available teaching,

learning and assessment time, coverage of the National Curriculum and the overall size of the qualifications.

- Take account of relevant policy and developments in wider teaching and learning, including the forthcoming White Paper on 21st Century Schools.

The Group is asked to provide to Ministers (Lord Drayson and Baroness Delyth Morgan):

- advice during the summer on new GCSE science criteria to feed into QCA's consultation exercise;
- further interim advice in early autumn on other issues within this general remit; and
- further advice and recommendations by the end of the 2009 calendar year.

The need for any further advice will be agreed in due course in the light of the progress and outcomes of the Group's work.

Science And Learning Expert Group Progress Report And Ministers' Reply

Sir Mark Walport
Gibbs Building
215 Euston Road
London NW1 2BE

The Rt. Hon. Lord Drayson
Minister for Science and Innovation
Department for Business, Innovation and Skills

Diana Johnson MP
Parliamentary Under-Secretary of State for Schools
Department for Children, Schools and Families

Dear Ministers,

Following our productive meeting on 1st September, I am writing to advise you of the progress made by the Science and Learning Expert Group to date and outline the five priority areas where we intend to focus our attention as we move forward.

Key challenges and priorities

Science and mathematics are essential components of a broad and balanced education and central to a thriving modern economy. Good education in these subjects provides:

- knowledge and skills essential for everyday life and the ability to make well-informed decisions on a wide range of personal, family and social issues – finance, health, politics etc
- knowledge and skills needed in most jobs
- entry to specialist science, engineering and mathematics higher education and careers

None of these is more important than the others, but we have been asked to focus specifically on the science and mathematics education up to the age of 19 needed to secure the ongoing supply of highly-trained engineers, scientists and mathematicians.

This supply route is often referred to as the "STEM (Science Technology Engineering Mathematics) pipeline", but is actually just one of the many interconnected educational pathways open to young people. Young people make their way guided by their own preferences, abilities, experiences and perceptions, and by the advice, information and judgements provided by parents, peers and professionals. The decisions and choices along the way are not straightforward and obvious. It is not a mistake to follow a pathway other than science – and it is certainly not "leakage" in a pipeline to move from science to other subject areas: these are legitimate choices.

Science and mathematics pathways in school need to become more effective at capturing young people's interest early and translating this into achievement, progression and enthusiasm for STEM, thereby influencing choices about higher education and careers. STEM learning brings access to a wide range of interesting, varied and fulfilling careers, and STEM graduates enjoy higher average earnings than most other graduates.[46] Yet many science and engineering first degree courses under-recruit and a significant number of employers continue to report difficulties in recruiting people with STEM skills.

STEM pathways must compete on their merits to engage and enthuse young people, both providing the motivation to succeed and delivering the learning necessary to do so.

Our approach to the enquiry

We are in the midst of conducting our enquiry. Here we set out our approach to our work. After initial meetings of the Expert Group to frame our areas of enquiry and identify key issues we have conducted an extensive consultation, which we plan to publish as part of our report. We have also undertaken an international comparison and literature review, since much has been published on the subject of science, engineering and mathematics education.

Our online consultation is complete and 129 written responses were received by the deadline of 18th September which we are in the midst of analysing. The extent of the response has been gratifying and reflects the widespread interest and concern to strengthen science, engineering and mathematics education. The demography of our responses is as follows:

Higher Education Sector	**41**
Other*	**26**
School Sector	**21**
Further Education Sector	**9**
Union/Professional Association	**8**
Local Authority	**6**
Science Association/Body	**6**
Employer	**5**
Parent	**4**
Training Provider	**3**

46 A study by PWC for the IoP and RSC placed the earnings premiums for physics, chemistry and engineering degrees behind only those for medicine and law [PriceWaterhouseCoopers, 2005, *The economic benefits of higher education qualifications*]

**Those which fell into the 'other' category included non-departmental public bodies, charities, sector skills councils, funding bodies, individuals and a range of STEM-related organisations.*

In addition to the online consultation we have held over twenty 'one-to-one meetings with key stakeholders and the notes and letters arising from these will form part of the evidence in support of our eventual conclusions.

Finally we are planning a series of workshops between now and publication of our report in which we will test and challenge the direction and nature of our recommendations.

In this way we are planning that our recommendations will be supported by evidence and capable of implementation.

The main areas of our recommendations

Our consultation so far has identified the following key issues and concerns, that, although primarily relevant to potential high achievers in STEM subjects, in most cases are relevant to STEM education for all, and in many cases to education in other subject areas.

Out respondents have all emphasised that teaching, the curriculum and assessment are intimately linked, and that deficiencies in any one of these domains has serious implications for the whole educational process. This is stating the obvious – but it is also clear from our consultation that whilst there are important opportunities in each domain, assessment has been identified as posing particular problems.

It is an inherent danger of any system of testing and assessment that this becomes 'the tail that wags the dog' – *i.e.* that education becomes focused predominantly or even solely on ensuring the best outcomes for participants in the tests. This is a difficult incentive to remove – and it therefore becomes paramount that the nature of the assessment and testing is driven by the primary educational aims. If this can be achieved, then 'teaching to the test' will deliver the education that is required. In this context our evidence shows that the present system of assessment and testing has significant deficiencies. In particular, many of our respondents note that the assessment and testing system has become removed from those who have the greatest interest in its rigour and success. Specifically it has become separated from its key stakeholders, the school, further education, higher education and workplace communities.

Science education is often considered in terms of 'push' – i.e. science and mathematics are 'good things' and a measure of success has to been to measure numbers of students studying these subjects and their levels of attainment. However, 'pull' mechanisms from higher education and the workplace are key to offering children at school the best opportunities to make their choices within the education system based on the best possible evidence.

Teaching success does not occur as a result of the isolated efforts of individual teachers. The environment in which education occurs, school or FE college is crucial. It has been apparent that the ethos of schools and FE colleges that are particularly successful in science and mathematics education is key to their success.

Following our stakeholder engagement and consultation, and based on research evidence and international comparisons, we have identified five priority areas where we intend to focus our attention and around which the final report will be structured:

i. *The STEM school and college workforce:* the supply of science and mathematics teachers, continuing professional development (CPD) for science and mathematics teachers to promote high quality teaching and learning, strong subject leadership within schools and colleges, and mechanisms for collaboration amongst schools, colleges and higher education.

ii. *Curriculum delivery:* the quality of teaching and learning and the classroom delivery of science and mathematics including considering the different pathways through the education system, engagement, motivation and enrichment, and stretch and challenge for the most able students.

iii. *Qualifications and Assessment:* the impact on achievement and motivation of existing and planned science and mathematics qualifications, the extent to which key curriculum objectives are translated via the design of qualifications into outcomes for learners and the way that science and mathematics are assessed within schools and colleges affects students' ability to achieve and progress.

iv. *Market pull:* how effectively the workplace and HEIs interact with schools and FE colleges, for example to communicate the value of STEM careers and to strengthen links between the various sectors. Our recommendations will touch on delivery of information, advice and guidance.

v. *School and college ethos:* enhancing the commitment of all schools and colleges to excellence in science and mathematics, and improving incentives to value and celebrate achievement and to encouraging participation and progression.

Although we are making excellent progress on developing recommendations in each of these areas, we do not wish to present these recommendations in a 'half-baked' form. We will continue to consult and refine our recommendations during the autumn, with the aim of presenting advice that is relevant, practical and achievable. We are aiming to produce a set of recommendations that will have a substantial impact to improve STEM education. We will deliver our report to Ministers during December 2009.

I hope this is helpful and look forward to our next meeting, scheduled for 24th November.

Best wishes,

Sir Mark Walport
Chair of the Science and Learning Expert Group

The Rt. Hon. Lord Drayson
Minister for Science and Innovation
Department for Business, Innovation and Skills

Diana Johnson MP
Parliamentary Under-Secretary of State for Schools
Department for Children, Schools and Families

Sir Mark Walport
Wellcome Trust
Gibbs Building
215 Euston Road
London NW1 2BE

November 2009

Dear Sir Mark,

Thank you for your letter updating us on the progress of the Science and Learning Expert Group. We are pleased to hear that you have been consulting widely and that the science, mathematics and education communities are engaged with this important work.

The five areas that you have identified as priorities are insightful and cover a wide range of complex issues, which take us into some quite challenging terrain. We look forward to discussing this and your emerging recommendations in detail at our meeting on 24 November.

Your letter stresses the importance of assessment as a key driver of what young people are taught and how their learning develops. We agree that any assessment and qualification system should meet the needs of employers and higher education, and that science and mathematics qualifications in particular must provide the underpinning knowledge and skills to support progression to further study in STEM subjects. In your work so far, you will have seen examples of many of the initiatives we have already introduced or which are in train. These include revisions of science and mathematics A levels to include increased stretch and challenge, revisions of science and mathematics GCSEs (in the former case to directly address the concerns identified about the existing qualifications by Ofqual in March), and the development of the new Science Diploma for introduction from 2011. We look forward to hearing your ideas for how we realise maximum value from our efforts to date, and in turn identify how we might make further improvements in science and mathematics education. We remain committed to positioning science as a priority in schools at all levels, to improving the teaching and learning of science in all schools, and to inspiring more young people to study and work in science. It is imperative we develop robust ways for every child to have the opportunity to fulfil their potential. As Government takes this vital work forward, we await your final report with interest.

DIANA JOHNSON **LORD DRAYSON**

Science and Learning Expert Group Membership

Sir Mark Walport (Chair)	Director of the Wellcome Trust
Prof Julia Goodfellow	Vice-Chancellor, University of Kent
Frank McLoughlin	Principal, City and Islington College
Martin Post	Headteacher, Watford Grammar School for Boys
Joan Sjøvoll	Headteacher, Framwellgate School Durham
Sir Martin Taylor	Formerly Vice President, Royal Society
David Waboso	Director of Engineering, London Underground

Secretariat

Matthew White	Department for Children, Schools and Families
Rory Gallagher	Department for Children, Schools and Families
Alex Morris	Department for Business, Innovation and Skills
Heeran Buhecha	Department for Business, Innovation and Skills

Glossary

Accreditation	The process by which the qualifications regulators confirm that a qualification and associated specification conform to the relevant accreditation criteria.
ACME	Advisory Council on Mathematics Education
Advanced Skills Teacher	An AST post enables excellent teachers to concentrate on using and sharing their skills in classroom teaching by supporting the professional development of other teachers and raising standards of teaching and learning. ASTs normally spend 80 per cent of their time working in their own school and teaching their own classes and 20 per cent working with and for teachers from other schools
AS Levels	Advanced Subsidiary Levels. AS levels can currently be taken as free standing qualifications or as the first half of a full A level.
AQA	The Assessment and Qualifications Alliance, one of the three major English awarding bodies.
Awarding bodies	Independent organisations (charitable and/or commercial) that are recognised by the qualifications regulator to develop, offer and award qualifications
BIS	Department for Business, Innovation and Skills
Core and Additional Science	Two GCSEs which the majority of students take at the end of Key Stage 4. Both GCSEs cover Biology, Chemistry and Physics as well as 'how science works'. In 2009 72% of students took Core Science and 51% also took Additional Science.
CPD	Continuous Professional Development – consisting of training, study and/or reflective activity designed to improve a teacher's knowledge, understanding, professional practice and skills through coaching, external courses, in-school sessions or cross-school/college networks for example.
Criteria (for GCSE and A level Subjects)	The rules on the design, subject content and assessment of GCSEs and A level courses in specific subjects. Used by Ofqual and the equivalent regulators for Northern Ireland and Wales as a basis for accrediting the A level

	and GCSE specifications offered by each of the awarding bodies.
DCSF	Department for Children, Schools and Families
DDPs	Diploma Development Partnerships are responsible for developing Diploma line of learning statements, and are partnerships between employers, higher education and other subject experts and education representatives. DDPs are led by the most appropriate Sector Skills Council.
DIUS	Department for Innovation, Universities and Schools. Now the Department for Business, Innovation and Skills.
EBPs	Education Business Partnerships – these partnerships aim to improve the education and training of young people to prepare for them for the world of work, and raise teachers'/lecturers' awareness of the world of work, the work-related curriculum and assist with employer engagement.
Edexcel	One of the three major English awarding bodies
Extended Project	Level 3 qualification introduced in 2008, equivalent in size to half an A level and in standard to a full A level. It is graded from A* to E. Students must produce a single, stand-alone piece of work of their own choosing, showing evidence of planning, preparation, research and autonomous working. It is a compulsory part of the Advanced Diploma and can be taken alongside A Levels, or as a free-standing qualification.
FE	Further Education. The English further education system provides a wide range of education, skills and training opportunities for individuals from age 14 upwards and employers. Learning opportunities are provided at all levels from basic skills to higher education.
Functional Skills	Defined as "those core elements of English, maths and ICT that provide an individual with the essential knowledge, skills and understanding that will enable them to operate confidently, effectively and independently in life and at work". In essence they are being introduced to improve literacy and numeracy skills, and responding to industry's demand for 'work-ready' young people.
HE	Higher Education, that is, university level education.

HEI	Higher Education Institution
How Science Works	An element of GCSE science, based around the processes of scientific investigation
IAG	Information, Advice and Guidance related to careers and progression. Information is the data about how to access learning and work opportunities. Advice is the additional support given to understand the information. Guidance offers even more in-depth help from a trained adviser.
ITT	Initial Teacher Training – the major route into teaching for graduates
Linear assessment	Assessment in which all examination components are taken in one examination series at the end of the course.
National Strategies	A Government initiative with the aim of raising standards of achievement and rates of progression for children and young people.
NCEE	National Council for Educational Excellence
NFER	National Foundation for Educational Research
Ofqual	Office of Qualifications and Examinations Regulation – the new independent regulator of qualifications, exams and tests in England
Ofsted	Office for Standards in Education, Children's Services and Skills
OCR	Oxford, Cambridge and RSA Examinations, one of the three major English awarding bodies
OECD	Organisation for Economic Cooperation and Development
PISA	Programme for International Student Assessment. An evaluation of 15 year olds' academic performance coordinated by OECD and carried out every three years.
QCDA	Qualifications and Curriculum Development Agency. Formerly the Qualifications and Curriculum Agency (QCA) – the body which develops the National Curriculum and criteria for qualifications, and advises awarding bodies in developing their individual specifications.
Rarely cover	An agreement whereby, as of September 2009 teachers should only rarely cover for absent colleagues.
SCORE	Science Community Representing Education

SORP	Statement of Recommended Practice. This document provides accounting recommendations and provides the format and content of charity reports and accounts.
Specialist schools and colleges	Any maintained secondary school that has successfully applied for a curriculum specialism in a specific subject. DCSF's vision for science specialism states that, 'A Science College will provide a centre of excellence in scientific, technological, enterprising and vocational education. They will be an active contributor to local and national developments within science and mathematics. They will encourage post-16 learners to pursue science and mathematics'.
Specification	Developed by awarding bodies to provide a "complete description – including optional and mandatory aspects – of the content, assessment arrangements and performance requirements for a qualification. A subject specification forms the basis of a course leading to an award or certificate. Formerly known as a 'syllabus'." (www.qcda.gov.uk)
STEM	Science, Technology, Engineering and Mathematics
Synoptic assessment	A form of assessment that tests candidates' understanding of the connections between the different elements of a subject.
TDA	Training and Development Agency – the body responsible for the training and development of the school workforce.
TIMSS	Trends in International Mathematics and Science Study. A four-yearly comparative study of standards in mathematics and science at age 10 and 14.
Triple Science	Separate GCSEs in Biology, Chemistry and Physics. Taken together as an alternative to Core and Additional Science, and permitting greater depth of study in each discipline. There is currently a non-statutory requirement that all students who have attained Level 6 or above at Key Stage 3 are entitled to study Triple Science.

Science and Mathematics Secondary Education for the 21st Century

Volume 2: Annexes E to M

Report of the Science and Learning Expert Group

February 2010

Summary of Relevant Recommendations From Previous Reports

Devonshire Commission: Royal Commission on Scientific Instruction and the Advancement of Science (2nd Report) (1874)

1 We recommend, as regards the elder children in the Elementary Schools, that the teaching of such rudiments of Physical Science as we have previously indicated should receive more substantial encouragement than is given in the Regulations of the New Code.

2 We recommend, as regards the younger children, that Her Majesty's Inspectors should be directed to satisfy themselves that such elementary lessons are given as would prepare these children for the more advanced instruction which will follow.

3 We recommend that the mode of instruction of Pupil Teachers; the conditions of admission to Training Colleges; the duration of the course of study in them; and the syllabus of subjects taught, should be so modified as to provide for the instruction of students in the elements of Physical Science.

4 We recommend that the instruction in elementary science classes under the Science and Art Department, be so arranged as to work in complete harmony with the general system of public elementary education, but, at the same time, we consider it important that the Education Department and the Department charged with Instruction in Science shall continue to be co-ordinate.

5 We recommend that a more efficient inspection of Elementary Science Classes be organised, and that the Inspectors should advise the Local Committees and report on :

- The apparatus of instruction.
- The state of the discipline and methods.
- The general efficiency of the arrangements.

6 We recommend that teachers who have already qualified by passing the May examination in either of the advanced classes shall continue to be recognised as qualified to conduct Elementary Science Classes, with the title of Elementary Science-Teacher, and to earn the grants awarded by the Department of Science and Art on the results of the examination of their scholars; but that this qualification and title shall in future only be attainable by passing in the first of the advanced classes.

7 We recommend that should such arrangements as are herein-after set forth for conducting the practical instruction of teachers, and for providing for them

practical examination at several centres, be adopted, all elementary science teachers shall, after such practical instruction, be admissible to a further examination, which, in all suitable subjects, shall be practical. We recommend that success in this examination shall entitle a teacher to a certificate of Second Grade Science Master.

8 We recommend that, as an inducement to teachers to prepare (or and pass this further examination, payment for results in the case of a Second Grade Science Master be made at a somewhat higher rate than in that of the Elementary Science Teacher.

9 We recommend that an examination, both by papers and by practical tests, in any group of allied subjects defined by the Department which the candidate may select, shall be open to all those teachers who have passed in the advanced classes, or who have been otherwise admitted as Science Teachers; and that success in this examination shall entitle the candidate to receive a certificate of First Grade Science Master in that group.

10 We recommend that a greater capitation grant be payable in respect of the scholars of a First Grade Science Master teaching in any group of allied subjects with or without assistance, than in respect of the scholars of a Second Grade Science Master, provided that the Inspector report that the apparatus is sufficient, and that practical instruction has been given in each suitable subject.

11 We recommend that, with a view of maintaining uniformity of standard in these examinations, they shall be conducted at the several local centres by the staff of Examiners acting under the Science and Art Department.

12 We recommend that the more systematic training of the teachers of science referred to, be provided for

- By the adoption of special arrangements for this purpose in the Science School which has been referred to in our First Report; and by the recognition by the Department of similar arrangements for the instruction of this class of students in any University or College, and in Science Schools as herein-after described.
- By giving to the students of Training Colleges the opportunity of remaining a third year, during which scientific instruction may either form a principal part of the curriculum of such Colleges or be accessible in some adjacent College or School of Science approved as efficient for that purpose.

13 We recommend that the Science and Art Department be at liberty to dispense with the preceding examinations and to accord the privilege of First and Second Grade Science Masters in consideration of University Examinations in Science, or of a satisfactory course of study in Colleges in which Science is taught, as well as in other cases of obvious scientific qualification.

14 We recommend that in schools recognised as Science Schools, as hereinafter set forth, facilities for the employment of Assistant Teachers be afforded as an experiment on a limited scale, some addition being made to the emoluments of the teacher in consideration of the instruction afforded; provided the Department be satisfied, on the report of an Inspector, that such assistant teacher has received practical instruction in subjects in which it is prescribed, and that he has been actively engaged in teaching. To encourage the more advanced scholars to become assistant teachers under First Grade Masters in such schools, a small stipend, rising in successive years, might be granted on condition that a like sum was raised locally, subject to such conditions as the Department might deem expedient. The proportion of assistant teachers should not exceed one for every 15 successful scholars in any science school, and no scholar should be recognised as an assistant teacher until he has passed in the first division of the elementary class in the May examination.

15 We recommend that, with a view of training First Grade Science Teachers, exhibitions of sufficient value and in sufficient numbers be offered to elementary science teachers and to assistant teachers who have served three years, and passed in the first division of the advanced class in the May examinations; and that such exhibition should be tenable in any University, College, or Science School recognised in Recommendation XII.

16 We recommend that the grants made by the Science and Art Department for buildings be extended, under sufficient guarantees, so as to embrace institutions for scientific instruction, although they may not be built under the Public Libraries Act, or be in connexion with a School of Art.

17 We recommend that grants similar to those now made for apparatus be given for laboratory and museum fittings under proper guarantees.

18 We recommend that whenever the arrangements for scientific teaching in any institution shall have attained a considerable degree of completeness and efficiency, such institution be recognized as a Science School, and be so organized as to become the centre of a group of elementary science classes; and to provide the assistance of First Grade Science Masters, the loan of apparatus and specimens, and the means of instruction in the laboratories and museums to the more advanced students of the group.

19 We recommend that assistance be given for the formation and maintenance of such Science Schools by special grants, the conditions of which shall be determined by regulations to be framed by the Science and Art Department.

20 We recommend that when laboratories are attached to second grade grammar schools in the schemes issued by the Endowed Schools' Commissioners, the Trustees of such schools be encouraged and enabled to invite the formation of elementary science classes, to be taught therein.

Thompson Report: Report of the Committee appointed by the Prime Minister to Enquire into the Position of Natural Science in the Educational System of Great Britain (1918)

General

1 That Natural Science should be included in the general course of education of all up to the age of about 16.

2 That the tests of such a course, recommended in the Report, should with necessary modifications be accepted as the normal qualification for entrance to the universities and professions.

3 That real progress in education depends on a revolution in the public attitude towards the salaries of teachers and the importance of their training.

4 That a large increase in the number of scholarships at all stages of education is necessary.

5 That periodical inspection should be compulsory on all schools and that this inspection should be under the direction of the State.

Secondary Schools

7 That Science should be included in the general course of education for all pupils in Public and other Secondary Schools up to the age of about 16, and that this general course should be followed by more specialised study whether in Science or in other subjects

11 That a larger number of state-aided schools should be encouraged to provide advanced instruction in Science-and that those which undertake advanced work should be staffed on a more generous scale.

Science Course 12 to 16

17 That the science work for pupils under 16 should be planned as a self-contained course, and should include, besides Physics and Chemistry, some study of plant and animal life.

