Making Mathematics Count

The report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education

February 2004

Printed by The Stationery Office Limited
2/04 937764

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FOREWORD

The Rt. Hon. Charles Clarke, MP
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February 2004

I am pleased to present to you the report of the Post-14 Mathematics Inquiry.

I am grateful to have been given the opportunity to lead this Inquiry and would like to thank the many organisations and individuals who provided me with such a wealth of invaluable facts, figures, opinions and advice. I would particularly like to thank the members of my Steering Group for their patient support and wise counsel; my expert advisers for their tutorial advice, and my secretariat for their professional support. All have contributed enormously to my report.

In carrying out this UK Inquiry, I have been mindful of the fact that responsibility for mathematics education is devolved to all three devolved administrations. The degree of common ground with England varies markedly across the territories of the UK, as do territorial perceptions of the problems they face regarding mathematics education. I should therefore make clear that, for the most part, my analyses and recommendations refer more directly to England than to Scotland, Northern Ireland and Wales. Nevertheless, I hope that many elements of the report will be useful to all the devolved administrations.

Mathematics is of central importance to modern society. It provides the language and analytical tools underpinning much of our scientific and industrial research and development. Mathematical concepts, models and techniques are also key to many vital areas of the knowledge economy, including the finance and ICT industries. Mathematics is crucially important, too, for the employment opportunities and achievements of individual citizens.

The Inquiry has therefore found it deeply disturbing that so many important stakeholders believe there to be a crisis in the teaching and learning of mathematics in England. There are three major areas of concern.

First, we have a curriculum and qualifications framework that fails to meet the mathematical requirements of learners, fails to meet the needs and expectations of higher education and employers and fails to motivate and encourage sufficient numbers of young people to continue with the study of mathematics post-16. Secondly, we have a serious shortage of specialist mathematics teachers in schools and colleges and this is having an adverse effect on pupils' learning experiences.

Thirdly, there is a lack of support infrastructure, both at national and local levels, to provide continuing professional development and resources, including ICT, in support of excellence in the teaching and learning of mathematics.

My report makes a number of recommendations for addressing these problems. Some, I believe, can be implemented straightaway and would produce immediate improvements. Others require more radical, longer-term changes.

So far as the curriculum and qualifications framework is concerned, it is timely that the publication of the report of this Inquiry follows so closely after the publication of the Interim Report of the Working Group on 14-19 Curriculum and Qualifications Reform. The Post-14 Mathematics Inquiry strongly welcomes and endorses the broad philosophy of the Working Group's proposals. I believe that the proposals I make in this report for designing new pathways for mathematics are fully compatible with the Working Group's proposals for the overall 14-19 framework.

So far as support for the teaching and learning of mathematics is concerned, the Inquiry believes it to be vital that we provide teachers of mathematics in schools and colleges with greatly enhanced resources and with sustained access to professional support and development. Specifically, I propose a model of national and local infrastructure that I believe will enhance the mathematics teaching environment, nurture and support individual teachers of mathematics and encourage collectively in mathematics departments in schools and colleges a renewed sense of confidence and professionalism.

The implementation of the recommendations set out in this report will begin the process of averting the crisis in mathematics education. I commend these recommendations to you.

I am also copying this letter to Jane Davidson in Wales, Jane Kennedy in Northern Ireland and Peter Peacock in Scotland.

Professor Adrian Smith, FRS

EXECUTIVE SUMMARY

Purpose of the Inquiry

0.1 At the time of Budget 2001, the Government commissioned a review into the supply of people with science, technology, engineering and mathematical skills. In the context of the Government's strategy for improving the UK's productivity and innovation performance, this reflected a concern that the supply of scientists and engineers should not constrain the UK's future research and development and innovation capability. The review was carried out for the Chancellor of the Exchequer by Sir Gareth Roberts, who published his report, *SET for Success: The supply of people with science, technology, engineering and mathematical skills,* in April, 2002.[1]

0.2 The Roberts report examined the supply of science and engineering skills in the UK in the specific contexts of the biological sciences, the physical sciences, engineering, mathematics and computer science. It presented a number of findings relating to the difficulties faced by employers in recruiting appropriately qualified scientists and engineers and raised a number of issues about the development of science and engineering skills in schools, colleges and higher education.