18 That more attention should be directed to those aspects of the sciences which bear directly on the objects and experience of every-day life.

19 That there should be as close correlation as possible between the teaching of Mathematics and Science at all stages in school work.

21 That all through the science course stress should be laid on the accurate use of the English language.

Science Course 16 to 18

22 That the amount of time devoted from 16 to 18 to the subject or subjects in which a pupil is specialising should be not less than one-half or more than two-thirds of the school week.

23 That those specialising in Science should continue some literary study, and those specialising in literary subjects should give some time to science work of an appropriate kind.

25 That pupils who do advanced work in Science should be enabled to acquire a reading knowledge of French and German.

Examinations

27 That in the First School Examination all candidates should be required to satisfy the examiners both in Mathematics and in Natural Science.

28 That in this examination there should be co-operation between the teachers and examiners, and weight should be attached to the pupil's school record.

29 That the examinations in Science for the Leaving Certificate of the Scottish Education Department should include a written test.

Teachers in Secondary Schools

30 That it is essential that salaries and prospects of teachers in Secondary Schools should be substantially improved and a national pension scheme provided.

31 That a full year's training shared between school and university is necessary for all teachers in Secondary Schools.

32 That grants for teachers in training should be available for all suitable inspected Secondary Schools.

33 That short courses of training of various types should be provided for teachers.

Engineering

46 That a thorough and practical training in Mathematics and Science is essential to the school education of engineers: it cannot be replaced and need not be supplemented at school by practice in an engineering workshop.

Supply of trained scientific workers

83 That concerted efforts should be made by employers, teachers, local education authorities and the State to increase the flow of capable students to the universities and higher technical institutions with a view to securing the larger supply of trained scientific workers required for industrial and other purposes.

Spens Report: Secondary education with special reference to grammar schools and technical high schools (1938)

Conclusions and recommendations regarding the curriculum for the secondary stage in education

58 The prime duty of a school providing secondary education is to cater for the needs of children who are entering and passing through the stage of adolescence, giving the pre-adolescent and adolescent years a life which answers to their special needs and brings out their special values.

59 The curriculum should be thought of in terms of activity and experience rather than of knowledge to be acquired and facts to be stored.

60 Both the conservative and creative elements in the activities of the community must be represented in the curriculum and a larger share must be found for those activities which are creative.

61 The studies of schools providing secondary education should be brought into closer contact than at present with the practical affairs of life.

62 While studies should not be introduced which are beyond the present comprehension and unrelated to the present experience of pupils, yet, especially towards the end of the course, studies may well be introduced to a limited extent which have a definite bearing on the next stage of their life.

64 We recommend the growing practice in large schools of including on the staff a 'Careers Master'.

78 School mathematics should be taught as one of the main lines which the creative spirit of man has followed in its development. If it be taught with this purpose it will be no longer necessary to devote the number of hours to the subject that are now generally assumed to be necessary.

79 The common practice of concentrating from the beginning on a systematic study of particular sciences lays too early a stress on abstract theory and too little on the earlier phases of 'romance' and 'utility', and is not the best approach to science for adolescent pupils.

Norwood Report: Curriculum and examinations in secondary schools (1943)

The School Certificate Examination

9 In the interest of the individual child and of the increased freedom and responsibility of the teaching profession change in the School Certificate Examination should be in the direction of making the examination entirely

internal, that is to say, conducted by the teachers at the school on syllabuses and papers framed by themselves.

10 For a transitional period of seven years the examination should (a) continue to be carried out by existing University Examining Bodies, but should be conducted in each case by a Sub-Committee containing strong representation of teachers; (b) become a 'subject' examination, pupils taking whatever subjects they wish to take. A certificate stating the performance of the pupil should be given to each candidate; to this statement should be added by the school authorities an account of the pupil's school record.

11 At the end of the transitional period the decision should be made whether conditions make possible a change to a wholly internal examination, or whether there should be a further transitional period in which teachers would take still greater control of the examination, and the Universities still less.

James Report: Teacher Education and Training (1972)

1 The education and training of teachers should be seen as falling into three consecutive stages or 'cycles': the first, personal education, the second pre-service. training and induction, the third, in-service education and training.

2 The highest priority should be given to the expansion of the third cycle, i.e. of opportunities for the continued education and training of teachers.

6 Serving teachers in the schools and FE colleges should be directly involved in professional training and a high priority should be given to the improvement in staffing ratios which such an involvement, together with the substantial release of teachers for third cycle work, would inevitably require.

9 There should be a National Council for Teacher Education and Training (NCTET), linked with the RCCDEs and strongly representative of all branches of the teaching profession.

The third cycle

Entitlement to in-service education and training

10 All teachers in schools and full-time staff in FE colleges should be entitled to release with pay for in-service education and training on a scale equivalent to not less than one school term (say, 12 weeks) in every seven years of service and, as soon as possible, the entitlement should be increased to one term in five years, and the entitlement should be written into teachers' contracts of service.

11 The entitlement should be satisfied only by release for substantial courses lasting at least 4 weeks full-time (or their approved part-time equivalents) and such courses should be those designated. for the purpose by the RCCDEs.

12 The entitlement should be in addition to shorter-term third cycle activities, whether or not involving release from teaching, and these short-term opportunities should themselves be substantially expanded.

Professional tutors

13 A member of staff of every maintained school and FE college should be designated a 'professional tutor' to coordinate second and third cycle work affecting the institution and to be the link with the other agencies concerned.

14 Teachers designated as professional tutors should be among the first to be released for third cycle courses, so that they could be trained for their new responsibilities.

Professional centres

15 To accommodate third cycle work, there should be a national network of 'professional centres' which would include not only the colleges and departments of education but also a number of other centres, based on existing facilities and in some cases developed from teachers' centres.

16 Professional centres should be so located as to ensure that schools and FE colleges normally had easy access to at least one of them.

17 All professional centres should require designation by the RCCDEs and approval for specific purposes, and some might be designated as regional, multi-regional or national centres for particular needs.

Special needs in the third cycle

23 Suitably placed professional institutions and centres should give a high priority to courses of training for teaching in multiracial schools.

24 There should be opportunities in the third cycle for immigrant teachers to equip themselves to teach in British schools.

25 The third cycle should not only provide courses leading to the special qualifications required of teachers of some kinds of handicapped children, but should also cover the needs of teachers who wish to turn to those kinds of such teaching for which formal qualifications are not required.

Research and development

26 Teachers in schools and colleges should have full opportunities to take part in curriculum development projects and other projects and investigations.

27 Teaching staff in colleges and departments of education should be enabled to undertake suitable projects of fundamental research.

28 Research workers coming into the schools to pursue their studies should cooperate fully with the teachers.

29 Teachers wishing to take part in this kind of activity should have in-service opportunities to familiarise themselves with research techniques.

Beyond 2000: Science Education for the Future (1998)

1 The science curriculum from 5 to 16 should be seen primarily as a course to enhance general 'scientific literacy'.

2 At Key Stage 4, the structure of the science curriculum needs to differentiate more explicitly between those elements designed to enhance 'scientific literacy' and those designed as the early stages of a specialist training in science, so that the requirement for the latter does not come to distort the former.

3 The science curriculum needs to contain a clear statement of its *aims* – making clear *why* we consider it valuable for all our young people to study science and *what* we would wish them to gain from the experience. These aims need to be clear and easily understood by teachers, pupils and parents. They also need to be realistic and achievable.

4 The curriculum needs to be presented clearly and simply, and its content needs to be seen to follow from the statement of aims (above). Scientific knowledge can best be presented in the curriculum as a number of key 'explanatory stories'. In addition, the curriculum should introduce young people to a number of important ideas-about-science.

5 Work should be undertaken to explore how aspects of technology and the applications of science currently omitted could be incorporated designed to enhance 'scientific literacy'.

6 The science curriculum should provide young people with an understanding of some key ideas-about – science, that is, ideas about the ways in which reliable knowledge of the natural world has been, and is being, obtained.

7 The science curriculum should encourage the use of a wide variety of teaching method and approaches. There should be variation in the pace at which new ideas are introduced. In particular, case-studies of historical and current issues should be used to consolidate understanding of the 'explanatory stories', and of key ideas-about-science, and to make it easier for teachers to match work to the needs and interests of learners.

8 The assessment approaches used to report on pupils' performance should encourage teachers to focus on pupils' ability to understand and interpret scientific information, and to discuss controversial issues, as well as on their knowledge and understanding of scientific issues.

9 *In the short term:* The aims of the existing science National Curriculum should be clearly stated with an indication how the proposed content is

seen as appropriate for achieving those aims. Those aspects of the general requirements which deal with the nature of science and with systematic inquiry in science should be incorporated into the first Attainment Target 'Experimental and Investigative Science' to give more stress to the teaching of ideas-about-science; and new forms of assessment need to be developed to reflect such an emphasis.

10 *In the medium to long term:* A formal procedure should be established whereby innovative approaches in science education are trialled on a restricted scale in a representative range of schools for a fixed period. Such innovations are then evaluated and the outcomes used to inform subsequent changes at national level. No significant changes should be made to the National Curriculum or its assessment unless they have been previously piloted in this way.

Tomlinson Report: 14-19 Curriculum and Qualifications Reform (2004)

Recommendation 1: balanced programmes

To provide all young people with a balance of generic and specialised learning, all 14-19 programmes should comprise:

- Core learning, designed to ensure that all young people develop a range of generic knowledge, skills and attributes necessary to progress and succeed, including progression over time to at least level 2 in functional mathematics, functional literacy and communication, and ICT; and
- Main learning designed to ensure achievement and progression within recognised academic and vocational disciplines which provide a basis for progression within the diploma framework and access to employment, work-based training and HE. Main learning defines the type of programme and may be chosen to reflect learners' strengths, interests and aspirations.

Recommendation 2: programmes and diplomas

The existing system of qualifications taken by 14-19 year-olds should be replaced by a system of diplomas, available at entry, foundation, intermediate and advanced levels.

Each diploma should be sub-divided into separately assessed components.

A diploma should be awarded for successful completion of a coherent programme meeting threshold requirements at a particular level. Achievements in the programme beyond the threshold should be recorded on a transcript of achievement.

Young people should be able to enter the framework at age 14 at the level that best meets their capabilities and complete more than one diploma as they progress through the 14-19 phase.

Existing qualifications such as GCSEs, A levels, GNVQs should cease to be free-standing qualifications in their own right but should evolve to become components of the new diplomas.

Recommendation 6: the core

We propose that the core, common to all programmes and diplomas, should comprise:

- functional mathematics;
- functional literacy and communication;
- functional ICT;
- an extended project;
- common knowledge, skills and attributes (CKSA);
- personal review, planning and guidance; and
- an entitlement to wider activities.

Recommendation 22: assessment of the extended project

Assessment of the extended project should be in-course, carried out by teaching staff or suitably qualified people in other organisations, and should assess the quality of the processes as well as the final piece of work; and

Assessment should take place in stages throughout the project, including an oral presentation or *viva* by the learner, and against level descriptions and nationally agreed guidance and criteria.

The UK Science and Mathematics Teaching Workforce, A State of the Nation Report (2007)

2.1 Define what is meant by the term 'specialist' science/mathematics teacher The Government, Devolved Administrations and the wider community should agree on definitions for specialist science and mathematics teachers. These definitions must be unambiguous so as to ensure their application accurately informs future surveys and studies.

2.2 Better assess supply of, and demand for, science and mathematics teachers. The Government and the Devolved Administrations should employ a much more rigorous and systematic approach to tracking the demand for science and mathematics teachers across the UK. The Department for Children, Schools and Families should, as a matter of urgency, update its Teacher Supply

Model, consult with the science and mathematics education communities over the setting of recruitment targets into initial teacher training, and explain publicly the basis of its target-setting.

2.3 Improve access to science and mathematics initial teacher training courses and support for qualified teachers throughout their teaching careers. Higher education institutions that offer secondary PGCE courses and which have strong reputations in science should be encouraged to offer PGCE courses in the separate sciences or in other ways support the training and development of teachers in these subjects. Creative strategies aimed at retaining science and mathematics teachers, and at supporting their return to the profession, need to be devised alongside a greater understanding of the reasons why teachers leave the profession. The Department for Children, Schools and Families should redouble its efforts to increase progression in science beyond GCSE and, in particular, uptake of the physical sciences and mathematics at university in order to help ensure that there are adequate numbers of teachers available to provide specialist teaching in these subjects in all schools.

2.4 Improve quality-control procedures and record-keeping of science and mathematics teachers' careers. The Government, the Devolved Administrations of the UK and their agencies (particularly the General Teaching Councils and Lifelong Learning UK) should agree shared guidelines and protocols for regular collection of data on the science and mathematics teaching workforce throughout the maintained school, independent and learning and skills sectors. The Government, the Devolved Administrations of the UK and their agencies should maintain much more detailed and comparable records on the retention of trainee, newly qualified and more experienced science and mathematics teachers and the factors affecting their retention.

Research needs

Research is needed into:

i. the impact of subject specialism/subject knowledge in relation to teacher confidence and competence and the engagement and subsequent achievement of young people.

ii. the number, deployment and qualifications of science and mathematics coordinators in primary (including preparatory) schools, and their impact on learning and attainment.

iii. the number, deployment and contribution of overseas teachers to UK science and mathematics education.

iv. the provision and popularity of combined science PGCE courses in England and Wales, including the reasons why providers offer this PGCE, the qualifications of those taking this PGCE and the reasons why trainees opt to take a PGCE in combined science in preference to a specialist science PGCE course.

v. assessing differences in the quality of newly qualified science and mathematics teachers from different initial teacher training providers.

vi. the movement of science and mathematics teachers between educational levels and sectors, regionally and across the UK nations, and particularly into how variations in teacher supply affect individual schools, especially those in challenging circumstances.

Science and Mathematics Education 14-19, A State of the Nation Report (2008)

Strengthening and using the evidence base

1 There should be greater collaboration between the education authorities in England, Northern Ireland and Wales to ensure that comparative data are collected and presented more consistently and coherently, in order to facilitate evaluation of participation and performance in public examinations.

2 Across the UK, published annual education statistics should include much greater detail about patterns of socioeconomic and ethnic participation and attainment in science and mathematics.

3 All commercial organizations with responsibility for administering 14–19 examinations should be obliged to make available specific subject-based data on examination participation and performance, which need not compromise their commercial viability.

4 The provision of alternative 14–19 qualifications (eg the International Baccalaureate), beyond those that are most widely available, should be closely monitored so that the true choice available to young people in different localities, and the value of the extent of this choice, may be assessed and evaluated.

5 The UK Government should routinely draw on the evidence base it oversees, in consultation with its STEM partners, before committing to educational reform that could have unintentional effects on science and mathematics uptake and progression.

Overseeing and monitoring the education system

1 There should be a fully independent body responsible for curriculum reform in each of the UK nations.

2 Each of the relevant agencies across the UK should have robust systems in place to monitor standards over time at key levels in its qualifications framework.

3 The mapping of individual nations' qualifications frameworks should continue to be updated and maintained, identifying comparable levels and the standards of attainment that are associated with those levels.

4 The impact, in England, on progression to science post-16 of the 'entitlement' for certain students to study separate science GCSEs from 2008 should be monitored.

5 The impact, in England, of the move to two mathematics GCSEs on progression to mathematics qualifications post-16 should be monitored once these are introduced.

Research needs

Research is needed into:

i. the drop in science and mathematics participation post-16, with a particular focus on students' decision-making and actions, and this should be conducted in a coordinated way across the UK.

ii. patterns of socioeconomic and ethnic participation and attainment, making use of large-scale national datasets.

iii. the comparatively higher rates of attainment in science and mathematics by GCSE students in Northern Ireland, in order to explore potential lessons that may be learned by other UK nations.

iv. the greater participation in the separate sciences in Scotland, in order to explore potential lessons that may be learned by other UK nations

v. the differences between UK nations revealed in PISA 2006, in order to explore whether differences may be accounted for by socioeconomic status or whether other factors are involved.

vi. the lower proportion of 15-year-old UK students attaining at the upper levels of difficulty in mathematics, as identified in PISA 2006 and TIMSS 2003, and what might be done to achieve a level comparable to other industrialized countries.

vii. schools with relatively high take-up of mathematics and science subjects post-16, using a sufficient number to take account of variation in the student population, particularly in prior attainment, and the variation in school circumstances.

viii. variation in schools' policies concerning entry requirements to A-level sciences and mathematics and their equivalents

ix. in Scotland, and in particular the options that are made available to pupils awarded B and C grades in their GCSEs who wish to continue studies in these subjects post-16.

List of Meetings With Senior Stakeholders

Marianne Cutler and Annette Smith, ASE – 20 July 2009

Julia Higgins and Nick Bowes, ACME – 22 July 2009

Jonathan Bach, SNS – 27 July 2009

Sir Roland Jackson and Diana Garnham, Science for All and Science for Careers Expert Group Chairs – 30 July 2009

Hugh Lawlor, Science DDP Chair – 27 August 2009

Richard Lambert, CBI – 1 September 2009

Anthony Tomei, Nuffield Foundation – 14 September 2009

Alan Wilson, Chair SCORE – 15 September 2009

Martin Rees, Royal Society – 16 September 2009

Peter Main and Charles Tracy, IoP – 18 September 2009

Richard Pike, RSC – 24 September 2009

Michael Reiss, IoE – 6 October 2009

Andrew Hall, QCDA – 8 October 2009

Janet Holloway, Anne Trant and Geoff Hurst, AQA – 9 October 2009

Clara Kenyon and John Noel, OCR – 13 October 2009

Lynn Tomkins, SEMTA – 15 October 2009

Kathleen Tattersall, Ofqual – 21 October 2009

John Beddington, GCSA – 23 October 2009

Nicola Dandridge, UUK – 23 October 2009

Nick Chambers, Employer Education Taskforce – 27 October 2009

Diana Garnham and Kate Bellingham, Science for Careers Expert Group – 2 November 2009

Jerry Jarvis, Jim Dobson, Peter Canning, Edexcel – 9 November 2009

Philip Greenish and Matthew Harrison, RAEng – 11 November 2009

Richard Sykes, NHS – 11 November 2009

Graham Holley, TDA – 17 November 2009

Mike Tomlinson – 17 November 2009

Sir Alan Langlands, HEFCE – 25 November 2009

Mick Brookes, NAHT – 19 January 2010

Darren Northcott, NASUWT -29 January 2010

John Dunford, ASCL – 29 January 2010

Summary Report of Individual Stakeholder Meetings

Priority 1: STEM workforce

Improving recruitment and retention

There was universal support amongst stakeholders for improving the recruitment and retention of specialist physics, chemistry and mathematics teachers. There was acknowledgement of the success of schemes such as Teach First, Graduate Teaching Programme and Transition to Teaching, which it was felt were helping to bring wider experience to the profession. It was widely recognised that the current economic situation has had a positive impact on recruitment and it is hoped that this can be built upon.

Stakeholders acknowledged the positive role that technicians played in supporting science teachers, and particularly in the delivery of engaging practical work. Whilst a number of stakeholders highlighted that teaching assistants played a similarly positive supportive role, a key stakeholder from the education community expressed concerns that this had the unfortunate impact of reducing the time that teachers spend with some pupils.

A number of stakeholders underlined that providers of Initial Teacher Training differ in how they run PGCE courses (e.g. with some running science PGCEs whilst others run them in individual science subjects), and suggested that there is scope for a rebalancing of the general pedagogical and subject-specific elements of PGCEs. Stakeholders from the science and mathematics communities were particularly focused on improving subject-based knowledge, whereas others argued that whilst this is helpful, the most fundamental factor in encouraging progression in science was felt to be good teaching and learning skills. They argued that subject knowledge could be gained through sharing expertise within schools and through effective CPD.

CPD

All stakeholders acknowledged that effective CPD is essential for improving outcomes in science and mathematics education. Several stakeholders argued that there needs to be a cultural shift in schools' and colleges' attitude to CPD, to ensure that it becomes embedded. It was argued that CPD needs both 'carrots' and 'sticks', and that neither currently exist to the necessary degree. A number of stakeholders argued incentivising CPD through accreditation would be the most effective mechanism, which could be linked to professional recognition from the learned societies or career progression.

The proportion of CPD delivered in-school was felt likely to increase, given the introduction of the 'rarely cover' agenda. In-school CPD was felt to be especially important in weaker schools and colleges, since it is often these institutions where senior leadership are most reluctant to release staff. Several stakeholders underlined that the most effective CPD is often not comprised of external courses, but teachers working together in collaborative communities.

Incentivising collaboration

Collaboration between schools/colleges was also felt to be vital for sharing specialist expertise and teachers, and should be incentivised to become more widespread. The Further Mathematics Networks were felt to have worked well and are relatively inexpensive to run. Whilst it was suggested that it may be possible to build on this model and bring children together to centres of excellence to study Physics A Level, some stakeholders argued that there was a risk that schools that used these networks may not then be able to attract specialist physics teachers (who invariably want to teach A level) and so the children lower down the school will suffer.

Priority 2: Delivering the curriculum

Developing the curriculum

There was a feeling amongst several stakeholders from the science and maths communities that there has not been a joined-up view of the curriculum and it has been changed piecemeal over recent years so that topics are repeated at all Key Stages, which disengages brighter students in particular. There was acknowledgement of a potential tension between the 'stretch and challenge' and 'widening participation' agendas, as well as between competing opinions within the science and mathematics communities.

GCSE Science

The criticism of 'How Science Works' at GCSE was felt by many to have been unhelpful, with several stakeholders arguing that this has been an important and valuable addition to the KS4 science curriculum, which has helped increase post-16 take-up. Several stakeholders also argued that it is unproductive to get into a debate around theoretical versus applied science. Moreover, key stakeholders from the mathematics community suggested that they supported the concept of a shift to a more contextualised teaching and learning in mathematics, to create a similar type of '21st century mathematics'. Nevertheless, whilst it was agreed to be a sound concept, several stakeholders acknowledged that there is evidence that it is not being delivered as intended (especially in regard to a lack of stretch and challenge), partly due to the rather narrow and limited assessment framework.

There was broad support for increasing access to and take-up of Triple Science, which was almost universally agreed to provide greater stretch and challenge and encourage progression. However, some concerns were expressed about the emphasis placed on Triple Science as potentially the only route into A level. They argued that we should be wary of confusing correlation with cause here (i.e. the brightest students do Triple Science and then do well at A level – because they are the brightest not necessarily because they did Triple Science). They were also concerned about creating a situation where progression to study science at HE depends on choices made by young people when they were 14, particularly when they may already be doing two English and, in the future, two maths GCSEs, which when on top of three sciences may only leave them with two other subject options.

There was also recognition of the difficulties of teaching classes with mixed intake of core/additional and triple science. It was suggested that summer schools to help progression from KS4 to A level may be helpful (particularly for those who have studied core/additional science, or who need extra support in maths). It was felt that if this could be provided at HEIs, this would also help to further links between the school and HE sectors.

Applied pathways

Some stakeholders argued that applied pathways play a vital role in science education, in terms of both Applied Science GCSEs and Diplomas. The Engineering Diploma was widely felt to have been successful and was welcomed by school/colleges, industry and HE, providing sufficiently rigorous maths content for entry to a Russell Group university. It was also agreed to have filled a valuable ecological niche in STEM qualification pathways. However, there were significant concerns expressed by many in the science community over the Advanced Science Diploma, which it is feared is being pulled in a variety of directions. It was widely believed that the Advanced Science Diploma is unlikely to be the qualification of choice for the majority of the highest-achieving students who wish to study a pure natural science degree at a top university and who are likely to take A-levels in natural sciences and mathematics. Consequently, clearer messages on the purpose and target audience of the Science Diploma were felt to be vital. In addition, good IAG was felt to be key to enable students to choose the right qualifications; those that prefer traditional, academic ways of learning may be better suited to A-levels, whilst those who prefer more applied, 'hands-on' learning may benefit from Diplomas. Some industry representatives are concerned about Diplomas being seen as second class qualifications and argued that it is important that they are seen as different, but not inferior.

Several stakeholders underlined that Diplomas provide many best practice examples of engaging practical work, including through the extended project. There was significant support for the extended project, due to the stretch and challenge provided by long-term research and practical projects. However, there were fears that it would only be 'good' schools/colleges who take up this opportunity, and therefore some stakeholders argued that such projects should be incorporated into science A levels.

Practical work and curriculum enrichment

Practical work was agreed to be the ingredient that makes science unique and different from other school subjects, but it was recognised that it is not always as effective as it could be. Practical work was acknowledged to be crucial to engaging students with science, especially if it can be shown that it involves modern science and 'real world' examples'. However, there were concerns raised that modern technology is too complex to be explained at school level – whereas in the past school students could make radios and engines, current students cannot make (or even study) the workings of an iPod for example.

To ensure more effective practical work, it was felt that CPD, technician support and facilities were all key, as well as planning and timetabling (e.g. some practical experiments take the whole morning, rather than a 50 minute lesson, but this is not factored in at an early enough stage). It was felt that many teachers do not bring knowledge and process together in relation to practical work.

Finally, it was agreed that the focus for engagement and enrichment interventions should occur well before the end of KS4, preferably at both primary and KS3. There was also recognition of the need to rationalise STEM schemes, since many lack scaleability and the outcomes of projects are often not measured.

Priority 3: Assessment

It was widely argued that even with inspirational teaching and engaging curriculum, problems with assessment can turn pupils off science and maths.

There was also recognition that the assessment and examination structures 'become' the curriculum and that since school performance is based on GCSE results there is a tendency to 'teach to test'. It was felt that there has been a cultural shift, so that teachers now feel that they must teach to specifications and for exams. Moreover, several stakeholders argued that given the increasing volume of tests due to modularisation, more time is devoted to revising for exams. In this context, getting the assessment right is crucial.

The assessment framework

The assessment framework was felt to have a number of different groups of stakeholders: young people (and their parents); HEIs; employers; schools/teachers; learned societies/subject bodies; and government regulators. Assessment is used by each of these groups for different purposes: for young people/parents assessment constitutes a guide to what they should or could do next; many school leaders and teachers see it primarily as a school accountability measure; employers as providing transferable skills; HEIs to provide an indication of aptitude for further study; learned societies as a reflection of their subject; and Ofqual for maintaining standards. These competing pressures can cause significant tensions.

Most stakeholders agree that the assessment framework requires separate bodies to design the curriculum, deliver exams, and a regulator that is able to say when it is working well and step in when it is not. There is a sense that the governance model is set up along the right lines, but is not working optimally at present. This is largely because employers, HE and the science and maths communities feel removed from the process of assessment, and several stakeholders feel the system lacks transparency and scrutiny. There was a perception amongst some stakeholders that there is currently a lack of subject leadership and knowledge at QCDA, Ofqual and the exam boards.

There was also some criticism of the five year cycle for developing new specifications on the basis that it was felt to constrain innovation, since changes can only be made sporadically. These stakeholders argued that this creates years of fossilisation with no evolution and then rapid revolution. Often new specifications are developed and implemented relatively quickly, and the tight timeframes involved constrain the level of stakeholder engagement that is possible. On the other hand, other stakeholders argued that specifications were changed too frequently, and that they should only be reviewed at certain intervals.

Those stakeholders involved in designing and delivering assessment noted that they had difficulties in engaging teachers and HE representatives in the assessment process, since there are not sufficient incentives for these actors to be involved. School teachers and university lecturers no longer get recognition for participating in this process, with an increasing focus on teaching in schools and research in universities. Indeed, it was suggested that there is an increasing reliance on retired teachers, and it was felt that the 'rarely cover' agenda was likely to exacerbate this trend further. Whereas previously involvement in the assessment system would have been beneficial for career progression for teachers and lecturers, it was argued that this was no longer the case. Due in large part to this lack of engagement, there was a perception that schools/colleges, HE and employers had lost trust in the system. To combat this, several stakeholders argued that greater collaboration (for example through secondments and the establishment of standing committees) should be encouraged between schools, HE, awarding bodies and QCDA.

Awarding bodies system

Several stakeholders questioned the advantage of a structure of commercial awarding bodies, with many suggesting that there was a perverse incentive to lower standards in order to increase market share. Indeed it was widely believed amongst the science and mathematics communities that schools will select awarding bodies that will enable their students to attain the best grades and their school to be placed highly on external performance league tables. However, several education stakeholders highlighted that awarding body choice was also heavily influenced by the background of the teacher, learning styles of their pupils, as well as inertia. It was suggested that research on why schools choose awarding bodies would be beneficial to understand this issue more fully.

Whilst some stakeholders suggested more radical solutions, such as only having one awarding body, others argued that this would be a rather 'Stalinist' approach, which may have several unintended consequences, such as reducing choice and flexibility. Nevertheless, several concerns were raised over the current governance arrangements. It was felt that QCDA has limited levers over the awarding bodies, whilst Ofqual has technical, but not necessarily practical or especially powerful levers (primarily ensuring that awarding bodies follow the correct process and maintain standards). Having said that, stakeholders agreed that Ofqual's report on GCSE Science did have a significant impact and did identify the major problems (e.g. the level of mathematics in science and the assessment of How Science Works).

Mathematics in science

There was near universal agreement that the level of mathematics in science at GCSE and A-level has been significantly reduced, meaning that there is now a very notable jump to HE. This was largely believed to be the result of the drive to increase participation, particularly in Physics. However, some stakeholders argued that putting the mathematics back into the science curriculum would be unlikely to put students off (especially if taught well), since numbers for A level mathematics are high and rising. Whilst some in the science community argued that Physics could be taught in such a way that different modules are available for those who want to do Physics at HE (which includes demanding levels of mathematics) and those who are just interested in Physics A level and nothing further, stakeholders from the school sector argued that this is unlikely to be viable (particularly with small cohorts). Furthermore, although the focus has largely been on the maths content of Physics and Chemistry (to a lesser degree), it was argued that Biology may become increasingly mathematical with a greater emphasis on bioinformatics, so should not be left out of this issue.

Stretch and challenge

Several education stakeholders argued that the new GCSE criteria and changes to A-level should help to address the issues raised by Ofqual and wider concerns over stretch and challenge (e.g. by incorporating more extended writing questions, which will be assessed for the first time in January 2010).

The new A* grade, and the fact that individual marks are now also available to schools and HEIs, was also felt to support the stretch agenda.

SATs

The National Strategies argued that there is evidence that since the removal of Key Stage 3 SATs GCSEs are being started in Year 9. It was suggested that there needs to be clear messages from the centre against this, since they were removed to add more creative and flexible teaching at KS3.

Mathematics

Mathematics stakeholders argued that assessment in mathematics was particularly challenging since the ability range is narrower than in other subjects – either you can do it or you can't. Mathematics has the highest drop-out rate at university, because the jump is so significant and it is difficult to test for aptitude using A levels and interviews. Finally, the mathematics community also argued that early and multiple entry for GCSEs is a problem, with teachers 'banking Cs', which means that in some schools pupils don't do mathematics in Year 11, making progression to A level very difficult.

Priority 4: Market Pull

Supply of STEM graduates

The STEM 'pipeline' was felt by some to be a bad metaphor, since it implies that there is only one output and that any 'leakage' is an inherently bad thing.

It was asserted that there are three categories of users of science education in the workplace: those where science is the main activity e.g. academic researchers; those where science is critical e.g. medical profession; and those where science is enhancing e.g. many professions.

The CBI highlighted that STEM skills (such as quantitative and logical thinking skills) are highly rated by employers, but that greater work experience would be valued before and during STEM degrees

IAG

The CBI underlined that young people need to understand subject choices in terms of opportunities at HE and in terms of careers and earning potential (a CBI survey indicates that STEM careers pay the highest after management). It was stressed that IAG should be delivered both in and outside the curriculum, and should continue throughout school/college and HE education. The lack of IAG in HEIs was also lamented by stakeholders.

Employers strongly believe that young people are not hearing the right message about careers in science and engineering. While some areas of the sector are experiencing difficulties, others are growing and suffering skill shortages. Earning levels for the sector are good, and the opportunities for development, travel, and really making a difference in the world are growing all the time. Young people were felt to be drawn to some areas of science which are seen to be useful in 'saving the world'. For example Britain has technological influence in clean energy and more people apply to work in the Renewable Energy section at BP than any other area of the company. Moreover, the image of engineering and manufacturing as a "dying" sector is not true and needs to be challenged.

It was also suggested that STEM careers are relatively meritocratic, once someone has good science A levels their chances of progression are relatively equal with their peers, irrespective of socio-economic background. This was argued to extend all the way up the science profession, in contrast to careers such as law. However, other stakeholders argued that STEM careers can be very hierarchical and that it should be acknowledged that new recruits must put in a lot of lower-level work before they can be promoted.

The mathematics community highlighted there can be a danger of lumping mathematics and science together, especially when it comes to talking about careers. They also argued that mathematics should be marketed far better – the statistic that if you take mathematics A-level you earn 10% more over your lifetime should be widely used and disseminated. It is also important to demonstrate how mathematics is used in society e.g. the importance of modelling rather than calculus. They also asserted that there is an issue with public perception of, and engagement with, mathematics: the culture that it is acceptable not to be good at mathematics needs to be challenged. It was also suggested that employers and HEIs should be more transparent about what they want from young people (i.e. mathematics A level, specific grades), which would highlight that you close many doors by not taking mathematics.

Links with HE and industry

It was universally acknowledged that links between schools, HE and employers should be significantly strengthened. A range of stakeholders stressed that there was not a lack of will on either side, but a lack of resource and time constraints. However, others suggested that there was a mutual suspicion between teachers and industry, similar to that between the medical and pharmaceutical sectors.

Employer stakeholders suggested that Sector Skills Councils and Education Business Partnerships vary significantly in terms of quality and impact. However, there was support for the National Education Employer Partnership Taskforce, chaired by Bob Wigley, which has been set up specifically to improve links between industry and schools/colleges.

There was also significant support for current school/college-industry/HE schemes such as 'Researchers in Residence' and the STEM Ambassadors schemes, but it was felt that the awareness and impact of these schemes could be improved. For example, STEM Ambassadors receive an induction and can access support in terms of their work with schools, but schools would also benefit from training and support to get the best from Ambassador visits and activities.

It was argued that there should be a more fluid interchange between school/colleges and HEIs and industry, for example through visits, CPD or secondments. Education Business Partnerships can help teachers to gain experience the world of work but it was acknowledged that it is very difficult for schools to find and fund cover for long periods. However, employer stakeholders suggested that it might be possible for teachers to use school holidays to spend time in industry (which currently happens to some extent in FE), although funding and incentives would still be an issue. The Diplomas were thought to provide an example of what can be achieved here through 'Teacher Industrial Placements' e.g. in engineering.

Priority 5: School/College Ethos

Teachers and leaders

Many stakeholders argued that school/college ethos and success in STEM is primarily about teachers. These stakeholders felt that excellent teachers should be rewarded and celebrated, with 'Teacher of the Year' TV program representing a good start. Other stakeholders felt that school/college leadership was the key to creating a positive ethos and that their buy-in to the STEM agenda was vital. It was noted that good leadership and management was paramount for retaining science teachers, particularly by providing support in the first five years of teaching and to middle management. It is also head teachers/principals who ultimately decide whether staff can attend external CPD and sign-off which qualifications a school will take.

Levers

A wide range of stakeholders underlined that school performance tables are the primary driver of school priorities. Several stakeholders suggested that if we are to really focus on stretch and challenge, league tables should recognise A/A*, rather than just A*-C, which they argued focuses teachers' energies on the C/D borderline and encourages teaching to the test. In addition, there was support for the idea that accountability for schools should include where learners go after school. In order to achieve this and track 'market pull', some stakeholders argued that there is a need for data on pupil progression and achievement from KS2 through to A-Level and on to HE, however, this is not yet available from the government, due to concerns around data protection.

Stretch, challenge and enrichment

Stakeholders argued that there should be an institutional approach that embeds stretch and challenge across the curriculum, rather than seeing it as an add-on or enrichment activity. There was a perception that 'science club' activities are extra-curricular and therefore more accessible to high performing and independent schools, which is also true of schemes like the Physics Olympiad. These activities should be targeted and made available at schools in challenging circumstances. It was felt to be vital to encourage both attainment and engagement simultaneously, and that whilst these are often mutually reinforcing this is not always the case (e.g.

stakeholders from the mathematics community suggested that many pupils do well in mathematics at GCSE, but do not enjoy it, so do not take it for A-level).

Cross-curricular links

Several stakeholders stressed that planning the delivery of science and mathematics should be more joined-up, taking advantage of overlaps between these subjects. It was argued that if the right school ethos is present then mathematics and science GCSEs can work in parallel, so that the mathematics content is provided in science lessons as well as in mathematics. This was felt to also be applicable within science (i.e. connections between biology, physics and chemistry). This is currently not a focus for ITT or HE e.g. it was argued that Chemistry at Russell Group universities is too specialised and would benefit from greater multi-disciplinarity. Interestingly, other stakeholders from the science community argued that it may be helpful to speak of 'the sciences' rather than science, and for departments to see themselves as, respectively, physics, biology and chemistry departments, rather than science departments.

School specialisms

The school specialist status scheme was felt to have had relatively little impact on improving teaching and learning in science, due in part to the fact that some schools chose science as a specialism due to a lack of alternatives or as an area to work on, rather than because they exemplified best practice. Interestingly, it was suggested that sports colleges performed well in science, largely due to their cross-curricular links.

Local data and leadership

National Strategies currently provide a STEM data service on attainment and progression at school and pupil level, which is used to identify schools that need targeted interventions. When they are wound up, it was noted that this data collection and locally targeted interventions should continue.

List of School and College Visits Undertaken

Members of the Expert Group and the secretariat have visited the following schools and colleges.

- Morpeth School, Tower Hamlets. 29 June 2009
- Highams Park School, Walthamstow Forest. 10 July 2009
- Lordswood Girls' School, Birmingham. 14 July 2009
- Macclesfield College, Macclesfield. 25 September 2009
- John Leggott College, Scunthorpe. 4 November 2009
- Deptford Green School, Deptford. 9 November 2009
- City and Islington College, Camden. 10 November 2009
- Simon Langton Grammar School for Boys, Canterbury. 19 November 2009
- Simon Langton Grammar School for Girls, Canterbury. 19 November 2009
- St Augustine's School, Westminster. 3 December 2009

List of Focus Groups

The Secretariat to the Expert Group have facilitated focus group discussions at the following forums:

- *Physics for Non-Specialists* course at the National Science Learning Centre. 2 July 2009
- LSIS STEM Programme Summer School, Bristol. 6 July 2009
- *New Skills for Laboratory Technicians* course at the National Science Learning Centre. 7 July 2009
- NCETM Board meeting. 14 July 2009
- Association of Colleges Science Focus Group. 15 July 2009
- Association of Colleges Principals' Portfolio Group, 16 July 2009.
- National Youth Parliament AGM. 25 July 2009
- LSIS STEM Programme Board meeting. 30 September 2009
- WebEx with school leaders via NCSL. 21 October 2009
- SCORE meeting. 18 November 2009

List of Workshops and Process Followed

Four workshops were held at the Wellcome Trust's Gibbs Building on 16, 17, 23 and 30 November 2009. They were facilitated by Carl Reynolds and Ali Crowther of Sciencewise-ERC. The following process was used for all four workshops.

Time (h/m)	Process
00.00	**Introduction** Purpose of workshop, how it will run, the role of facilitator and who you are. **Sir Mark Walport** (Chair of Science and Expert Learning Group) to introduce the recommendations, how they evolved and what happens next with your input
00.20	**Workshop – Priority one** Discuss the recommendations and discuss - What you like about the recommendations? What you think is missing? What you don't like? Potential levers to effect change in this area? You will work with a small group of other stakeholders.
00.40	**Whole group – Feedback** Whole group share key points from discussions
00.55	**Workshop – Priority two and three** As above
01.35	**Whole group – Feedback** As above
01.50	**Workshop – Priority four and five** As above
02.30	**Whole group – Feedback** As above
02.45	**Wrap up** Answer key questions about process and indicate next steps Evaluate the session
03.00	**End**

List of Workshop Attendees

16 November

Norma Honey (LSIS)

Malcolm Trobe (ASCL)

Ian Richardson (Ofsted)

Roland Jackson (BSA)

Peter Cooper (London Maths Society)

Alice Hynes (Guild HE)

Hannah Baker (Wellcome Trust)

Alan Smithers (University of Buckingham)

Claire Donovan (SEMTA)

Hilary Leveers (CaSE)

Sandra Stalker (QCDA)

Matthew Barker (Simon Langton Grammar School for Boys)

Becky Parker (Simon Langton Grammar School for Boys)

Heather Hawthorne (RAEng)

Steven Hill (RCUK)

Lizzi Holman (CBI)

Laura Seabright (Deptford Green School)

Richard Pike (RSC)

Kirsten Bodley (STEMNET)

David Swinscoe (City and Islington College)

17 November

Joanna Conn (Hertfordshire CC)

Hugh Lawlor (Science DDP)

John Noel (OCR)

Andrew Shore (Biosciences/Cardiff University)

Nansi Ellis (ATL)

Aileen Allsop (Astrazeneca)

Daniel Sandford Smith (Gatsby)

Jim Dobson (Edexcel)

Carolyn Mason (SEMTA)

Mike Goulette (Rolls Royce)

David Fox (Pfizer)

Helen Thomas (Foundation Degrees Forward)

Debbie McVitty (NUS)

Chris Kirk (Biochemistry Society)

Martin Post (Watford Grammar School for Boys)

David Weston (Watford Grammar School for Boys)

23 November

Peter Main (IoP)

Alan Wilson (SCORE)

Wendy Wright (Macclesfield College)

Nick Bowes (ACME)

Sarah Jones (ABPI)

Celia Hoyles (NCETM)

Gaynor Sharp (Becta)

Peter Canning (Edexcel)

John Chilton (Oakham School)

Yvonne Fleming (AiME)

Bernard Silverman (Royal Statistical Society)

Gareth Young (NASUWT)

Antony Tomei (Nuffield Foundation)

Debbie Ribchester (AoC)

Derek Bell (Wellcome Trust)

David Winstanley (SEMTA)

Ginny Page (SAPS)

Annette Smith (ASE)

Rachel Forsythe (SoB)

Alan Brewin (NPL)

Nick Chambers (Education-Employers Taskforce)

Tom Welton (Imperial College)

Nick von Behr (Royal Society)

Laura Dillingham (TDA)

John Green (Imperial College)

30 November

Andrew Urwin (Park Community School)

Charles Tracy (IoP)

Sue Horner (QCDA)

Julia Higgins (ACME)

Pauline Hoyle (Secondary National Strategies)

Sue Sissling (SSAT)

Anne Trant (AQA)

Dennis Opposs (Ofqual)

Janet Holloway (AQA)

David Youdan (IMA)

Prof Nigel Steele (IMA)

David Bassett (SEMTA)

Marion Scott (UKRC4SETwomen)

Ros Wall (UKRC4SETwomen)

Jenifer Burden (NSLC)

Philip Greenish (RAEng)

Alex Thompson (Russell Group)

Angela Berryman (LLUK)

Professor Mary Radcliffe (NSLC)

Howard Darwin (John Leggott College)

Sion Peters-Flynn (John Leggott College)

Stu Billington (Fallibroome High School)

Jo Gaisford (Simon Langton Girls' Grammar School)

Jonathan Bach (Secondary National Strategies)

Summary Report of Workshops

The Science and Learning Expert Group held workshops on 16, 17, 23 and 30 November with a wide variety of stakeholders from a range of sectors to discuss the Group's emerging recommendations. The workshop process and attendees at each workshop can be found at annexes J and K. These workshops discussed the recommendations in five broad areas and common themes which emerged are covered below.

Priority 1: Teaching Workforce

There was general agreement from stakeholders with the direction of travel of the report on both of the main issues raised under this heading (recruitment and CPD), although there was some concern that at present the recommendations represented aspirations rather than hard recommendations and that further work should focus on how these ideas are implemented. There was also a concern that not enough was currently said about retention of good teachers. There was some feeling that the recommendations dealt primarily with schools and that different problems existed in FE colleges, in fact FE models such as 30 hours *pro rata* CPD could be explored for the schools workforce. It was further noted that recommendations should try and be science and mathematics specific, rather than affecting the profession more generally. Finally, it was felt that real impact could be made here on enforcing current initiatives.

Improving recruitment and retention

There was a general feeling that improving the status and salary of teachers would encourage more high quality graduates into the profession. This could be achieved through treating teachers as professionals and it was felt that the MTL and Chartered Teacher status could help. In a similar vein, several people commented that giving teachers a greater sense of empowerment would encourage teachers to stay in the profession. It was also thought that providing a more stretching syllabus would make teaching a more attractive career for top-end graduates.