0.3 The report noted that although, relative to many other countries, the UK has a large and growing number of young people studying science and engineering, this overall growth has masked a decline in the numbers studying the physical sciences, engineering and mathematics. For example, the report drew attention to the drop during the 1990s of nearly 10 per cent in the numbers taking A-level mathematics in England. At the same time, the report also noted that the demand for graduates and postgraduates in these strongly mathematically oriented subjects has grown significantly over the past decade, not only in science and engineering areas, but also in the financial services and ICT sectors. In addition to the supply problem, the report identified concerns expressed by employers about the mismatch between skills acquired during formal education and those required in the workplace.

- The Roberts report concluded that this mismatch of supply and demand is leading to skills shortages that will adversely affect the Government's productivity and innovation strategy. These shortages will become increasingly serious unless remedial action is taken. The report raised a number of concerns about the image and perception of science and engineering among young people. It concluded that many young people have a poor experience of science and engineering education. It also concludes that many have a poorly informed view of career opportunities arising from the study of science and engineering.

[3] The large majority of the recommendations were endorsed by Government in *Investing in Innovation* in July 2002 and significant funding has been committed to both schools and universities in areas such as science laboratories, equipment, studentships and assistantships.

0.4 *SET for Success* was concerned with these generic issues across the range of science and engineering and its overview and recommendations for the most part apply to all the relevant individual disciplines.

0.5 However, it has been widely recognised that mathematics occupies a rather special position. It is a major intellectual discipline in its own right, as well as providing the underpinning language for the rest of science and engineering and, increasingly, for other disciplines in the social and medical sciences. It underpins major sectors of modern business and industry, in particular, financial services and ICT. It also provides the individual citizen with empowering skills for the conduct of private and social life and with key skills required at virtually all levels of employment.

0.6 In addition, many of the generic problems identified across science and engineering in *SET for Success* manifest themselves most acutely in the area of mathematics. For example: there has long been deep concern about the supply of appropriately qualified mathematics teachers in secondary schools and colleges; there has also been considerable concern about many young people's perception of mathematics as being "boring and irrelevant" and "too difficult, compared with other subjects".

0.7 These and other specific concerns about mathematics in its own right led the Government to conclude that there was a need for a closer examination of current mathematics education provision. The intention to set up this independent Inquiry into Post–14 Mathematics Education was announced by the Chief Secretary to the Treasury, on 23 July 2002. The appointment of the Chair of the Inquiry was announced on 25 November 2002.

0.8 The Terms of Reference of the Inquiry were announced at the same time. They were:

> *To make recommendations on changes to the curriculum, qualifications and pedagogy for those aged 14 and over in schools, colleges and higher education institutions to enable those students to acquire the mathematical knowledge and skills necessary to meet the requirements of employers and of further and higher education.*

0.9 This Inquiry was commissioned by the UK Government and we therefore focus our recommendations on the UK Government's areas of responsibilities. Responsibility for mathematics education is devolved to all three devolved administrations, but the degree of common ground with England varies markedly across the territories of the UK as do territorial perceptions of the nature of the problems they face regarding mathematics education. This has meant that much of our analysis and many of our recommendation refer more directly to England than to Wales, Northern Ireland and Scotland. It is hoped, however, that many elements of this report will be useful to all the devolved administrations, as well as to the Department for Education and Skills (DfES) for England.

Overview of the report

0.10 The Post–14 Mathematics Inquiry has identified three key issues of major concern:

- the shortage of specialist mathematics teachers, particularly in England and Wales;
- the failure of the current curriculum, assessment and qualifications framework in England, Wales and Northern Ireland to meet the needs of many learners and to satisfy the requirements and expectations of employers and higher education institutions;
- the lack of resources, infrastructure and a sustained continuing professional development culture to support and nurture all teachers of mathematics.

0.11 The main body of the report consists of six chapters:

- Chapter 1 reviews the very special nature and *importance of mathematics* and the need for more young people to acquire greater mathematical skills;
- Chapter 2 reviews problems related to the *supply of mathematics teachers*;
- Chapter 3 provides a detailed account of *current 14–19 mathematics pathways* in the UK;
- Chapter 4 reviews the fitness for purpose of current pathways and considers possible *action on current and future mathematics pathways*;
- Chapter 5 considers the issues of how we could provide better *support for the teaching and learning of mathematics*;
- Chapter 6 details possible *national and regional support infrastructure* for the teaching and learning of mathematics.