It was acknowledged that current evidence on retention is poor and it was also questioned to what extent the problem of retention is more acute in science and mathematics than in other subjects. However, it was agreed that current shortages were unequivocal and sustained policy, rather than just taking advantage of a current spike in applicants, would be needed to address current shortages.

There was some feeling, particularly in the fourth workshop, that differences between providers of initial teacher training (ITT) should be addressed. It was stressed that there should be some structured development of subject knowledge throughout ITT and the first year of teaching. It was also noted that mentoring schemes which exist for teachers during their ITT and Newly Qualified Teacher (NQT) years were not carried on and that the continuation of such support mechanisms might improve retention.

Finally, it was strongly put to the group that trainee teachers needed to be able to secure high quality placements during their ITT. It was also felt that creating more opportunities for undergraduates to visit schools and colleges and participate in classroom teaching might help make people consider whether they wanted to go into teaching after university.

CPD

There was universal acknowledgement that all teachers should undertake regular high quality CPD. This was said to be especially true for teachers in STEM subjects, which evolve and develop faster than many other subjects and which also involve practical learning for which specific CPD is required. To this end, whilst all teachers are currently entitled to 5 days a year of CPD, it was thought that science teachers might benefit from an increased entitlement or that for science teachers part of this entitlement should explicitly be for subject-specific CPD.

Resources are the greatest barrier to greater CPD take up. Schools and colleges are often reluctant to let staff attend events that are not held onsite. One of the most significant barriers is the problem of covering for staff who do attend training and this will become more acute with the 'rarely cover' initiative. Institutions and individual teachers would need to be given incentives to attend CPD events, especially those which happened outside of teaching time. It was noted that writing the duty to attend CPD into teachers' contracts would encourage greater numbers to take up the opportunities. The suggestion was made that science specialist schools might be able to lead local clusters of schools and colleges by providing high quality CPD.

Several specific areas on which CPD should focus were mentioned. These included:

- Practicals
- Information, advice and guidance on post-16 choices
- Recent developments in science
- Making science relevant to everyday life

Priority 2: Curriculum

There was general support for the recommendations, in particular for an increase in mathematics within A level science curricula. There were more mixed receptions to recommendations on Diplomas, the abolition of AS levels and the extended project. The point was also made that the report would have to be clear what outcome was wanted – is it simply more STEM graduates or better equipped

STEM graduates? If the latter, then the currently favoured metrics of numbers of A level students will not necessarily be appropriate to measure success.

The variety of science pathways

1. GCSEs

There were some concerns about the rigour of current GCSE science examinations. It was particularly noted that there needs to be greater mathematical content in all science GCSEs.

It was noted that the core/additional science route should allow progression to A-level, since it provides the bulk of A-level students, and therefore 'booster classes' would not be necessary for people wanting to progress from core and additional science to A level.

The option of an additional maths GCSE received some support although there was concern that if students were encouraged to take Triple Science and Double Maths (alongside two English GCSEs) they would use up 7 of their GCSE options without having to make any choices about doing geography, history, a language etc.

2. Diplomas

The Science and Engineering Diplomas were not widely discussed although there was a feeling that the Diploma was designed to provide an applied learning experience not applied science (so that the end goal can be the same as with A levels). It was stressed that Diplomas should not be seen as second rate.

3. A levels

There was interest in but limited support for the removal of AS levels. Some people raised the fact that students don't necessarily choose what subjects to study to full A level until after getting their AS results. It was also noted that AS levels provide important breadth and that the positive outcomes outweigh the negatives, although some felt that more data was needed on these issues – particularly insofar as AS levels have an impact on the uptake of STEM subjects. However, it was felt by some that the Sixth Form was now very broken up with exams which compromised the learning of real science. There was support for cutting down the number of resits and the removal of January modules.

There was some concern that there is currently a mismatch between the current content of A levels and expectations within the HE sector, specifically there was support for mathematics being reintroduced to post-16 science pathways although this should be within the science qualifications rather than by an assumption that everyone should do A level mathematics. This would help to ensure that it was more relevant and specific e.g. more statistics in Biology, more mechanics in Physics. There should be an acknowledgement that it is not *just* mathematics that is missing but some key scientific concepts as well.

4. Other qualifications

The extended project was seen as a good motivator but not necessarily a good assessor of students, particularly as it does not specify any content which could be assessed. There were thought to be some difficulties in using this for science as, for example, it was thought that it would be difficult to assess the extended project in groups. It was also clear that this should not be at the expense of the widening participation agenda and that the extended project could not become something that only elite schools provided and that only elite universities accepted.

Curriculum development

It was said that the development of the curriculum needs to be considered and developments should be made so that the curriculum is seen in context. There may be potential for greater collaboration with industry in the development of the curriculum, as has been the case with the Engineering Diploma. There was also some discussions here (and under assessment) about reviewing the role of the awarding bodies.

Enrichment

It was acknowledged that enrichment should ideally take place in all science lessons and should not be seen as an 'add on' or luxury. There was a feeling that enrichment could also be done in collaboration either with industry or with other schools and colleges, as in the Further Mathematics Network. Online resources can also be used cheaply and effectively. It was also thought that professional bodies should accredit enrichment activities to incentivise participation.

Priority 3: Assessment

There was support for the direction of the recommendations in this area, although some delegates felt that the recommendations could be tougher on awarding bodies and that the inherent 'difficulty' of science subjects should be recognised in league tables. It was acknowledged that assessment can drive the whole education system and that the market of awarding bodies meant that some schools and colleges might be drawn towards those awarding bodies which they felt offered 'easier' exams. With both curriculum and assessment it was felt that there had been a large degree of change in recent years and that there should be a period of stability, although others suggested that there was a need for change. Alongside this it was noted that, from an equity point of view, pilots of qualifications are hard to undertake and that, if changes are made, greater support needs to be provided to teachers to be able to deliver new qualifications.

Development of assessment

There was agreement that awarding bodies have become disengaged from end-users (i.e. schools and colleges), but some felt that industry end-users should not contribute to the content of qualifications. It was asked what incentive there was for both individual teachers and academics to be involved with designing assessment. It was also acknowledged that it is difficult to get academics who are *able* to engage, even if they were willing, as the qualification and assessment organisations have their own impenetrable language. To this end the idea of standing committees of subject experts within QCDA and awarding bodies was supported. It was seen to be crucial that current science teachers were included on these as well as school and FE bodies.

There was a strong feeling amongst the attendees at the workshops that the awarding bodies market was not adequately regulated and that there was an incentive for schools and colleges to do what they felt were the easiest exams, creating a 'race to the bottom'. It was also suggested that awarding bodies producing text books was a practice that should be stopped. However, there was some refutation of this, specifically: there is competition at IGCSEs but this is not seen as dumbing down; teachers request text books from exam boards, and it is likely other organisations would produce similar materials to meet this demand; and there is limited correlation between numbers entered for exams and 'easiness' of exams.

Some suggested that a single awarding body would be an effective solution, but others considered that this would create an unstable system.

There was some call for more innovative examining practices rather than 'old fashioned' written exams. This could include assessing practical work; although it was acknowledged that this presents some difficulties.

It was agreed that syllabuses and curricula are changed too often and not given time to embed – this is not the case with international exams.

Priority 4: Market Pull

The two broad themes of improvements to information, advice and guidance (IAG) and better links between HE/industry and schools were agreed in discussion although it was felt that many of the solutions proposed had already been attempted or are being implemented and that there is no merit in 'reinventing the wheel'.

IAG

Several stakeholders acknowledged that IAG in science is not consistently of a high quality. An element of this problem is that it is hard for teachers to keep abreast of the most recent developments in the science world and know what the best job opportunities are (and the nuances of where shortages exist in 'science'). It was therefore suggested that better CPD on science careers should be provided for science teachers. However, whilst it was noted that IAG should ideally come through in science lessons, so that young people see a clear link between what they are being taught and how they might use it in a career or degree, IAG should also come from a range of other sources. A particular group who might provide this is parents and it was felt that there was currently a lack of resource focused on informing parents of the current and recent developments pertaining to STEM careers and higher education. It was also thought that work experience might provide better information for young people on careers than traditional IAG but that this was difficult in STEM. Others suggested that former pupils should be encouraged return to schools and colleges to inspire current pupils to pursue science careers.

There was a strong feeling that the HE sector should be clearer on what A levels they require for certain subjects and also that industry and the government should make clearer specifically where shortages exist (rather than simply stating that there are 'shortages of STEM graduates').

Links with business and HE

It was generally acknowledged that links between schools and colleges on the one hand and business and HE on the other have a positive impact on young people's STEM education. Enabling young people to see the 'real world' relevance of their science work often encourages them to pursue science further. It can be difficult for schools and colleges to engage with other organisations, and often businesses do not want to engage (although it was said that the more 'enlightened' businesses saw such engagement as 'essential') but it was felt that consortia of schools and FE colleges (i.e. 14-19 partnerships) can make HE and employer engagement more manageable.

It was observed that there are many local schemes of which account must be taken, but there must be a reality check on scope and scale. There may also be problems with ensuring parity across the country for schools in HE/STEM industry 'deserts'. It was felt therefore that national frameworks were needed.

Priority 5: School and College Ethos

On the question of governance there was some concern about how to ensure that governors who were recruited were of an adequate calibre. There was also concern about to whom the governors' report would be addressed, as governing bodies are accountable to a number of stakeholders – it was also thought that giving governing bodies too many responsibilities would be impractical. However, some thought that governance arrangements currently are overcomplicated and could be streamlined to accommodate new roles. It was widely thought that leadership was important to creating a positive ethos in schools although it was questioned whether school ethos can relate specifically to science and maths. The question of how schools were accountable for this was also raised. There was a feeling that schools would struggle to get round general, societal perceptions of science and engineering especially in the media.

Governance and accountability

The direction of travel of governance was broadly supported although it was felt that a report card should become more than a tick box exercise. There was a feeling that there should be some recognition in the report of the variation in quality of governing bodies and whilst there are undoubtedly some excellent governors and governing bodies, many are not working optimally. Collaboration and shared governance might be a means to combat this problem, as might providing schools with advice on how to appoint governors who have knowledge or experience of industry or HE.

League tables were felt to strongly influence parental choice of schools and schools' reputation, and therefore the 5 A*-C model was questioned as this focuses attention on the C/D boundary. It was also suggested that a league table that focused on A*/A grades might discourage schools from entering students from science exams, which are often perceived to be harder. Several delegates did think that measures like a school report card might work better and could be more sophisticated than just looking at a single measure, although it was acknowledged that it could not be a receptacle for everything.

The impact of specialist schools was questioned – although several participants thought that working in clusters and local/regional partnerships was a possible solution, it was not thought that all specialist schools sufficiently exercised their outreach responsibility.

Leadership was thought to be the most important aspect to the question of ethos (Heads, Principals, Senior Teachers, and Governors). It was also thought to be important that time and resource was dedicated to subject leadership in schools, to enable teachers and senior management to think strategically about science and mathematics provision.

Analysis of Responses to the Written Consultation Document (by the Consultation Unit, DCSF)

Introduction

This report has been based on 129 responses to the consultation document.

As some respondents may have offered a number of options for questions, total percentages listed under any one question may exceed 100%. Throughout the report, percentages are expressed as a measure of those answering each question, not as a measure of all respondents.

The organisational breakdown of respondents was as follows:

Higher Education Sector	41
Other*	26
School Sector	21
Further Education Sector	9
Union/Professional Association	8
Local Authority	6
Science Association/Body	6
Employer	5
Parent	4
Training Provider	3

**Those which fell into the 'other' category included non-departmental public bodies, charities, sector skills councils, funding bodies, individuals and a range of STEM-related organisations.*

The report starts with an overview, followed by a summary analysis of each question within the consultation. There is then a selection of responses to the consultation, whilst the final section lists all respondents to the consultation document

Overview

Although the Science and Learning consultation asked questions of four different stakeholder groups, namely: schools and colleges, the higher education (HE) sector, employers and any other interested parties, there was a good degree of commonality in the responses given across these groups.

When asked how to encourage engagement, participation and progression in science and mathematics, respondents generally agreed that this could best be done through enrichment activities, raising awareness of the progression routes available, making the curricula more interesting and relevant and improving teaching in these subjects.

The main barriers to engagement, participation and progression in science and mathematics were identified as being poor curricula and the perception of these subjects as being difficult, dull and irrelevant. Respondents suggested that these barriers could be overcome by a review of the curricula and improved teaching.

All respondent groups who were asked at which stage they thought engagement reduced agreed that Key Stage 3 was a critical stage. It was noted that this period coincided with the time that GCSE option decisions were being made and the start of adolescence when young people were more likely to succumb to peer pressure. Schools, colleges and the HE sector also believed that engagement could diminish during Key Stage 5 when students found A Levels courses too demanding.

The majority of respondents from the schools, colleges and HE sectors felt that the current national qualifications in science and mathematics were not appropriate. It was considered that the lack of scientific content in the GCSE double science award failed to prepare students for the significant leap to A Level study. In turn, respondents believed that Level 3 qualifications such as A Levels and the BTEC National Diploma, and the modular approach to assessment, left students ill-equipped for degree level study.

It was thought that the best ways to enable schools and colleges to be better able to deliver science and mathematics teaching were to ensure that teachers were well-qualified in their particular specialism, undertook regular development opportunities to keep their knowledge current and were able to convey enthusiasm for their subject in order to motivate their students.

Schools and colleges said that they generally provided information, advice and guidance to students during Key Stage 4 and 5. It was considered that the most effective way to do this was to expose students to scientists and engineers in real life contexts, such as attending summer schools at university or taking up work experience placements in industry. Using interactive media such as websites was also thought to be a good way of imparting information on the progression routes available to students.

Responses to questions relating to the skills needed by students to succeed in HE and employment resulted in the identification of key common areas. These included good numeracy, literacy and communication skills, practical and technical skills, the ability to solve problems and work in a team and the capacity for independent study, creativity and critical/analytical/logical thinking.

There was general consensus amongst respondents that links between schools, colleges, universities and employers to support engagement, participation and progression in pure science subjects and engineering could be improved by various collaborative activities. Suggestions included: visits between sectors, taster days in HE, secondments to industry for teachers, mentoring schemes and student ambassador schemes. Difficulties in funding and organising such activities were highlighted however and it was acknowledged that appropriate support was necessary if they were to be sustained.

Summary

SECTION 1: SCHOOLS AND FURTHER EDUCATION SECTOR

Q1 How does your school/college encourage engagement, participation and progression in science/mathematics, particularly for the most promising students? (please use specific examples where possible)

There were 27 responses to this question.

The majority of respondents said that they encouraged engagement, participation and progression in science/mathematics, particularly for the most promising students by offering a range of enrichment activities. Schemes such as the British Science Association Creativity in Science and Technology (CREST) awards and the Nuffield Bursary Scheme, where young people undertook projects, which they wrote up and presented, were cited as useful means of making science and mathematics more attractive. Competitions, such as the Science Olympiad and the Hans Wayda Mathematics Competition, were also mentioned as ways to broaden the appeal of science and mathematics. Respondents gave many other examples of enrichment events and activities used by schools and colleges, including:

- National Science and Engineering Weeks
- Engineering Enhancement Scheme
- STEM festival
- UK Aerospace Youth Rocketry Challenge (UKAYRoC)
- Big Bang Fair
- Headstart
- visits/fieldstudy e.g. The Eden Project
- after school clubs.

A number of respondents said that they offered triple science subjects at GCSE for their most promising students, for example those identified as working at level 6 in Year 9. It was felt that this helped to maintain interest and challenge for such young people where the more widely offered double science award failed. Respondents also said that they enrolled those pupils who showed the most promise for Extended Project Qualifications and Advanced Extension Awards, along with offering GCSEs outside the normal curriculum, such as Astronomy and Psychology as after-school options.

Around a fifth of respondents said that they provided specialist teaching. They employed teachers who were well-qualified in their particular area (Biology, Chemistry, Physics and Mathematics) which they felt provided high quality teaching, greater depth and more challenge for the most promising.

There was some mention of careers advice. Schools and colleges said that they provided information, advice and guidance (IAG) to young people choosing their Level 2 and 3 options by advising on the most appropriate qualifications depending on academic ability, preferred learning styles and HE/career choices. Careers events such as NPower Enthuse were cited as means to make young people aware of the range of careers options available to those interested in science, technology, engineering and mathematics (STEM) subjects.

A small number of respondents stated that they forged links with local universities to encourage high achievers to study science and maths in HE. Various methods were highlighted, such as:

- attending HE open days and taster sessions
- inviting university lecturers to speak in schools and colleges
- participating in the Researchers in Residence Programme where university researchers worked with science students in schools and colleges.

Three respondents identified monitoring and assessment of their pupils' performance as a means of identifying the most promising. This, it was felt, enabled teachers to allocate them to the highest sets in order to provide stretch and challenge and to enrol them for the most appropriate qualifications, such as the IGCSE which was considered to provide more depth and rigour than the GCSE.

Three respondents said that they operated 'fast-tracking' programmes for the most able students where their learning was accelerated, for example by starting the GCSE syllabus early to allow them to take the exam in Year 10.

Q2 How do you identify and provide stretch and challenge for the most promising students in science/mathematics?

There were 23 responses to this question.

The majority of respondents said that they challenged their most promising students through teaching by helping them to work at a pace that matched their ability and was tailored to their interests. Examples included:

- accelerated programmes of study and early exam entrance
- offering Triple Science GCSE from the end of Year 9
- teaching beyond the exam specifications to broaden knowledge
- providing a more academic, less applied approach for top sets
- supplying more challenging and stimulating materials for study
- offering project work and other activities which required reasoning and creativity
- providing additional support outside lessons
- setting more demanding homework.

Around half of the respondents provided enrichment opportunities such as extra-curricular activities, clubs and competitions, such as the Maths Challenge and Cipher Challenge and HE masterclasses.

A number of respondents stated that they used baseline testing and ongoing teacher observation and assessment to identify and challenge high achievers. This, it was noted, enabled them to select students for Gifted and Talented Programmes.

8 (35%) respondents said that they used data and other 'softer' information from feeder schools to identify the most promising students in science and maths. Screening of MidYIS and ALIS data and access to Key Stage 2 and 3 teacher assessments were viewed as the best means of doing this.

Q3 What are the major barriers inside or outside your school/college to ensuring that students are engaged and participate in science/mathematics, and that those with the potential to do well progress to more advanced levels?

There were 27 responses to this question.

The majority of respondents thought that the main barrier to ensuring that students were engaged and participated in science/mathematics, and that those with the potential to do well progressed to more advanced levels, was the negative perception of science and mathematics. It was believed that both subjects were widely considered by students to be difficult, boring, irrelevant and unpopular with girls. Respondents observed that pupils, when deciding on their GCSEs and A Level subject choices, were likely to choose those other than science and mathematics as they felt that they could achieve better grades in subjects they perceived to be easier. It was also acknowledged that, in an increasingly celebrity-obsessed culture, science and mathematics lost out to subjects such as music, sport and drama, given that science/mathematics-related careers were viewed as lacking status and being poorly paid. Several respondents reported an increase in the number of schools and colleges which were withdrawing A level sciences and maths from their offer in favour of easier and more popular subjects, given that poor results in science and mathematics had a detrimental impact on funding levels and Ofsted ratings.

A number of respondents identified the science and mathematics curricula as a barrier. They were viewed as being over-prescriptive which meant that teachers felt constrained to prepare student for tests and exams, rather than being able to explore areas in more depth and make time for more practical work. It was also suggested that the content of the science curriculum had become woolly with a lack of focus on real science which failed to equip students with the knowledge they needed for advanced level study. Respondents also noted that students, at various stages throughout their formal education, did not have adequate numeracy skills, which hampered their progression in mathematics and science at higher levels.

A small number of respondents said that lack of resources prevented them from engaging students in science and mathematics. Difficulties in recruiting and retaining qualified teachers were expressed which, it was felt, impacted on teaching and the ability to offer triple science subjects. Poor laboratory facilities, lack of equipment and learning materials and the inability to fund extra curricular activities were also mentioned. The reduction in Aimhigher funding was thought to be a measure which would disadvantage young people from progressing to higher level studies.

Location was highlighted as a barrier by a few respondents. Schools and colleges in poor catchment areas said that lack of ambition, poor family history of academic progression and lack of local employers made it more difficult to encourage students to follow advanced levels of study. Those in rural areas cited lack of proximity to universities and employers as being problematic when trying to make links, attract visitors and arrange travel to enrichment activities.

Other barriers identified included:

- lack of parental support
- specialist schools and colleges failing to promote science and mathematics in favour of their own specialist areas
- student debt being a deterrent to entering HE
- demise of the manufacturing sector reducing career opportunities.

Q4 Why, and at what stage in secondary school/further/higher education pathways, do you think engagement of some promising young people in science/mathematics reduces?

There were 24 responses to this question.

Around half of these responses suggested that engagement of some promising young people in science/mathematics reduced at Key Stage 3/Years 9 to 10. It was considered that the curriculum could be uninspiring during this period with a focus on preparation for exams and much time spent on revisiting topics already covered. Year 9 was viewed as a critical time as students had the option to drop science when choosing their GCSE subjects. It was believed that if young people had failed to engage with science by this time it was likely that they would select subjects which they found easier and more interesting. It was noted that Key Stage 3 also coincided with puberty, which led to some students losing interest in their studies, succumbing to peer pressure and developing other interests.

A number of respondents considered that Key Stage 5 was a trigger point at which some promising young people became disengaged, given that the leap from GCSE study to A level could be significant. It was also felt that students were limited in their A level choices and the attraction of easier or more enjoyable subjects could deter them from opting for triple science. Respondents also suggested that young people were prone to avoid science A levels where they did not envisage a science degree leading to well-paid professions.

Eleven respondents thought that the main reason for lack of engagement in science and mathematics was the current curriculum and examination specifications, given the focus on acquisition and recall of knowledge and the revisiting of topics studied previously. Recent changes to the science GCSE, with a focus on How Science Works, was felt to provide little challenge for the most promising pupils, and respondents suggested that the IGCSE and Pre-U Diploma were more stretching.

Q5 How appropriate are the content and assessment of the national qualifications in science/mathematics (e.g. GCSEs, A-Levels, Diplomas) for ensuring engagement and participation and supporting progression, especially for those students with high potential?

There were 32 responses to this question.

1 (32%) Very appropriate
7 (22%) Appropriate
13 (40%) Not very appropriate
6 (19%) Not at all appropriate
5 (16%) Not Sure

Views were mixed on the content and assessment of the national qualifications in science/mathematics in ensuring engagement and participation and supporting progression, especially for those students with high potential. However, by a small majority respondents deemed the qualifications to be inappropriate.

Approximately half of respondents found the current science and mathematics GCSEs to be poor. Science Double Awards were believed to have limited use in that students did not have to do a great deal to gain a pass. They were thought to be unchallenging for the highest achievers and had contributed to a general decline in GCSE standards. How Science Works was identified as being too generalised and lacking in scientific theory which failed to prepare students for higher level study. GCSE Additional Science and the IGCSE were proposed as better options for helping to engage students with high potential.

The view that A levels were unsatisfactory as they have been 'dumbed down' so that they are too easy for the most able students yet have a high failure rate amongst weaker students was noted in seven response and six respondents highlighted the gap between GSCE and A level, noting that this represented a huge leap for some students. It was suggested that some embarked on A Level courses, based on good marks achieved at GCSE, yet found them daunting as the GCSE curricula had failed to prepare them with the subject knowledge and study skills needed.

Only four respondents viewed diplomas as being inadequate. BTEC National Diplomas were thought to leave students poorly prepared for degree courses, compared to those completing A levels. Experience of the new Diplomas was unfavourable and the currency of the proposed Science Diploma for entry to science subjects at HE was called into question.

Some respondents commented on qualifications in general, finding them to be lacking in that specifications did not cover basic concepts and were not designed to create scientists. The modular nature of the specifications and assessment process was also criticised as failing to enable students to grasp vital connections between different units.

A small number of respondents said that the current science and mathematics assessment regimes had led to teachers focussing on enabling their students to pass exams rather than engendering a broad understanding of the subjects taught and instilling a sense of enjoyment in learning.

Q6 What suggestions do you have for overcoming the barriers to improving engagement, participation, and progression in schools and colleges?

There were 22 responses to this question.

Ten respondents proposed a review of the GCSE science curriculum, given that it was failing both to provide academic rigour for the most promising students and to stimulate the less able. It was suggested that the former should be enabled to study separate science subjects wherever possible, with perhaps a 'general' science GCSE being offered to the latter. There was also a call for more content and less context within the curriculum, perhaps by reducing the 'How Science Works' element. Respondents also proposed requiring GCSE students to undertake project work and improving cross-curricular links between science and mathematics.

Improved teaching was cited by several respondents as a means of removing barriers to improving engagement, participation, and progression in schools and colleges. It was felt that well-qualified teachers whose specialism was in the subject they were teaching would help to instil more confidence in their pupils and improve their learning experience. Respondents believed that teachers should undertake training and continuous professional development (CPD) and look for opportunities to spend time in HE or industry in order to keep their knowledge current.

Some respondents thought that engagement and participation levels could be improved by making lessons more appealing to young people, particularly by enabling them to undertake more practical work. It was suggested that students could be enthused by taking part in more hands-on experimental and laboratory work and by getting involved in the numerous STEM-related enrichment opportunities on offer.

Better links with HE and industry were thought by a small number of respondents to be a means of overcoming the barriers to improving engagement, participation, and progression in schools and colleges. It was thought that such links would enable students to gain a better understanding of possible progression routes through, for example, work experience with local employers.

A small number of respondents said that more should be done to raise the profile of STEM subjects amongst young people and their parents to encourage greater participation.

Q7 What skills, qualifications and experience are most important for a school/college to be able to deliver effective science/ mathematics teaching, which provides appropriate stretch and challenge for the most promising students?

There were 24 responses to this question.

A large majority of respondents said that it was important that schools/colleges had qualified, specialist teachers in order to deliver effective science/mathematics teaching, which provided appropriate stretch and challenge for the most promising students. It was believed that teachers should have, as a minimum, a degree in their specialism to give them the depth of knowledge needed to teach effectively. Respondents also mentioned the necessity to have good leadership within schools/colleges, for example to deal with disaffected young people and allow teachers to teach.

Several respondents identified training and CPD for teachers to help them to deliver effective science/mathematics teaching. Regular INSET courses were suggested along with opportunities to gain experience outside the classroom, such as undertaking research or a secondment to industry.

A number of respondents considered that teachers must be enthusiastic about their subject in order to teach in a way that engaged their pupils, that they should be able to make lessons stimulating and should have good communication skills. It was also felt that teachers should be self-motivated to keep their knowledge up to date and learn new skills in order to keep their teaching fresh and current.

Some respondents believed that the science/mathematics curricula should be reviewed in order for schools/colleges to be able to deliver effective teaching in those subjects. It was suggested that they should be less prescriptive to allow teachers to be more innovative and give them time to explore areas other than those covered by the exam specification. Respondents also proposed an improved GCSE specification to stretch the most promising students, perhaps by including elements of problem-solving.

Q8a) Do you consider that your school/college has the necessary capacity and expertise to deliver single subject science/ mathematics effectively for the most promising students?

There were 31 responses to this question.

26 Yes 5 No 0 Not Sure

The majority of respondents considered that their school/college had the necessary capacity and expertise to deliver single subject science/mathematics effectively for the most promising students. Moreover, several respondents noted that they already did so where their school/college had sufficient specialist teachers and that exam results and pupil progression rates showed this to be a successful strategy.

Q8b) If not, why not and what could be done about it?

Respondents identified the following as reasons why their school/college lacked the capacity and expertise to deliver single subject science/mathematics effectively for the most promising students:

- lack of specialist qualified teachers and laboratory facilities
- large class sizes containing pupils with varying levels of ability from the disaffected to the most talented
- a focus on pushing borderline pupils to gain passes at the expense of developing the most promising.

A number of measures were proposed as a means of combating these problems, including:

- offering attractive pay and conditions packages to attract specialist teaching staff
- investment in equipment
- removing disruptive students
- providing advanced learning for the most promising students
- investigating the causes of decline in the take-up of A Level physics and chemistry courses
- more involvement from the HE sector in science/mathematics in school/ college.

Q9 How and when do you provide information, advice and guidance about higher education and careers in science and engineering?

There were 29 responses to this question.

There were a range of responses regarding the stage at which schools/colleges provided information, advice and guidance about higher education and careers in science and engineering.

Around a third of respondents said they provided it in Key Stage 4 (age 14-16) particularly around the time when students were considering subject choices and another third said that they provided it in Key Stage 5 (age 16-18), especially when students enrolled on further education courses.

8 respondents said they provided it before Year 10 (before age 14) believing that it was important to make students aware of the various pathways available at an early stage.

In terms of how information, advice and guidance were provided:

vi. 8 respondents did this within lesson and tutorial time such as through activities in schemes of work or in relevant modules within courses

vii. 7 used the expertise of the Connexions service and careers advisors to advise students

viii. 5 made their students aware of opportunities for further study in science and engineering though HE events, such as presentations, taster sessions, conventions and conferences

ix. 4 provided information, advice and guidance as part of Personal Social and Health Education (PSHE) and pastoral education.

Q10 What more could schools and colleges do to improve the skillset of science/mathematics students to help them progress successfully to pure science subjects and engineering in higher education and science-related employment?

There were 19 responses to this question.

Around half thought that developing the science/mathematics curricula would help to improve the skillset of students studying these subjects. It was suggested, that revising the exam specifications to reflect the skills needed would help students to progress successfully to pure science subjects and engineering in higher education and science-related employment. Making GCSE courses more challenging and less superficial by removing the 'pseudo science' and social studies aspects was believed to be a means by which students could become better prepared to study pure sciences. Cross-curricula links between science and mathematics, it was believed, would help to build core skills, such as how to apply mathematics in various aspects of the physics curriculum. It was also suggested that students should be encouraged to focus on science/mathematics subjects rather than pursue a wide portfolio of science/arts subjects at Level 2.

The opinion that students should be equipped with generic skills which would better prepare them for higher level study and employment, was expressed in seven responses believing that the current focus on 'teaching to the test' had left many deficient in these areas. The main skills identified were:

- independent study
- further reading and note-taking rather than using material from the internet
- problem-solving and abstraction
- people skills and team-building

- investigation skills
- mathematics skills at a sufficient level to undertake degree level study.

Only four respondents felt that they were already enabling their students to acquire the skills in science and mathematics that they needed to progress to pure science subjects and engineering in HE and employment and that they could do no more. Distance from universities and inability to attract scientists who were willing to work with schools were mentioned as problems which restricted schools and colleges from doing more to help their students.

There were a number of other suggestions which included:

- doing more to promote the benefits of pursuing pure science subjects and engineering in HE and employment, for example through careers advice and events and inviting guest speakers to schools and colleges
- providing enrichment activities such as competing for the Rolls Royce Science Prize and visiting research facilities to enthuse students
- better support for students, such as help with applications to HE.

Q11 How do HE and employers help you understand the science-related skills and knowledge they are looking for in their potential recruits?

There were 21 responses to this question.

Around half of these responses considered that HE and employers did nothing or very little to help them understand the science-related skills and knowledge they were looking for in their potential recruits. Employers were acknowledged as being particularly poor in liaising with schools and colleges on their requirements. It was suggested that a lack of interest on the part of students to local employment opportunities and the propensity in some schools for the majority of their students to progress to HE contributed to the lack of engagement with employers.

Seven respondents said that they used events such as HE open days and careers/recruitment fairs to ascertain the science-related skills and knowledge required by HE and employers. Workshops run by local companies and HE masterclass lectures were mentioned as a means of demonstrating to students the skills needed both in the workplace and for higher level study.

A small number of respondents thought that collaboration with employers and the HE sector had helped, for example through the development of the Diploma Development Partnerships, in the case of employers, and the validation of foundation degrees in the case of HE.

A couple of respondents mentioned that resources such as websites and prospectuses, particularly for HE, had proved to be useful.

Q12 How useful is information from higher education and employers in preparing your students for progression in pure science subjects and engineering?

There were 28 responses to this question.

3 Very useful
8 Useful
10 Not very useful
4 Not at all useful
3 Not Sure

There was a mix of views on the usefulness of information from HE and employers in preparing students for progression in pure science subjects and engineering. However, the majority judged the information as being not very useful.

A number of respondents said that the information they received from HE and employers was of limited use, in that it could be self-promotional in nature and failed to reflect the broad range of career opportunities and the qualifications needed to access them. There was also a view that it could be difficult to find the precise information needed when there was so much available and that, whilst there was plenty of information for those at Key Stage 5, it would be helpful to have materials suitable for younger students. It was suggested that outreach, such as dialogue, visits and access to facilities was more effective in preparing students, than prospectuses, posters etc.

Several respondents stated that HE and employers provided very little to help their students progress in pure science subjects and engineering.

Where respondents found information to be useful they highlighted that from HE in helping young people considering a university application, such as course profiles, National Student Surveys and student blogs on the UCAS website.

Q13 How could the links between schools, colleges, universities and employers be improved to support engagement, participation and progression in pure science subjects and engineering?

There were 25 responses to this question.

A substantial majority of respondents considered that engagement, participation and progression in pure science subjects and engineering could be supported by providing more outreach between schools/colleges and universities/employers. Various opportunities to improve links in this way were identified, including:

- HE/employers visiting schools for masterclasses, lectures etc.
- students visiting HE/employers for taster days, work experience etc.
- student ambassadors working in schools/colleges to pass on information and experiences of available courses and careers

- schools/colleges becoming involved in commercial/industrial research, design and development
- teachers undertaking secondments/exchanges to HE/industry
- field trips to see science and engineering in practice e.g. power stations.

A number of respondents highlighted difficulties in forging links with universities and employers, given that schools/colleges were constrained in terms of cost, time, travel, providing cover and prioritising outreach activities whilst under pressure to achieve exam successes. The unwillingness of employers to support students or provide speakers was also mentioned as making links problematic.

SECTION 2: HIGHER EDUCATION SECTOR

Q14 How do you engage with schools and colleges to widen participation in science/mathematics and support progression to pure science subjects and engineering in higher education?

There were 42 responses to this question.

Nearly all respondents said that they undertook enrichment activities in order to engage with schools and colleges to widen participation in science/mathematics and support progression to pure science subjects and engineering in higher education. There were numerous examples of such activities, including:

- mentoring schemes and e-mentoring
- science research projects e.g. Nuffield Bursary Scheme and CREST awards
- gifted and talented workshops
- masterclasses and lectures
- residential summer schools and revision programmes
- Student Ambassadors/Associates Scheme
- exhibitions and roadshows
- Researchers in Residence Programme
- competitions such as the Royal Society of Chemistry Schools' Analysts Competition.

A number of respondents stated that they provided information for schools and colleges in order to widen participation and support progression. The HE sector said that they provided open days and websites to inform students of what their individual universities offered in addition to taking part in UCAS/careers fairs and contributing entry profile details for the UCAS website.

18 respondents gave various examples of the support they provided for schools and colleges, such as training and resources. HE education departments highlighted the training and CPD opportunities they provided for teachers, such

as INSET courses and secondments. Respondents also said that they supported schools and colleges by developing teaching resources and activities for use in lessons and by providing access to university laboratories. Direct support to students was evident through on-site tuition, particularly GCSE and A Level revision classes and numeracy support, such as the Millennium Mathematics Project. There was also mention of universities supporting the delivery of diplomas and adapting their degree courses to accommodate those embarking on them, by extending courses to four years and streaming first year undergraduates depending on their ability.

Several respondents said that they aimed to widen participation in science/mathematics by taking measures to attract under-represented groups. Several supported national schemes such as Aimhigher and had developed local schemes to target students with high potential from lower socio-economic groups with little direct experience of HE to gain access to degree courses. Foundation courses were highlighted as helping students to gain the necessary qualifications needed for entry to degree courses for those who had failed to achieve them in Key Stage 5. One university said that they had developed a new 'Interdisciplinary Science' course to widen access for those who had been unable to take triple science at A Level. Respondents also stressed the importance of increasing the number of female students progressing to pure science and engineering degrees. Running events to raise awareness amongst secondary school age girls of the range of career opportunities available was mentioned as a means of addressing this.

Q15 How do you identify the most promising pure science and engineering students from schools and colleges?

There were 25 responses to this question.

The majority of respondents said that they identified the most promising pure science and engineering students from schools and colleges by interviewing them. It was noted that speaking to an applicant allowed HE tutors to identify students with high potential even if they had lower grades, perhaps by presenting them with hypothetical situations and inviting them to discuss how they would approach them.

A similar number used GCSE and AS results, and predicted results in the case of level 3 qualifications, believing that this gave a good indication of academic ability and capacity to perform well.

UCAS applications were cited in 14 responses. The personal statement, it was felt, allowed students to demonstrate their portfolio of achievements and interests whilst the teacher reference provided a recommendation as to the suitability of the candidate for higher level study. Contextual information, such as whether the applicant had spent time in care, was also considered.

A small number of respondents said that they used admissions tests or entrance exams and, in some cases, assignments or projects to assess students. Mathematics proficiency tests were mentioned along with problem-solving exercises which helped to determine the student's ability to use their thinking skills, rather than relying on previously acquired knowledge.

Respondents also said that they relied on schools and colleges, particularly those with specialist status e.g. science and technology colleges, to identify gifted and talented students and those targeted under widening participation initiatives.

Q16 What more could be done to help you better identify and recruit promising students in pure science subjects and engineering?

There were 31 responses to this question.

Around half of these considered that they could work more closely with schools and colleges in order to better identify and recruit promising students in pure science subjects and engineering. Having more personal contact between university staff and students, such as working together with them in summer schools or workshops was believed to be a good means of helping the HE sector to target the most promising students and nurture their talent.

A number of respondents thought that the information, advice and guidance available to students needed to be improved in order to raise recruitment levels in pure science subjects and engineering. Given that the HE sector relied on schools and colleges to identify suitable candidates for university entrance, respondents believed that they should:

- be more aware of the requirements for progression to university in science and engineering
- do more to promote these subjects
- understand the progression routes available in order to advise students on choosing the right subjects and courses to equip them for entry to their chosen careers.

Improvements to the curricula and in the teaching of pure science subjects and engineering were proposed by several respondents. In terms of curriculum, it was thought that these subjects should better prepare students to study them at HE level, such as:

- providing more opportunity for students to use quantitative understanding and problem-solving skills by undertaking more investigative work
- mapping the HE curricula across A Levels and vocational courses
- developing initiatives in science and engineering in primary education
- standardising the mathematics curriculum.

Respondents suggested that teaching could be improved by ensuring that science and engineering teachers were well-qualified and able to inspire and motivate their students and that they provided more opportunities for practical work.

A number of respondents were of the opinion that addressing A Level grade drift would enable them to better identify and recruit the most promising students. It was acknowledged that improvements in A Level results in successive years had resulted in many HE applicants achieving top grades, which made it more difficult to distinguish those of the highest calibre. A number of measures were identified as helping to rectify this situation, such as:

- using a broader range of marks
- ensuring that only the top 10% of students achieved the top grade
- providing more detail on individual performance, such as a breakdown of results within each unit
- reconsidering the modular approach to assessment
- introducing the extended project element to qualifications
- widening the use of the International Baccalaureate
- moving the admissions process to follow, rather than precede, exam results.

Q17 Why, and at what stage in secondary school/further/higher education pathways do you think engagement of promising young people in science/mathematics reduces?

There were 38 responses to this question.

There was a range of views on the stage at which the engagement of promising young people in science/mathematics reduced:

17 respondents considered that this occurred at Key Stage 3 (age 11 to 14) particularly around the time that students were making GCSE subject choices and might not be able to take triple science subjects

8 thought that engagement reduced from primary school age, where learning was focussed on preparing for Key Stage 2 SATs

8 said that the transition from primary to secondary education was a key time as if students had not developed an interest or aptitude for mathematics/science in primary school they were unlikely to in secondary

6 said that engagement reduced at A Level stage (Key Stage 5) where many students found the leap from GCSE to be too much to handle.

The main reason for the fall in levels of engagement was identified as poor teaching. The lack of specialist, motivated teachers was blamed for failing to fire the enthusiasm of students in mathematics and science. It was felt that this resulted in formulaic teaching as unqualified teachers lacked the confidence and ability to stray from textbooks and provide more interesting and challenging lessons. Respondents also believed that the absence of practical work made for uninspiring teaching, given that 'hands on' experience as part of learning did much to improve the engagement of students. It was suggested that lack of facilities and restrictive health and safety policies should not be allowed to restrict the level of practical work offered.

A significant number of respondents highlighted the negative perception of mathematics and science as a reason for disengagement. Both subjects were acknowledged as being more difficult than many arts and humanities subjects which could be off-putting. Peer pressure was also mentioned in that mathematicians and scientists were often stereotyped as being 'geeky' and 'uncool' which could deter some students from following these career paths.

Q18 How appropriate are the content and assessment of the national qualifications in science/mathematics (e.g. GCSEs, A-Levels, Diplomas) for ensuring engagement and participation and supporting progression, especially for those students with high potential?

There were 40 responses to this question.

1 Very appropriate
9 Appropriate
18 Not very appropriate
4 Not at all appropriate
8 Not Sure

The majority view was that the content and assessment of the national qualifications in science/mathematics for ensuring engagement and participation and supporting progression, especially for those students with high potential was not very appropriate.

A number of respondents were of the opinion that current assessment regimes were unsatisfactory. The main concern was that students were over-assessed and that teaching had largely been reduced to preparing them for tests and examinations, at the expense of giving them a holistic understanding of the subject and how to apply their knowledge. Respondents felt that the examination system was geared towards answering a question correctly rather than demonstrating an understanding of key principles, reasoning and independent thought. The modular system of assessment for A Levels was criticised for being too piecemeal and it was suggested that the focus on preparing for the AS exam prevented students from immersing themselves in the subject. Recent measures to remove the coursework element from assessment were welcomed.

A significant number of respondents considered that the national qualifications in science/mathematics did not prepare students with high potential for HE. The lack of some qualifications, such as the BTEC National Diploma, to equip students with the numeracy skills they needed for their chosen course at HE was particularly highlighted. Respondents noted the increasing need for universities to provide mathematics support to ease the transition of students to courses with a mathematics component. Other skills which respondents felt qualifications failed to develop in students included: self-study, critical thinking, literacy, problem-solving and familiarity with scientific method.

Around a quarter of respondents believed that the current national qualifications were insufficiently challenging for the most talented students. There was a view that exams had become too easy and that curriculum content had become too shallow. '21st Century Science' and 'How Science Works' were mentioned as failing to stretch those students with the most potential.

Q19 What suggestions do you have for improving engagement, participation and progression from schools and colleges to pure science subjects and engineering in higher education?

There were 37 responses to this question.

The majority of these responses suggested that engagement, participation and progression from schools and colleges to pure science subjects and engineering in higher education could be improved by offering enrichment opportunities to students. Events which were designed to stimulate an interest in these subjects and expose young people to scientists and engineers as role models, it was felt, would help to encourage more of them to follow these pathways. Activities which brought students onto campus were proposed, such as taster days, as well as those which brought HE staff into schools and colleges, for example student ambassadors who could convey their experience of university study and instil enthusiasm amongst students.

A large number of respondents thought that improving the teaching of science and engineering would encourage more students to study these subjects at HE. There were many suggestions for how this could be achieved, such as:

- utilising the expertise of HE staff to tutor in schools and colleges
- incorporating more practical work and project-based learning
- teachers spending time in HE/industry to refresh their knowledge and skills
- encouraging more science/engineering graduates into teaching to impart their specialist knowledge and advise students about university
- making better use of learning resources such as the Nrich website
- increasing pay for teachers to attract the best scientists and engineers
- greater collaboration between schools/colleges and HE to develop curricula and pedagogies
- training and CPD for teachers to keep their subject knowledge and careers advice to students up to date
- teaching generic skills such as how to use reference material

- being motivational and helping to instil curiosity amongst students
- improving mathematics provision given that it underpinned science subjects and engineering.

Greater promotion of science and engineering and the careers to which they could lead was suggested in 15 responses. It was considered that engaging students at primary school age would help to establish more positive attitudes to these subjects and perhaps encourage more to opt for separate science subjects at GCSE. Better marketing of career opportunities through improved IAG and combating the myth that science and engineering were difficult subjects were also envisaged as a means to encourage more students to progress within these fields.

Q20 What skills do you think need to be developed further at school and college to succeed in pure science subjects and engineering in higher education?

There were 37 responses to this question

The most pressing need for skills to be developed further at school and college to enable student to succeed in pure science subjects and engineering in higher education was considered to be numeracy skills, with a majority of respondents identifying this. The lack of mathematics proficiency in students accessing science and engineering courses at HE, even where they held a mathematics qualification, was thought to affect their ability to progress, whilst those who had neglected to take mathematics at A level found themselves particularly compromised. Respondents said that having to provide mathematics support for first year undergraduates in science and engineering was common practice.

Several respondents believed literacy and communication skills to be important. It was felt that standards in this area had declined, given that some students entering HE were unable to construct a coherent essay. One reason suggested for this was the current modular assessment regime where tickbox questions had replaced essay questions.

A considerable number of respondents thought that practical/technical skills could be improved as students currently had little ‘hands on’ experience. Many, it was noted, were unable to apply their knowledge by designing and setting up experiments and lacked expertise in dissection, use of microscopes etc.

Independent learning skills were suggested in 14 responses as something that schools and colleges could do more to foster. This was acknowledged to be a requirement at HE where contact time with tutors formed only part of the course and where students were expected to manage much of their own learning. Greater dependency on teachers in school and college was felt to ill-prepare students for HE study. Respondents also said that it would be helpful if students were taught research skills, particularly using reference and textbooks rather than relying on the internet.

12 respondents identified problem-solving, both independently and in groups, as a necessary skill for science and engineering. It was suggested that this could be achieved by schools and colleges instilling a greater sense of enquiry, investigation and creativity amongst students.

The same number of respondents felt that schools could do more to encourage critical, analytical and logical thinking, such as getting students to build arguments based on reasoning and examination of evidence. It was also noted that students entered HE with limited ability to think laterally and make links between different disciplines.

A number of other skills which respondents felt could be developed further at school and college were identified, such as: teamwork; computer skills e.g. modelling, programming and data handling; and recognising the societal importance of science and engineering.

Q21 What more could schools and colleges do to improve the skillset of science and engineering students coming into higher education?

There were 28 responses to this question

The vast majority of respondents thought that better teaching in schools and colleges would help to improve the skillset of science and engineering students coming into higher education. Suggestions included:

- improving mathematics teaching and encouraging take-up of further mathematics
- ceasing to 'teach to the test' to allow students to investigate other areas and apply their knowledge more broadly than for exams
- using project work to help develop independent learning skills
- encouraging students to research by reading beyond the exam syllabus and being more discerning in what information was appropriate from what was available
- using exercises in lateral thinking to help students develop logical arguments
- increasing the practical element of the curriculum to improve experimentation skills
- improving students' communication/literacy skills through, for example, essay writing and note-taking
- making cross-curricula links between STEM subjects
- undertaking training, CPD and secondments to HE and industry
- employing more specialist teachers and encouraging more STEM graduates to teach in schools and colleges.

A number of responses thought that schools and colleges could collaborate more with HE in order to improve the skillset of science and engineering students. Working together more closely, it was acknowledged, would allow sectors to better understand each others' environment and curricula and determine the skills needed for students entering HE. Advantages of a closer working relationship were identified for each sector in that schools and colleges would gain a better understanding of the requirements of HE courses whilst universities could help to influence the A Level exam specifications.

Q22 How do you provide school and college students with information, advice and guidance about higher education and careers in science and engineering?

There were 37 responses to this question.

A large majority of respondents said that they provided school and college students with IAG about HE and careers in science and engineering through a range of events, such as:

- visits and open days where students were invited to tour the university campus, participate in activities and speak to tutors
- STEMNET careers fairs and UCAS conventions
- residential summer programmes for teachers and students
- Aimhigher events for schools with low HE application rates
- teacher meetings such as the Institute of Physics HE Group
- events for careers counsellors
- parents/options evenings.

Most respondents provided IAG through resources, for example:

- prospectuses and course-specific information packs
- individual university and UCAS websites
- guidance for teachers on HE application and admissions
- student profiles which demonstrated career options.

Where other methods were mentioned they included:

- incorporating IAG as an element of teacher training
- student associate/ambassadors schemes
- media coverage
- mentoring schemes
- compact schemes.

Q23 How could the links between schools, colleges and higher education be improved to support engagement, participation and progression in pure science subjects and engineering?

There were 37 responses to this question.

21 of these believed that links between schools, colleges and higher education could be improved to support engagement, participation and progression in pure science subjects and engineering through enrichment opportunities. Respondents considered that outreach activities supported collaboration between sectors and mentioned many of the examples given previously, such as taster days, seminars, visits and conferences.

Whilst respondents welcomed the National STEM Programme which provided dedicated resources for schools, colleges and HE to work together, 13 raised the issue of funding and resource to make such links possible, particularly in the current economic climate. It was noted that much collaborative activity was undertaken on the basis of goodwill and came at a cost. Paid time for teachers and lecturers, financial support for travel and extra resource to provide cover were suggested as measures to ensure that existing links were sustained and new ones created.

A number of respondents thought that teaching and IAG could be improved. It was proposed that teachers should be encouraged to keep their knowledge current by linking with HE, for example using career breaks to do research or making time to participate in partnership programmes. Respondents also considered that HE could supply academics to tutor in schools and that student ambassadors could act as mentors to provide more up to date advice to school and college students.

Several responses mentioned curriculum support would help to improve links between schools colleges and HE and, as a result, engagement levels by, for example:

- alignment of the curricula from age 11 to 21
- HE input to curricula to make them more contemporary
- co-development of lesson packages
- university lecturers setting GCSE and A Level specifications
- HE development of web-based learning materials to help students prepare for university.

Other proposals for improving links included:

- developing formal partnership arrangements
- making collaboration part of the Ofsted inspection criteria
- reducing bureaucracy in schools to allow more time for link activities
- making links with HE at Key Stage 3 to allow early exposure for students to science and engineering pathways.

SECTION 3: EMPLOYERS

Q24 At what qualification level do you recruit young people with science/mathematics qualifications as part of general recruitment or for specialist/technical posts? (what levels of previous science learning do you look for i.e. GCSE, A-Level, first degree, post-graduate, post-doctorate?)

There were 7 responses to this question.

6 respondents recruited young people with degrees in pure sciences and mathematics for graduate schemes and more specialist posts.

5 respondents recruited young people with A Levels or vocational qualifications for junior posts where training was provided.

4 respondents recruited at post-graduate and post-doctorate level.

3 respondents recruited at GCSE level for Apprentice and Advanced Apprentice posts.

One employer said that they recruited laboratory technicians at Higher National Diploma/Certificate level and equivalent.

Q25 What scientific skills and knowledge are you looking for in non-graduates recruited to your organisation? (Please specify at what level)

The main skills and knowledge employers looked for in non-graduates recruited to their organisation was minimum GCSE level competence in mathematics and science subjects. Other skills and knowledge required included:

- interest/enthusiasm in the job
- common sense/health and safety awareness
- ability to understand and follow instructions
- basic laboratory skills
- organisation
- initiative
- research/analysis
- communication skills
- IT skills/data entry
- ability to work as part of a team
- physical measurement.

Q26a) What barriers are there to recruiting young people directly from school or further education colleges, in particular non-graduate science technicians, with the right science and mathematics skills to undertake jobs in your organisation? (please specify at what level)

Whilst several employers thought that there were no barriers to recruiting young people directly from school or further education colleges with the right science and mathematics skills to undertake jobs in their organisations, others identified the following:

- lack of posts which required school/college level qualifications
- lack of basic training in workshop/drawing/materials as part of the Design and Technology curriculum in schools and colleges
- lack of skills and knowledge in recruits, such as problem-solving, project management and working with people
- lack of funding to enable schools/colleges to equip young people with specialist skills required for local employers.

Q26b) How could these barriers be overcome?

One respondent suggested that barriers to recruiting young people directly from school or college could be overcome by providing volunteering opportunities to give them experience of different working conditions and help them to develop their interpersonal skills. It was also hoped that the planned Science Diploma would enable young people to study science in an applied way, which could motivate them to seek technical roles.

Q27 What skills do you think need to be developed further at school and college to succeed in pure science subjects and engineering in higher education?

Respondents thought that the following skills needed to be developed further at school and college to succeed in pure science subjects and engineering in higher education:

- basic measurement
- knowledge of materials
- problem-solving
- creative thinking
- initiative
- enthusiasm
- concentration
- research.

It was suggested that school and college students should study separate, rather than combined, science subjects and should be encouraged to undertake work experience and internships to better equip them for study in HE.

Q28 How do you work with schools, colleges and universities to improve engagement, participation and progression in science/mathematics?

Several respondents said that they undertook outreach with schools, colleges and universities in order to improve engagement, participation and progression in science and mathematics. Examples of such work included: visits to schools and colleges, providing education sessions, talks and activities such as the Institute of Physics Lab in a Lorry. Two employers said that they offered work experience placements.

Q29 How could the links between schools, colleges, universities and employers be improved to support engagement, participation and progression in science/mathematics?

There were a number of suggestions for how the links between schools, colleges, universities and employers could be improved to support engagement, participation and progression in science/mathematics, including:

- secondments and work experience in industrial settings for teachers and lecturers
- employers gaining a better understanding of the science and mathematics curricula and offering training in particular topics
- national seminars attended by education and employment sectors
- input into education projects by different employers through partnerships with institutions
- mentoring of students by experts in HE and industry
- brokering links between education and employers through organisations such as STEMNET
- employers offering support to young people such as mock interviews, curriculum development, and careers information.

SECTION 4: ALL OTHER RESPONDENTS

Q30 What are the most effective ways of encouraging engagement, participation and progression in science/mathematics, particularly for the most promising students?

There were 47 responses to this question.

The majority (40) respondents considered that the most effective way of encouraging engagement, participation and progression in science/mathematics, particularly for the most promising students was to make these subjects more interesting and current. Many and varied ways to achieve this were proposed and included:

- demonstrating how science/mathematics affects everyday life, using popular culture and current media stories
- providing more opportunities for practical work, undertaking experiments and laboratory investigation
- challenging the most promising students though mathematics and essay competitions, CREST awards etc.
- teaching beyond the classroom, using fieldwork and visits to local employers, for example, to see science in action and provide context to theoretical learning
- offering triple science subjects more widely to provide more depth and stretch for students and promote science study at higher levels
- providing a more challenging curriculum by extending learning beyond exam specifications and reducing the amount of repetition
- engaging the curiosity of students, nurturing their interests, challenging their beliefs and encouraging them to find things out for themselves
- offering enrichment opportunities such as after-school clubs and activities targeted at gifted and talented students.

Just under half of the respondents said that the most promising students could be encouraged to progress in science and mathematics by improved teaching, given that this was likely to result in more students opting to study these subjects at a higher level. It was considered that teachers should adopt a more learner-centred approach, by recognising individual learning styles when planning lessons. There was also a view that teaching should be inspirational and delivered by enthusiastic and knowledgeable people. Lessons, it was proposed, should provide variety, with a mix of interactive activities, discussions, games, workshops etc. supported by high quality resources in order to maintain engagement. Respondents considered it important that teachers kept their knowledge up-to-date through CPD.

Several respondents believed that more could be done to promote opportunities for progression in science and mathematics so that students could see the range of pathways available. Suggestions included:

- illustrating the range of rewarding careers available, to show students the value of science and mathematics, and identifying the qualifications needed and expected salaries
- exposing students to positive role models through visits to industry, work experience, guest speakers, student ambassadors, researchers in residence etc.
- increasing the profile of science and mathematics in the media and having more science programmes on television
- early access to IAG to encourage engagement from a young age

- rewarding and celebrating high-achieving scientists and mathematicians
- educating parents to have high aspirations for their children.

Q31 What are the major barriers to ensuring that young people feel engaged in science/mathematics and that those with the potential progress to more advanced levels?

There were 44 responses to this question.

A majority of respondents identified poor teaching as a major barrier to ensuring that young people felt engaged in science/mathematics and that those with the potential progressed to more advanced levels. Lack of specialist teachers, it was noted, meant that lessons were being delivered by people who lacked knowledge and experience of their subject resulting in dry, factual teaching which did not promote active learning. Respondents also thought that teaching was largely assessment-based with little opportunity to stray from the curriculum and be more creative. Health and safety concerns were also thought to stifle teaching as students were increasingly being prevented from performing their own experiments in favour of observing only.

The negative perception of science and mathematics was thought to be a barrier by 24 respondents. Take up of both subjects was thought to be hampered by the view that they were difficult, boring, irrelevant, not for girls and that better grades could be achieved in easier subjects with less effort. Respondents also cited stereotypical names attributed to mathematicians and scientists such as 'anoraks', 'nerds' and 'boffins' which did little to promote engagement with these subjects. Lack of young role models in these fields was also mentioned, along with the admission from high profile media figures that they were hopeless at mathematics which encouraged students to view this as acceptable.

Around half of the responses to this question highlighted the current curricula and assessment regime as a barrier, believing that young people failed to see the relevance of science and mathematics to 'real life' given the lack of focus on contemporary issues. The curricula were understood to be too prescriptive in that they were geared towards getting young people to pass exams rather than think for themselves. Lack of time in the curriculum was also blamed for preventing the development of a deeper understanding of the topics covered and as a result a genuine interest in what young people were learning. Respondents mentioned the repetitive nature of the Key Stage 3 syllabus and the lack of challenge for the most able students.

13 respondents thought that engagement and progression in science and mathematics was being compromised by poor knowledge of progression routes. It was believed that young people did not perceive these subjects as leading to a range of well-paid jobs as they failed to see how they could apply what they were learning to a possible career. Respondents were concerned that poor IAG services

and lack of media exposure were responsible for young people's ignorance of the rewards and pathways open to those progressing in science and mathematics.

Where other barriers were identified, they included:

- gender bias i.e. failure to attract girls to science and mathematics
- lack of parental support
- low aspiration and self-esteem amongst young people
- lack of funds to provide equipment for practical work.

Q32 Why, and at what stage in a young person's education do you think engagement of promising young people in science/ mathematics reduces?

There were 37 responses to this question.

A substantial majority (30 respondents) considered that promising young people's engagement in science/mathematics reduced at Key Stage 3/transition to secondary school. It was noted that young people's enthusiasm for these subjects in primary school could be deflated on accessing the secondary curricula. Respondents said that learning became more factual, test-driven and repetitive at this stage with less opportunity for learner interaction and practical work. It was felt that this was unlikely to make young people think positively about mathematics and science when considering their GCSE options.

A number of respondents held the view that engagement reduced earlier, at Key Stage 2 (age 7 to 11), given that revision for SATs at this time could be repetitive and dull. It was also suggested that starting on the National Curriculum in primary school could discourage a child's natural curiosity.

There was a view from some that engagement could reduce at any stage within a young person's education, dependent on the curriculum and quality of teaching. It was envisaged that there could be critical points where they failed to connect, such as the introduction of algebra in secondary school or calculus at A Level.

The main reason for reduction in engagement in science and mathematics amongst promising young people was thought to be their lack of interest in these subjects with 21 respondents mentioning this. It was felt that science and mathematics suffered when there was competition from other subjects which young people found more appealing, relevant and fun. Uninspiring, passive teaching which did not challenge the most talented was thought to contribute to this view.

Several respondents believed that the demanding nature of science and mathematics was off-putting and that some aspects of the curricula could be difficult for some to grasp. Fear of failure and pressure to get good grades, particularly at A Level, were cited as reasons why young people could be tempted to opt for easier subjects.

A small number of respondents highlighted the onset of puberty and its effects as a reason for disengagement. Personal changes happening at this time were acknowledged as making young people more susceptible to peer pressure and less likely to want to appear 'uncool' by being enthusiastic about science and mathematics. Respondents also noted that adolescence was a significant time for girls which might cause some to disengage from these subjects, viewing them as unfeminine.

Q33 What suggestions do you have for overcoming the barriers to improving engagement, participation, and progression in schools and colleges?

There were 41 responses to this question

The vast majority of these (37) suggested improving the curricula and teaching as a means of overcoming the barriers to improving engagement, participation, and progression in schools and colleges. It was believed that this could be achieved in a number of ways, including:

- providing CPD for teachers to improve their pedagogies and equip them with the skills and knowledge to make lessons more interesting, active, imaginative, and motivational
- making links between the science and mathematics curricula e.g. by introducing joint topics
- improving transition between the key stages so that there was a better learning continuum and less rehashing of previous levels
- making curricula more relevant by including contemporary issues such as climate change and promoting classroom discussion on science-related issues in the news
- freeing up time within the curricula to allow opportunities to study aspects in greater depth
- adding variety to the learning experience by encouraging research, investigation, groupwork, projects etc.
- taking learning beyond the classroom through fieldwork, visits to industry , science fairs etc.
- abolishing SATs at Key Stage 2 in favour of teacher assessment to reduce the focus on factual recall.

The was a view amongst some that funding would help to overcome the barriers to engagement, participation, and progression. Being able to offer attractive salaries to enable schools and colleges to recruit and retain the best teachers, whilst being able to fund CPD for others, along with supply staff to cover for their absence, it was felt, would do much to improve science and mathematics teaching. Respondents also believed that funding would allow schools and colleges to build and/or equip laboratories, employ technicians and ensure that young people had the opportunity to take part in enrichment activities, such as attending STEM-related events.

7 respondents said that careers advice should be improved in order to demonstrate to young people the range of pathways available to those studying science and mathematics. Promotion of these subjects was advocated to challenge negative perceptions and emphasise the long term benefits and rewards, for example by enabling young people to see mathematics and science in practice by visiting local businesses or undertaking work experience.

Several respondents thought that engaging parents would help, in turn, to engage young people. It was noted that where parents had bad experiences of science and mathematics at school, they were unlikely to convey positive messages to their children. Running courses for parents in these subjects, it was thought, could help to combat misconceptions and would enable them to help support their children's learning.

Q34 What skills, qualifications and experience are most important for a school/college to be able to deliver effective science/mathematics teaching?

There were 46 responses to this question.

A considerable number of these were of the opinion that having qualified and experienced teachers was essential in enabling schools and colleges to be able to deliver effective science/mathematics teaching. They considered that teachers must have a degree, as a minimum, in the subject they were teaching as well as a Post Graduate Certificate in Education to ensure that they were fully competent in their specialism as well as having well-developed teaching skills. Respondents also thought that teachers should have real world experience and should have an awareness of progression routes leading from science and mathematics study.

Half of the respondents said that it was important that teachers undertook regular training and CPD in order to develop their knowledge, skills and pedagogical expertise. Training in hard to teach topics, practical laboratory activities and fieldwork were proposed along with taking up industrial/research secondments in order to enhance teaching and learning.

Enthusiastic teachers were cited as best able to deliver effective science/mathematics teaching by 22 respondents. They stressed that teachers who were passionate about their subject were more likely to convey this to their students and engender in them the same interest. Respondents said that teachers who took an innovative approach to lessons, had the ability to engage with young people and had good communications skills would be most effective.

Respondents raised a number of other suggestions for how schools and colleges could best deliver effective science/mathematics teaching, such as:

- having strong school/college leadership which championed STEM subjects
- giving students access to triple science subjects
- offering a wider range of qualifications to suit all learners
- having a stable curriculum with which teachers could become familiar
- offering more personalised learning.

Q35 What are the most effective ways of providing young people with information, advice and guidance about higher education and careers in science and engineering?

There were 38 responses to this question.

A large number of respondents believed that having access to scientists and engineers in real life contexts was the most effective way of providing young people with IAG about higher education and careers in science and engineering. It was suggested that this could be achieved by, for example:

- young people attending residentials at university
- visiting employers see the range of science/engineering jobs available
- inviting inspirational speakers into schools/colleges and allowing students to interview them
- arranging work experience placements/projects
- running interactive workshops with visiting scientists/engineers
- providing mentors from HE
- encouraging young people to volunteer for relevant activities
- exposing young people to role models such as former pupils or STEMNET ambassadors
- linking with organisations such as the British National Space Centre.

18 respondents proposed that young people should have access to IAG via websites and other electronic media, given that this was the means of finding information with which they were familiar, trusted and found easy to use. Websites such as Futuremorph and MathsCareers were mentioned as good examples and it was suggested that information could be provided on sites that were popular with young people such as YouTube and Facebook. Respondents were keen that websites, online tutorials and e-learning packages should be interactive and feature video and audio in order to sustain interest and encourage more young people to take responsibility for researching information for themselves.

A number of respondents believed that young people could be provided with IAG in school/college, perhaps as part of the STEM curricula, by teachers who had a good knowledge of the available pathways for science and engineering students and who had access to IAG materials. Careers advisors were also thought to be well-placed to be able to help young people, though it was stressed that they should have specialist knowledge of science and engineering progression routes and have good links with HE and employers.

A small number of respondents said that promoting science and engineering was the best way to make young people aware of the HE and career opportunities in these subjects. A media celebration of science/engineering achievement, a television advertisement campaign and the promotion of role models were suggested. Respondents also thought it important to challenge cultural attitudes, so that scientists and engineers were respected and it was no longer socially acceptable to boast about being innumerate.

Q36 What more could be done to improve the skillset of science/mathematics students to help them progress successfully to pure science subjects and engineering in higher education and science-related employment?

There were 32 responses to this question.

The most common suggestion was that students need better numeracy skills to help them progress successfully to pure science subjects and engineering in HE and science-related employment. It was suggested that more should be done to promote the importance of mathematics when studying science and engineering, perhaps by making mathematics study compulsory beyond the age of 16.

Several respondents thought that students should develop problem-solving skills in preparation for HE and employment in science and engineering.

7 respondents stated that the ability to work as part of a team was an important skill that students would need to develop and the same number said that students needed communication and literacy skills to enable them to produce written work, deliver presentations etc.

It was suggested by some that the skillset of those studying science and engineering was dependent on good teaching and suggested that more specialist teachers, training and CPD would help to raise the quality of teaching.

Project work such as that incorporated into the International Baccalaureate, was considered by several responses to help students to develop a range of skills such as teamwork and presenting.

Some respondents were of the opinion that students should be encouraged to improve their independent learning skills particularly to equip them to succeed in HE.

A small number of respondents proposed that students should be proficient in the use of ICT given that this was a generic skill required for higher level study and employment.

Only 4 respondents suggested that work experience opportunities would give students access to the workplace and enable them to understand the skills they needed for future science/engineering-related employment.

Where other measures were identified, they included:

- reviewing the science and engineering curricula and examination specifications to accommodate the requirements of HE and employers
- changing the GCSE and A Level assessment process to more closely resemble that used in HE
- improving links between schools/colleges/HE/employers to ensure students were better equipped for entry to university or the job market.

Respondents highlighted many other skills which they believed would help students to progress to HE and employment, such as:

- research skills
- practical skills
- organisational skills
- analysis
- evaluation
- enterprise
- open-ended investigation
- time management
- note-taking
- leadership
- use of data
- emotional intelligence.

Q37 What skills do you think should be developed further as part of a science education to enable young people to succeed in employment?

There were 37 responses to this question.

Respondents largely identified the same skills which they thought should be developed further as part of a science education to enable young people to succeed in employment, as those outlined in the previous question.

21 respondents said communication skills and literacy i.e. the ability to write reports, emails etc. in clear English and to explain complex issues simply and coherently.

19 respondents said the ability to operate in multi-disciplinary teams and work collaboratively.

15 respondents said numeracy, a grounding in fundamental mathematical principles and the ability to understand statistics.

15 respondents said problem-solving and the ability to apply knowledge to find solutions.

8 respondents said science-specific knowledge and skills i.e. a solid foundation in pure science and proficiency in hypothesis, experimental design, observation, analysis and reporting.

8 respondents said creativity, creative thinking imagination and innovation.

6 respondents said independent learning and self-management.

6 respondents said research skills and information seeking.

6 respondents said management skills, leadership and decision-making.

Many other skills and attributes were thought to be necessary to enable young people to succeed in employment, including:

- business skills, enterprise and understanding markets
- enquiry, investigation and critical questioning
- practical skills and technical expertise
- negotiation skills
- time-management and working to tight deadlines
- organisational skills
- lateral/critical thinking
- use of evidence and interpretation of data
- project work
- ICT skills
- initiative
- reasoning
- objectivity
- evaluation.

Q38 What skills do you think society values in science students and graduates?

There were 24 responses to this question.

Several respondents considered that society valued innovation, creativity and the ability to think differently given that such qualities could lead to imaginative solutions and scientific breakthroughs.

10 respondents thought that the ability for science students and graduates to solve problems was valued and it was suggested that the ability to do this could be linked to competency in mathematics.

Scientists' potential to shape the future was identified by a number of respondents who acknowledged their ability to apply science to improve human wellbeing, find solutions to issues facing modern society and contribute to the economy through research and development.

Several respondents believed that society valued communication skills in science students and graduates in that this enabled them to demystify science by presenting ideas in a simple, understandable and unbiased way.

Other skills and qualities which were understood to be valued by society included:

- numeracy, calculation and accuracy
- analysis
- critical thinking and logic
- ICT skills
- teamwork and collaboration
- research skills
- interpretation of data and use of evidence
- intelligence and academic ability
- practical expertise
- leadership and decision-making
- independent/critical thinking
- objectivity and impartiality
- discipline, dedication, reliability and accountability
- enquiry
- reasoning
- understanding of abstract concepts
- time-management
- ethics
- empathy.

Q39 How could links between schools, colleges, universities, employers and other institutions be improved to support engagement, participation and progression in pure science subjects and engineering?

There were 27 responses to this question.

A majority of these were of the opinion that collaborative activities between schools, colleges, universities, employers and other institutions would help to support engagement, participation and progression in pure science subjects and engineering. Such activities, it was felt, could improve provision, generate interest amongst students, raise their awareness of progression routes, give them real life experience and equip them with the skills needed for entry to HE or employment. Respondents suggested various methods of improving collaboration, such as:

- involving HE/industry in planning and delivering science and engineering provision
- delivering engineering diplomas via consortia
- extending HE outreach
- creating more apprenticeships that led to degree courses
- offering more sandwich years and internships for undergraduates e.g. Project ENTHUSE
- providing work experience for students on vocational programmes
- developing networks, both actual and virtual, across sectors
- encouraging STEMpoint providers to work with local authority advisors
- organising visits for students to employers
- mentoring of school/college students by graduates
- encouraging teachers to take up work placements in HE/industry
- making collaboration/partnership part of inspection regimes.

Several respondents thought that engagement, participation and progression in pure science subjects and engineering could be improved by the various sectors sharing good practice. It was acknowledged that the 14-19 curriculum had provided a framework for schools and colleges to do this. Respondents believed that enabling them to tap into the knowledge and expertise of employers and universities, for example through training, and making use of their facilities and resources would improve provision to their own students.

There was a view from several respondents that employers could do more to link with schools, colleges and HE. Whilst it was accepted that there were financial and heath and safety implications associated with outreach activities and work experience placements, it was suggested that incentives, such as tax breaks, might encourage more employers to collaborate. The development of national occupational standards in employer engagement was mentioned as a way of encouraging more employer involvement.

Respondents also highlighted financial and organisational problems for other sectors, noting that making and sustaining links came at a cost and, as such, should be recognised and funded appropriately. Freeing up school and college staff to devote time to this and the logistics of transporting large groups of students for visits were cited as obstacles to collaboration.

A selection of responses

Q1 How does your school/college encourage engagement, participation and progression in science/mathematics, particularly for the most promising students? (please use specific examples where possible)

Lessons have clear learning objectives which are shared with pupils and practical, investigative work is used alongside a wide variety of other teaching and learning activities, including guided research on laptop computers, team tasks and discussion to maintain high levels of engagement and interest. Year 9 pupils who are working at level 6 or above are offered a Triple Science GCSE course which is completed in the same lesson allocation as other pupils complete Core and Additional Science or BTEC Applied Science Certificate or Diploma. This means that more able scientists do not have to give up another option in order to choose Triple Science and we can be more flexible over pupil-numbers. GCSE Psychology is being offered from Sept 2009 as an after-school option. The wide variety of courses available at Key Stage 4 helps to maintain engagement across the full range of ability.
(Secondary School Teacher)

Relevant courses to engage enthuse and interest pupils. Use of OCR 21st century science course to stimulate interest at KS4 and to highlight relevance. Introduction of ASE WIKID course at KS3 to demonstrate skills, relevance and careers. Two other courses offered at GCSE – additional for more academic/science enthused pupils and additional applied to engage less motivated pupils.
(College Lecturer)

Making lessons at KS3 as engaging and practically based as possible. Years 7 and 8 in particular are almost entirely taught through practical work. Avoiding KS3 SATS has also helped to generate a more dynamic KS3 curriculum, and enabled us to start GCSE work earlier.
(Secondary School Teacher)

Q2 How do you identify and provide stretch and challenge for the most promising students in science/mathematics?

Value Added mechanisms that give a points score on entry should be used to give students a target minimum grade, as well as an aspirational target. Arrange for students to attend master classes offered by local HEIs. Provide tailored learning exercises to include a variety of approaches to problem solving. Take advantage of the Aim Higher support that is available. Provide differentiated delivery – specific additional tasks in lessons – and get the more able students to help/teach/explain to others. Include additional questions in written work to stretch the more able.

Use AS Further Maths to stretch Maths AS.
(Association of Colleges)

Variety of teaching styles and topics to engage pupils. Teachers attended National Science Learning Centre courses on enthusing and engaging pupils. Pupils offered opportunities to attend university courses, chemistry jamborees etc.
(Secondary School Teacher)

They are identified by their progress in their courses. Challenging material is provided for the ablest students. Participation in project work and essay competitions is encouraged.
(College Lecturer)

Q3 What are the major barriers inside or outside your school/college to ensuring that students are engaged and participate in science/ mathematics, and that those with the potential to do well progress to more advanced levels?

Some pupils lack confidence in Maths from an early age, and this can affect their attitude to Physics; parental expectations (in quite a small minority of cases) can be that Maths and Physics are hard and possibly not too important for girls.
(Secondary School Teacher)

Lack of teaching time, and an overly prescriptive curriculum. If there was more freedom for science teachers to pursue project work and let students pursue their own interests as a significant chunk of academic awards, and if the prescribed content was much more limited, then the whole subject could be brought to life much more interestingly. In addition there would be time for additional trips, visits, talks, and extra curricular enhancements.
(Secondary School Teacher)

In this area (W. Midlands) there are few local high profile Science situations. Our Y10 students hardly ever go into a Science environment. The current maths curriculum is a mess so it doesn't provide the previously natural link to support GCSE or A-level Physics. Lack of high profile careers material for Y7 & 8 – Brainiac does its best but once we don't blow things up all the time we're seen as second best.
(Secondary School Teacher)

Q4 Why, and at what stage in secondary school/further/higher education pathways, do you think engagement of some promising young people in science/mathematics reduces?

The group felt that in general careers guidance in schools does not present the range of jobs and career opportunities in science, and that there is an urgent need to improve careers education 'not all chemists wear white coats'. There is a perception that science jobs need a high level of qualification achievement, and the range of technical jobs available below degree level is not understood. There are not many role models of scientists for young people. Science is not 'whizzy' or modern enough in its approach and there is a need to explain relevance of science to young people. (Association of Colleges)

For some, repetition of earlier work (spiral curriculum bores them – especially most able). The experience of students in secondary schools in our region can differ widely not just from school to school but from teacher to teacher. One class may get a completely different slant on the curriculum from another because the teacher may not be a specialist in a subject and may therefore not feel competent to include many practicals. Many of our feeder schools have small departments and may therefore not be able to timetable specialist teachers for science at GCSE level. (College Lecturer)

There is little doubt that engagement is reduced as the students are pushed through the revision process for the exams. At all other stages, they should be engaged. Clearly, a specification which has a low physics content, coupled with teachers who are not physics specialists (i.e., have a physics/engineering degree) is likely to impose its own restrictions upon the students.
(Secondary School Teacher)

Q5 How appropriate are the content and assessment of the national qualifications in science/mathematics (e.g. GCSEs, A-Levels, Diplomas) for ensuring engagement and participation and supporting progression, especially for those students with high potential?

Some GCSE exam boards seem to give inadequate content (or it may have been taught differently). As a result many students (but particularly the weakest) find AS daunting and the failure rate is high (especially in my subject, chemistry). I find it impossible to prepare students adequately for the AS exams in the teaching time which I have allotted.
(College Lecturer)

GCSE content is appropriate but assessment lacks challenge for higher level pupils.
(College Lecturer)

The last review of GCSE and A level have been excellent. We simply need some time running these systems to make them work perfectly. Small problems still in them will disappear as we get good at solving them.
(Secondary School Teacher)

Q6 What suggestions do you have for overcoming the barriers to improving engagement, participation, and progression in schools and colleges?

Increase science investigation units and use qualified science teachers to deliver science units.
(College Lecturer)

Lessons led by subject specialists using practicals to inform the teaching. Good links between schools and universities to allow students to experience university life at first hand. Funding to allow science students to pursue a degree without

having to worry about paying back 'borrowed' money.
(College Lecturer)

Improved assessment of the Sciences at GCSE. The emphasis on How Science Works has been successful in some ways but has really gone too far; a greater mathematical rigour should be rewarded for all students; triple science must be more readily available for all students of sufficient calibre since a separate GCSE in a science has to be a sensible foundation for study at sixth form level.
(Secondary School Teacher)

Q7 What skills, qualifications and experience are most important for a school/college to be able to deliver effective science/mathematics teaching, which provides appropriate stretch and challenge for the most promising students?

At secondary and FE level it is important that teachers have a high level qualification in the subject they are teaching and a teaching qualification. They and their primary colleagues should also have access to stimulating subject-based INSET and networking opportunities.
(College Lecturer)

Passion for the subject, motivation to keep learning new skills, concepts, knowledge etc.; evidence of further study (degree) and/or work-related experience in combination with teaching qualifications; ability to see potential and an enthusiasm to nurture.
(Computing at School)

The right balance of teaching staff within a department to meet the needs of the students. The most promising students need at least one expert teacher who has deep understanding of their subject such that they can go well beyond the curriculum and inspire the students with higher level discussions. I'm thinking in particular of A-level teaching when you really need a very good grasp of your subject to teach it in sufficient depth.
(Secondary School Teacher)

Q8 a) Do you consider that your school/college has the necessary capacity and expertise to deliver single subject science/mathematics effectively for the most promising students?

Teachers are receiving training in chemistry and physics through SASP.
(College Lecturer)

Without a shadow of a doubt. We have the teaching staff, the infrastructure, the equipment and very importantly, the full support of the SMT and trustees.
(Secondary School Teacher)

Timetabling is difficult in a school where the majority will still do double science GCSE. Lack of specialist teachers (particularly chemistry and physics).
(Secondary School Teacher)

Q8 b) If not, why not and what could be done about it?

Partnership provision in a local area of the full range of A-Levels and Diplomas. (Association of Colleges)

A generation ago, there was greater cross fertilisation between school and university staff and syllabuses. School Federations should be funded to pay for the direct involvement of higher education staff and learning experiences of a higher level. (Secondary School Teacher)

Q9 How and when do you provide information, advice and guidance about higher education and careers in science and engineering?

General careers advice and one session on science careers. We also offer taster HE sessions with HE lecturers for our own and surrounding FE colleges. (College Lecturer)

From when they arrive informally – asking students what their long term plans are, discussion of the A level curriculum in terms of 'what happens next'. Formally during tutorial sessions from mid AS year onwards including trips to HE conventions, discussions with Connexions leading to applications through UCAS. (College Lecturer)

Futuremorph resources in process of being integrated into our year 7 and 8 courses. Year 9 advice available when they choose their options. Year 10 and 11 on 1 to 1 basis and through connexions service. (Secondary School Teacher)

Q10 What more could schools and colleges do to improve the skillset of science/mathematics students to help them progress successfully to pure science subjects and engineering in higher education and science-related employment?

More cross curricular links between Science and Maths, especially Physics and Maths to build core skills at an early stage in secondary education and also for students to understand how to apply their Maths skills. How Science works helps to develop better 'Scientists' but does remove some content to allow it to be fitted in. (Secondary School Teacher)

Accelerate the learning for more able students. More one-to-one support to build skills for less able students. (Secondary School Teacher)

In-depth studies in certain topics (perhaps as an option) to get over the superficiality of most of the GCSE courses. (Secondary School Teacher)

Q11 How do HE and employers help you understand the science-related skills and knowledge they are looking for in their potential recruits?

The work of the Diploma Development Partnerships has helped this, and Diplomas should now include the skills needed by each occupational sector.

The links that Colleges have developed with their local universities as part of the process of the validation of Foundation Degrees, has been useful for the sharing of expertise and experience between organisations. Within National Diplomas, Colleges can direct the content in line with the needs of local employers because it is indicative rather than prescribed. Through Access provision in which there are close links between the College and local university. The group felt that the Extended Project provides the opportunity for students to gain an understanding of the skills needed by HE and employers. The group felt that employers need to be involved in qualification development as many of the current qualification specifications are very out of date and need to be reviewed. Sector Skills Councils were also seen to have a role here.
(Association of Colleges)

They have a lack of understanding about the content and assessment of the different GCSE courses. They look solely at raw grades and have no idea about the different types of course. Far greater overlap and communication between tertiary and secondary is needed.
(College Lecturer)

Very little is passed back to those of us in Secondary Education. It would be good to liaise with HE and employers so that students can see why they are studying certain skills and topics.
(Secondary School Teacher)

Q12 How useful is information from higher education and employers in preparing your students for progression in pure science subjects and engineering?

HEIs have a significant role to play, if only to communicate desired expectations beyond an expected grade or UMS point for entry. There is more opportunity esp. re. CPD for teachers. Hosting groups, guest lectures, access to Uni facilities etc. There is a need for coherent progression across all key stages leading to undergraduate study. This is currently absent from computing.
(Computing at School)

All we seem to get are prospectuses and fancy posters for the wall. How about a dialogue? How about some visits to talk to Y9, Y10, Y11, Y12, Y13 –having a hand throughout the latter stages of education?
(Secondary School Teacher)

Such material is dominated by a few prestige employers (such as pharma) and institutions and this doesn't reflect the breadth of possible careers and roles for science and engineering students.
(Secondary School Teacher)

Q13 How could the links between schools, colleges, universities and employers be improved to support engagement, participation and progression in pure science subjects and engineering?

The group felt that there need to be links to universities on systematic basis, and that universities need to commit to this and to provide a subject specialist to 'sell' the department – simply having a generic admissions tutor does not suffice. Visits from universities into colleges, including the sharing of staff where university lecturers come into the College and teach. Compact schemes with guaranteed interviews are a good way of bypassing some of the mystique of the HE applications process for those without prior experience of HE. Through the provision of masterclasses at universities. Support for field work with co-teaching. Greater awareness in colleges and universities of the benefits of Foundation years/Year Zero.
(Association of Colleges)

Employers are very poor and have been for years. Two years ago, I wrote to 30 companies who were part of the UK's engineering base, and asked for the opportunity to discuss university support for one of our students – only three replied, with only one interested in meeting the student. That is how poor they are. Government should provide incentives beyond the present ones, to allow industry to support students in this area – with work during vacation times, and financial support where possible.
(Secondary School Teacher)

Ensure that employers and universities are extensively consulted by QCA when planning changes to the curriculum which will impact them. Avoid links with employers that are purely done to advertise their brand in schools.
(Secondary School Teacher)

Q14 How do you engage with schools and colleges to widen participation in science/mathematics and support progression to pure science subjects and engineering in higher education?

It seems to me that there is little encouragement (and no institutionalised means) for University teachers in general (i.e. those not hired specifically into 'access' posts) to 'engage', and that science and maths teachers suffer likewise from a dearth of institutionalised means of going beyond what is beginning to look like a threadbare and formulaic official curriculum.
(Oxford University)

As a university we have an active engagement with local primary and secondary schools, tutoring, mentoring, master classes, visits to HE, summer schools in engineering with the Smallpiece Trust, placement years in schools to tutor maths and science etc.
(Aston University)

The Faculty is represented on local teacher networks and is involved in local initiatives to create 'science centres'. Faculty staff are members of the governing

bodies of local schools and colleges. Staff are engaged in national initiatives to raise the profile of science, largely through engagement with learned societies. The University runs a number of schemes to break down barriers to entering HE (e.g. 'UP for it' – http://www.upforitclub.org.uk/). One department (Sport and Exercise Science) has run a very successful bridging unit to encourage progression from FE to HE and other departments are considering doing the same.
(University of Portsmouth)

Q15 How do you identify the most promising pure science and engineering students from schools and colleges?

We depend largely on information contained within the UCAS forms, e.g. predicted A-level grades and personal statements. Schools sometimes request additional support for particularly talented young people. Others are identified on the widening participation programmes, particularly the Wales Summer University where teaching is provided by Science Departments.
(Aberystwyth University)

By their UCAS application and interview. Generally those with A-levels are easier to compare in ability, those from vocational qualifications vary very widely, especially between different FE colleges.
(Kingston Maurward College)

Consideration of contextual information (including taking into account any particular barriers the candidate may have faced during their education such as spending time in care) is an important part of admissions procedures. The candidate's academic success is therefore considered in a broader context.
(Newcastle University)

Q16 What more could be done to help you better identify and recruit promising students in pure science subjects and engineering?

Clear mapping of science and engineering curriculum across A Levels, Diplomas and the full range of vocational qualifications with the support of The Royal Society and leading science academics would aid the recruitment of the most promising students. The availability of such information would ensure that students could make more informed choices about Level 3 qualifications and admissions tutors would have a better understanding of the suitability of qualifications as a preparation for HE level learning.
(Kingston University)

Although we could do more by working closely with schools and perhaps offering opportunities (such as placements and science clubs) for their most gifted young scientists, what we really need to do is to increase school-level engagement with the sciences. Whatever add-ons are available it is the teachers in schools who will have the dominant impact on the choices that pupils make, so we have to ensure inspirational science teaching across the sector.
(University of Portsmouth)

More work could be done in schools to help promote science and engineering-related subjects and careers. More engagement between universities and schools to develop talented students in science and engineering subjects and improved methods of assessing the effectiveness of initiatives and their impact on students. Greater understanding in schools of the value of science and engineering degrees in terms of future employment. Improvements in the accuracy of grade predictions provided as part of the UCAS application.
(University of Nottingham)

Q17 Why, and at what stage in secondary school/further/higher education pathways do you think engagement of promising young people in science/mathematics reduces?

Students seem to become demotivated on entering secondary education. They are constantly assessed and tested and this removes the flexibility from the teaching. In addition practical based programmes are being reduced and there is little scope in the STEM curriculum for employer led insight into the reality of STEM in careers.
(Aston University)

Young people rarely see skilled STEM professionals in psychologically, socially and economically successful settings and too often the stereotypes that persist in schools and colleges about vocational courses serve to reinforce a stratified nature of STEM professions. In addition, the lack of highly skilled and appropriately qualified teachers in STEM subjects, limited resources and facilities in schools and colleges, the failure of Local Authorities to work across borough borders to share resources and the fear of health and safety issues all serve to make STEM subjects less exciting and less challenging.
(Kingston University)

One of the central beliefs underpinning the 14-19 Education and Skills White Paper is the view that 'young people begin tacitly to make choices early' and that those 'starting Year 11 with the view that they will leave education very rarely change their mind over that year. Similarly, we might expect young people's decisions about learning from 14 to be formed by Year 9'. RCUK wants to engage young people with research not just to support any who might be considering research careers and higher education, but to enhance all young people's learning experiences with the vitality that research and researchers can bring to a subject. We also want to help make sure that more young people get to know about the wide range of career opportunities available to them through research. RCUK believe that it is important to reach secondary pupils of all ages, not just post-16.
(Research Councils UK)

Q18 How appropriate are the content and assessment of the national qualifications in science/mathematics (e.g. GCSEs, A-Levels, Diplomas) for ensuring engagement and participation and supporting progression, especially for those students with high potential?

The new A-level and GCSE curricula seem better, but the impact of these remains to be seen. The new Diplomas are a rather unknown quantity. Assessment is a real issue, and it is clear that teaching to the exam has done no favours for anyone. This is something that has to be tackled across all levels and all areas of education.
(University of Portsmouth)

Many students find GCSE Mathematics and Science relatively easy, but are then unprepared for the jump in level expected for AS level. This especially appears to be the case for Mathematics. Current qualifications may be good at measuring achievement, but that is very different from encouraging progression.
(Aberystwyth University)

We have to accept that teachers will always want to maximise their students' performance in external tests. So those tests must be fit for purpose, not just driven by what is easy to measure. Some testing is of poor quality, especially: 'How Science Works'; mathematical aspects of science; and practical work. The assessment framework in science gives students few opportunities to follow their own interests and develop their understanding of the broad narratives and big questions in science.
(Science Learning Centre West Midlands)

Q19 What suggestions do you have for improving engagement, participation and progression from schools and colleges to pure science subjects and engineering in higher education?

Provision and take up of subject specific activities- particularly Taster Days at an early age. Availability of schemes encouraging the use of subject student ambassadors in schools and colleges. Subject specific relationships between staff in schools, colleges and HE. Awareness of various local progression routes (by learners, school and college staff and HE staff). Promotion to school and colleges learners of career opportunities after graduation.
(Kingston University)

We tend to focus our efforts towards helping what are probably the best and most inspiring teachers (they are proactive in working with us), but to improve the uptake of STEM subjects we need to work with the school sector more widely. This will require HE institutions and professional bodies to be far more proactive in broadening their engagement with teachers and supporting them in both challenging and engaging their pupils.
(University of Portsmouth)

To improve progression rates we recommend: encouraging the formation of informal partnerships from Primary to Higher Education level, allowing students

to become familiar with the concepts and learning style at HE from an early age; allowing progressive learning – subjects covered at KS2 should be truly developed at KS3, not by bolting on new areas of knowledge but by allowing exploration and experimentation; and that STEM should be taken out of the classroom, giving students information about careers, impact of STEM on their lives and the influences that new technologies (and they as scientists) could have. They need to appreciate the value of research and discovery.
(University of Central Lancashire)

Q20 What skills do you think need to be developed further at school and college to succeed in pure science subjects and engineering in higher education?

Emphasis on the nature of evidence and how it can be validated; development of quantitative thinking; emphasis on the societal importance of science and engineering and refutation of anecdotal and misinformed attacks on science.
(Boston University)

In particular there is a need to: improve the Mathematics curriculum at GCSE and A Level to encourage depth of understanding, especially of interconnectedness of topics; encourage independent learning and a spirit of enquiry amongst the very talented; reduce the mechanistic elements in the curricula; increase the weight given to quantitive and experimental work; and improve pre-university academic writing skills.
(University of Cambridge)

Research is becoming more interdisciplinary in nature, and this needs to be more fully reflected in STEM education, for example, how natural phenomena need to be understood using an integrative approach drawing on a variety of scientific perspectives, or how techniques developed in one area may be successfully transferred to another. Although this is becoming more widely recognised – for example the core content of the new Science Diploma has links with the RCUK multidisciplinary Grand Challenges – it is unclear whether or how much teaching at secondary and tertiary levels is adapting to these needs.
(Research Councils UK)

Q21 What more could schools and colleges do to improve the skillset of science and engineering students coming into higher education?

Opportunities for school, college and university staff to learn about each other's educational environments and curricula would enable better identification of the skills young people need to be successful in STEM subjects.
(Kingston University)

Better training and rewards for science teachers, including more exchanges with HE and industry.
(University of Hertfordshire)

We believe that schools/colleges need to be given the freedom to stop teaching to the test and allow students to investigate areas of STEM. Further training needs to be given to enable teachers to carry out practicals. Subject enhancement for teachers should be ongoing to ensure that teachers remain interested, enthused and able to demonstrate up-to-date knowledge.
(University of Central Lancashire)

Q22 How do you provide school and college students with information, advice and guidance about higher education and careers in science and engineering?

Information is sent to schools. It appears, however, that schools are swamped with information and it is not clear that the information received has much impact. Loughborough University also holds regular open days, which are very well attended, and participates in HE fairs across the UK. These events all provide opportunities for the dissemination of information and advice.

(Loughborough University)

We support careers fairs whenever invited and are also involved in national projects run by various bodies (e.g. STEMNET, Institute of Physics, Royal Society of Chemistry, Biosciences Federation etc.) to improve the delivery of careers advices in schools, which has long been a weakness in STEM subjects.
(University of Leicester)

A vast amount of information for potential applicants, teachers and other advisers is provided through University and subject prospectuses, websites, and specific course information brochures. Information about individual courses and related career options are also provided to applicants through the UCAS website.
(Newcastle University)

Q23 How could the links between schools, colleges and higher education be improved to support engagement, participation and progression in pure science subjects and engineering?

Paid time for linked activities at both school and HE end. It is unrealistic to expect people to take in extra work at the expense of current pupils/students. E.g. reduction of SSR by 10% in HE would provide this time. Incorporation of work increasing science uptake from schools in appraisal and reward system.
(University of Hertfordshire)

More university lecturers need to be involved in setting GCSE and A level specifications. Teachers need to be given more time to engage with universities. Although we hold teacher open days, many say that they find it difficult to take a day out to come (particularly those from the state sector).
(University of Oxford)

We need formal links between the HE sector and both schools and colleges, and we need to provide all of them with information about what we have to offer. We could and should make better use of our existing students as ambassadors for

their subjects and maybe as mentors. It needs to be stressed, however, that this is new activity and it cannot be accommodated within the already inadequate budgets for teaching STEM subjects.
(University of Portsmouth)

Q24 At what qualification level do you recruit young people with science/mathematics qualifications as part of general recruitment or for specialist/technical posts? (what levels of previous science learning do you look for i.e. GCSE, A-Level, first degree, post-graduate, post-doctorate?)

Entry requirements for Apprenticeships are usually 3-4 GCSEs at grades D-G. For Advanced Apprenticeship (the level at which half of Engineering apprentices are recruited) the requirements are usually 4-5 GCSEs at A*-C including English and Maths. Some large companies operating in a challenging technical environment prefer to recruit young people after AS or A level.
(Semta)

At all levels from GCSE/A-levels for our apprentice scheme, to first and second degree graduates for our graduate scheme. We also recruit a small number of post-doctorate candidates.
(Astrium Ltd)

Q25 What scientific skills and knowledge are you looking for in non-graduates recruited to your organisation? (please specify at what level)

The typical skills required to work in science and engineering companies are: appropriate technical skills and experience at level 2, 3 & 4; functional-type skills in communication, numeracy and IT level 2; team-working ability; ability to follow instructions and understanding of technical communications; health and safety awareness and consideration.
(Semta)

Good scientific and maths grades. Desire to work in a commercial research environment.
(National Physical Laboratory)

Q26 a) What barriers are there to recruiting young people directly from school or further education colleges, in particular non-graduate science technicians, with the right science and mathematics skills to undertake jobs in your organisation? (please specify at what level)

Part of the issue is a tradition of recruitment of graduates and post-graduates into these kinds of roles, which means school leavers are seldom considered for such posts. Previously, there was little formal training or national occupational standards for technician level skills.
(Semta)

No particular barriers however our apprenticeship scheme is quite small and specialised, involving combination of electrical and mechanical engineering, so it is difficult for the local FE college to find funding, especially against competition from local private sector training suppliers.
(Astrium Ltd)

Q26 b) How could these barriers be overcome?

We hope that the new Science Diploma will provide young people with the opportunity to study science in an applied way, which will in turn motivate them to seek technical roles at 16 and 18, as well as going on to higher education if appropriate.
(Semta)

Q27 What skills do you think need to be developed further at school and college to succeed in pure science subjects and engineering in higher education?

Need to study all science subjects separately to have a good understanding of what they are about. Good careers advice very early, so students can see the potential of a STEM qualification and where it might take them.
(National Physical Laboratory)

A greater emphasis on some of the practical applications of science in engineering would help to sell the career options. More encouragement of work experience and internships, as a fundamental part of achieving a qualification, not just as a nice to have for the few motivated students.
(Astrium Ltd)

Q28 How do you work with schools, colleges and universities to improve engagement, participation and progression in science/mathematics?

We run a large Science Ambassador Scheme with over 10% of our workforce involved in our 'bringing science to life' campaign, aimed at local schools – we provide talks, lectures, activities and tours all to raise our profile and the profile of science. We also run join activities with the Local Borough. We have won external awards for our outreach campaign.
(National Physical Laboratory)

We have a very active SEA community visiting many schools and colleges, as well as hosting many site visits.
(Astrium Ltd)

Q29 How could the links between schools, colleges, universities and employers be improved to support engagement, participation and progression in science/mathematics?

We advocate the use of organisations such as STEMNET, Education Business Partnerships, and Trident to broker links between education and employers in our sector. We also encourage employers to look beyond the most obvious

engagement activities (such as work experience) to things like project support, mock interviews, curriculum development, and careers information.
(Semta, Claire Donovan)

Real-world examples in coursework. Links with local employers about the issues they deal with.
(Jeremy Hodge)

More encouragement of industrial secondments and work experiences for teachers and academics so that they can experience and better understand the industrial environment for which they are preparing their pupils and students.
(Astrium Ltd)

Q30 What are the most effective ways of encouraging engagement, participation and progression in science/mathematics, particularly for the most promising students?

The science world needs an exciting and engaging curriculum that leaves room for teachers to learn and to innovate and allows the freedom to adapt quickly to changes in the landscape. It must develop content that is up-to-date and skills that students want to learn rather than being bogged down in thinking about how to pass their next test. There must be an attempt to fill the knowledge gaps of non-specialist teachers and develop their intrigue in the subject. Ultimately, science, like all subjects, needs inspiring teachers to inspire the young people they teach.
(Association of Teachers and Lecturers)

Essential requirements are that of (i) a curriculum and qualifications structure that is conducive to providing students of all abilities and ambitions with a solid, stimulating grounding in science and mathematics; (ii) sufficient numbers of teachers with specialist knowledge of these subjects capable of bringing these subjects to life, and of challenging, supporting and motivating their students so they may fulfil their potential in them; (iii) appropriate mechanisms of assessment that put emphasis on enabling students to show understanding of scientific concepts and apply mathematics as opposed to reproducing facts and testing numerical skills; and (iv) the demand among employers, and in wider society, for STEM professionals.
(The Royal Society)

High quality teaching and learning opportunities, which are relevant, inspirational and link theory and practical effectively. Such teaching includes variety, promotes discussion, challenges through differentiated tasks and checks understanding regularly. It is imperative that employers, HE and other stakeholders contribute to the design and delivery of programmes, to clearly identify to learners the progression opportunities available.
(National Science Learning Centre)

One of the most effective ways of encouraging engagement of the most promising students in science/maths, is to offer a more challenging and differentiated

curriculum that goes beyond the exam based norms. This could take the form of extended practical projects which may have relevance to examination work but could also be something that is identified naturally within the school/college environment or for a local community project. The importance of practical application is paramount. This could also be explored in workshops provided by local HE establishments or regular visits to such institutions with a project forming the base of a half term placement for example. Likewise a similar methodology could be used in terms of a link with a local employer where a particular need has been identified and a targeted outcome expected. Another way to engage young people is by giving them mentoring opportunities with younger children likewise identified with similar interests and talents.
(Association of Managers in Education)

Q31 What are the major barriers to ensuring that young people feel engaged in science/mathematics and that those with the potential progress to more advanced levels?

The emphasis on passing examinations and scoring points for league tables puts pressure on teachers and students to concentrate on those aspects of education which will receive recognition in the performance tables. The things which engage some students are not in the examination and so they can be missed out with a consequent impoverishment of the curriculum that students experience. Some schools are concerned about getting enough students to pass 5 GCSEs at grade C+ so may not give sufficient attention to stretching the more able leading to their disengagement. Other schools are concerned about getting high points scores so students are entered for a large number of qualifications and may be too overburdened to enjoy learning.
(Mathematics in Education and Industry)

It is widely viewed by pupils that the most popular part of the science curriculum is the practical work, while there is far less enthusiasm for written work. In a survey of over 1,000 UK secondary students by the examination board OCR in 2005, over 50% said science lessons were boring, confusing or difficult and that experiments are the best thing about learning science.
(Field Studies Council)

In some schools teacher turnover affects student engagement. Teaching is very much about relationships and trust. The schools which offer the greatest level of enrichment tend to be those with the lower staff turnover rates. Where turnover is high, pupil behaviour deteriorates as they become disengaged. This makes it hard for new entrants to the school and a spiral of decline can result.
(Kent County Council)

The curricula are very broad, prescriptive with large amounts of material. Teachers are not necessarily informed or enthused about all aspects of the curriculum and teaching can reflect this. Mechanical and assessment-based teaching does not

allow students to become engaged and have some ownership of the subject.
(Biosciences Federation)

Q32 Why, and at what stage in a young person's education do you think engagement of promising young people in science/mathematics reduces?

Young people entering Year 7 are inspired by the new practical learning opportunities, the access to laboratories and 'real science teachers', this enthusiasm tapers as they progress through their secondary education and focus more on the knowledge and understanding that is required to obtain the appropriate grades for further study.
(British Ecological Society)

KS3 is a crucial time in science and maths education. It is the defining moment for many pupils. If a pupil's experience at KS3 is dry, stale and test driven then pupils tend to think that this will be their experience at KS4 and KS5 too. Once these attitudes are formed disbelief in maths and science are often reinforced especially if they experience poor quality teaching and no application to real contexts.
(London Borough of Enfield)

The research seems to show many KS2 children are motivated for science, but that this diminishes at KS3 and does so further at KS4, as science becomes more remote and difficult for pupils to understand and to engage with.
(Earth Science Teachers' Association)

Q33 What suggestions do you have for overcoming the barriers to improving engagement, participation, and progression in schools and colleges?

ATL believes that careers education that supports participation in learning and raises aspiration can be of benefit to individual young people and society as a whole, as well as a school and its workforce. By working with partners in the community, schools can fill their own knowledge gaps around science careers and learning, provide impartial information and inspire young people to progress in science.
(Association of Teachers and Lecturers)

Guaranteed opportunities for teachers to undertake professional development related to their subject specific knowledge and interests rather than pure pedagogical content. Commitment to creating learning opportunities beyond text book and rote classroom learning. Greater links between schools, HE and relevant institutions to provide access to resources schools may not be able to access otherwise, e.g. electron microscopes, telescopes. More specific links being made between the science taught and the big problems being experienced in the real world (e.g. global food shortage, climate change).
(British Ecological Society)

Opportunities for parents, teachers and pupils to learn together, and for parents to develop skills and confidence in supporting pupils' learning, can raise aspirations, engagement, participation and progression. The Museum hosts many school trips every year involving pupils, parents and teachers where parents can become involved in the learning experience.
(Natural History Museum)

Breaking down the negative cultural image of mathematics will require a holistic and long-term focus across a range of areas. In particular, championing the role of enhancement and enrichment activities within schools will help to challenge the misconceptions of mathematics by students and help demonstrate the wider relevance and significance of the subject. Moreover, improved careers, information advice and guidance (CIAG) which will illustrate the careers and higher education options available to those who study mathematics (particularly beyond 16).
(Advisory Committee on Mathematics Education)

Q34 What skills, qualifications and experience are most important for a school/college to be able to deliver effective science/mathematics teaching?

Teachers that have a sound subject knowledge, excellent pedagogy and are experienced. A stable curriculum which staff have had time to engage with, make their own and refine. Teachers need to have a passion for their subjects, but it is also vital that they have an excellent understanding of their subject in the real world, not just in a traditional school, FE, teaching context.
(London Borough of Enfield)

Good leadership within the school which values the importance of science and promotes its study and a supportive and objective Board of Governors is important as is good IT support and library facilities. Adequate facilities/resources and training for those with limited laboratory experience undertaking practical teaching, and well trained technicians and removal of any health and safety barriers that prevent practical and field work.
(Biosciences Federation)

For science and maths teaching to be effective the workforce needs teaching skills, subject knowledge and related work experience. These need to be current and of high quality. In FE we support this dual professionalism through Business Interchange and Pass on Your Skills for example. One area of current debate is the role of research in successful teaching.
(Lifelong Learning UK)

In terms of the skills needed by schools and colleges to engage young people, staff involved in such projects must have an in depth knowledge of their subject and be able to communicate their passion for it. They must have the ability to show its relevance and application in everyday life and a novel and innovative approach to teaching and learning: setting out problems not providing ready made

answers.. Links to the community, business and HE are essential as is a flexible approach to the curriculum and timetable.
(Association of Managers in Education)

Q35 What are the most effective ways of providing young people with information, advice and guidance about higher education and careers in science and engineering?

There are many negative cultural attitudes to STEM, for example perceptions that STEM is for 'geeks' or 'nerds'. Professional organisations are working hard to change attitudes to STEM. The IET runs a series of programmes and activities, such as the well known Faraday Programme, which seek to demonstrate the fascination of engineering.
(Institute of Engineering and Technology)

More needs to be done to communicate online resources of information on STEM careers, notably the Future Morph and MathsCareers websites (http://www.futuremorph.org/; http:www.mathscareers.org.uk). Anecdotally, it is understood that there are few careers advisers who have a background in science and mathematics. An audit of the STEM skills/experience of information, advice and guidance (IAG) practitioners is desperately needed, with a view to developing a strategy to recruit sufficient numbers of these to meet national needs.
(The Royal Society)

Real work opportunities or work shadowing, working on real science problems. The STEMNET Ambassadors scheme has much to offer. Also mentors from HE. Talks in schools and colleges by current HE students. Opportunities to engage in science fairs and competitions.
(National Science Learning Centre)

The world wide web is one of the most used mediums by young people, consequently it is an appropriate vehicle to provide them with information, advice and guidance about higher education and careers in science and engineering. However, just providing a web site is not sufficient, the content must be engaging and relevant and it should use the applications that young people use on a regular basis, e.g. video and audio. Setting up channels on sites which are popular with young people such as YouTube and Facebook will give greater access to the audience.
(Becta)

Q36 What more could be done to improve the skillset of science/mathematics students to help them progress successfully to pure science subjects and engineering in higher education and science-related employment?

It is important that universities are honest in saying what the requirements of their courses are. If a course does not have A Level Mathematics as an explicit entrance requirement, students and their teachers will assume that mathematics is not needed for the course. If mathematics is beneficial for the course (as it is for all science and engineering degrees) students need to catch it up at university when there is less time for them to devote to it than there would have been if they had taken mathematics in the sixth form. This hinders students' progress. (Mathematics in Education and Industry)

There is scope for making improvements in the curricula of GCSEs and A levels to ensure that students are better prepared for university. This could be helped by a closer collaboration between HE, employers, bodies such as ABPI and the curriculum developers and government (through partnerships such as SCORE). Additionally, increased inquiry based learning and open ended investigative work (with emphasis on appropriate practical, field and maths skills) rather than summative assessment will in the long term aid reasoning and other higher level skills required for HE and the workforce.
(Biosciences Federation)

Government needs to: ensure the level of resource provided for the teaching of STEM in HE is sufficient to enable the delivery of high-quality and relevant STEM education; ensure that all young people continue in some form of maths or numeracy education after 16; encourage all students who have the capacity to take triple science at GCSE or Standard Grade to do so. Business needs to: provide financial support for new graduate recruits, for example, through sign-on bonuses; commit time and resources to participating in degree programme advisory boards. Government, universities and business need to: work together to provide students, their advisers and their family with an effective website so that students can compare the outcomes of different choices, based on high-quality information about employment prospects, teaching quality and economic returns from different courses.
(CBI)

In terms of improving the skills set of these students, the sixth form should be a time to truly broaden experience both in terms of extended projects, work experience and looking at 'softer skills' such as emotional intelligence, communication and written skills. There should be opportunities for oral presentations to different audiences. Emphasis should also be placed on team building and problem solving as well as exercises that encourage young people to be proactive and self motivated. (Association of Managers in Education)

Q37 What skills do you think should be developed further as part of a science education to enable young people to succeed in employment?

As well as developing science-specific skills, knowledge and expertise, a science education should also provide opportunities for young people to develop generic creative thinking skills ; enquiry-based approaches; ability to not only solve but also identify problems; applied imagination and disciplined innovation;

collaborative working and co-learning; leadership and decision-making.
(The Mighty Creatives)

Inherent in the practice of science is the development of investigative (including mathematical skills), creative thinking, critical questioning and thinking and problem-solving skills, and each of these skills is likely to be applicable to the workplace and should be emphasised in science education. But it is important that these skills are developed alongside other more generic skills, such as communication (including usage of English, ICT and presentation skills), teamwork and time-management.
(The Royal Society)

Notwithstanding the perceived demand for skills at an intermediate and higher level that enable industry to exploit and apply emerging technologies in a wide range of areas, indicative evidence from industry suggests that what they require are individuals who have a solid foundation in 'pure science' alongside a contemporary appreciation of how the 'science' can be applied in practice. Industry requires individuals who have breadth as well as depth (e.g. in specialist areas) of understanding, and the ability to work in multi-disciplinary teams.
(New Engineering Foundation)

Q38 What skills do you think society values in science students and graduates?

Employers value a range of mathematics-related skills in their workforce ranging from basic numeracy, through use of spreadsheets and data manipulation, right up to the highly technical areas. Moreover, skills such as problem solving abilities, perseverance and logic are also highly sought after and are commonly found in those with a high level of competency in mathematics.
(Advisory Committee on Mathematics Education)

They have the potential to shape our futures through their work in research which impacts on everything from solutions to global warming to medical breakthrough from stem cell work etc, and preparing manned missions to Mars. In a knowledge economy, future economic prosperity will be more closely linked with science/maths innovation.
(British Council)

Evidence for this may best be found in the CBI Education and Skills Survey, the latest of which (2008) indicated that particular STEM skills being valued among employers of STEM graduates were their numeracy, analytical and problem-solving skills, though it was recognised that these skills are demanded by every sector of the economy.
(The Royal Society)

Q39 How could links between schools, colleges, universities, employers and other institutions be improved to support engagement, participation and progression in pure science subjects and engineering?

NASUWT is concerned that many STEM employers are not sufficiently engaged with schools in helping to develop mutually beneficial partnerships. In order to ensure that students are entering the workforce equipped with the skills and qualities needed, STEM employers need to provide the necessary investment both in terms of resources and opportunities, including appropriate and engaging work experience, to enable this to occur.
(NASUWT)

More could be done by employers to engage with schools and help the pupils understand the place of science in these companies and how a science degree has helped the employees to succeed in their careers.-perhaps there could be better tax breaks to encourage employers to do this. Work placements can be effective. A greater opportunity for apprenticeships that have the potential to lead to degree courses – better partnerships between employers, FEs and HEs would help in this regard. The new diplomas may help integration here. More opportunities for undergraduates to do interns in industry as part of their undergraduate degree – these positions are becoming more difficult to attain in the current economic climate, particularly for short-term placements (e.g. 3 months). Greater opportunity for sandwich years for undergraduates would also be valuable.
(Biosciences Federation)

School management needs to be convinced that any interaction with scientists will be valuable to their pupils if they are to engage and schools must be given the flexibility in the teaching timetable to accommodate them.
(Medical Research Council)

Links between institutions need to be further developed at a strategic level. Representatives from various establishments need to come together and tackle the problem as a whole rather than separately. Financial and organisational incentives also need to be offered to individuals and groups who work to overcome barriers. There also needs to be a marketing campaign to change the perception of how such subjects are viewed. It is also essential that the views of young people are listened to so that there is a very clear idea of the issues and how they might be solved.
(Association of Managers in Education)

Printed in the UK on recycled paper containing a minimum of 75% post consumer waste.

Department for Business, Innovation and Skills. www.bis.gov.uk

First published February 2010. BIS/0.2k/02/10/NP. URN 10/738