The importance of mathematics (chapter 1)

0.12 The Inquiry regards it as vital that society fully recognises the importance of mathematics: its importance for its own sake, as an intellectual discipline; for the knowledge economy; for science, technology and engineering; for the workplace; and for the individual citizen.

0.13 All this underlines the importance of ensuring a sufficient supply of young people with appropriate mathematical skills. However, we currently face a situation of long term decline in the numbers of young people continuing to study mathematics post–16 in other than Scotland. The Inquiry draws attention to possible factors underlying this decline.

- the perceived poor quality of the teaching and learning experience;
- the perceived relative difficulty of the subject;

- the failure of the curriculum to excite interest and provide appropriate motivation;
- the lack of awareness of the importance of mathematical skills for future career options and advancement.

We examine these particular issues in greater detail in later chapters and make a number of recommendations.

0.14 We believe it to be crucial that the importance of mathematics is more clearly and visibly recognised within Government and its agencies. We also believe that the current division of responsibilities in England between the DfES and the Learning and Skills Council (LSC) for schools and colleges, respectively, creates an obstacle to providing a coherent strategy for mathematics education throughout the 14–19 stage. **The Inquiry therefore recommends that a high level post be created in the DfES with dedicated subject specific responsibility for mathematics and that the DfES and LSC create a high level joint forum for overseeing a coherent strategy for mathematics education.**

0.15 We are also concerned about the lack of a national body to champion the cause of mathematics and mathematics education to Government the DfES, the devolved administrations and others, and to ensure that the potential contributions of mathematics to the economy and society are appreciated at the highest levels. The Advisory Committee for Mathematics Education (ACME) already plays this role to some extent in relation to mathematics education and we envisage an extended role for ACME in taking forward a number of this report's recommendations. However, there is no corresponding body to speak on behalf of the mathematics community to Government and others on strategic issues relating to general research and industrial reach-out role of mathematics in the economy and society. **The Inquiry recommends that ACME be provided with enhanced support in order to play an active role in helping to take forward the recommendations of this Inquiry and that a corresponding body be set up to speak on behalf of the mathematics community on strategic issues relating to research and knowledge transfer in mathematics.**

Supply of teachers of mathematics (chapter 2)

0.16 The shortage of specialist mathematics teachers teaching mathematics is the most serious problem we face in ensuring the future supply of sufficient young people with appropriate mathematical skills. We think it likely that there is a current shortfall of around 3,400 specialist mathematics teachers in maintained secondary schools in England. We also note a recent survey finding that over 30 per cent of those currently teaching mathematics do not have a post A-level qualification in mathematics.

0.17 A further finding from the Inquiry that has concerned us is that there are apparently very significant numbers of teachers in schools qualified to teach mathematics who do not teach mathematics. If the figures we have are accurate, some 25 per cent of teachers in schools in England qualified to teach mathematics are employed in tasks other than teaching mathematics. This seems to the Inquiry to raise serious issues about current school level resource management and to merit at least some further investigation. **The Inquiry recommends that the DfES undertake a review of school level resource management of qualified mathematics teachers in England and consider, in particular, whether current career paths and rewards are providing appropriate incentives for qualified mathematics teachers to continue teaching mathematics.**

0.18 The above recommendation refers to incentives to those already in the system. In trying to recruit qualified mathematicians into teaching, we are competing with other employment opportunities for mathematicians that in recent years have increasingly offered career prospects that are perceived as considerably more attractive than teaching: the finance industry provide one obvious example. In this regard, the Inquiry has come to the same conclusion as the Roberts review: namely, that ultimately market forces will have to be recognised in setting remuneration levels for teachers in shortage subjects. We are aware that the Roberts recommendation was not accepted. However, we do not believe the issue can continue to be ignored. **The Inquiry therefore recommends to the DfES that the issue of enhanced financial incentives for teachers of mathematics (and subjects with similar recruitment difficulties) be reconsidered.**

0.19 The scale of the problem of the shortfall of specialist teachers is analysed in detail in Chapter 2 of the report. However, the Inquiry has found it very frustrating not to be able to arrive at a clear overall picture of current and future needs for mathematics teachers in schools and colleges due to irregular and radically incomplete official data collection, particularly in the Further Education sector. **The Inquiry makes recommendations to the DfES and the LSC about future data collection and its importance for policy. In particular, in setting appropriate targets for the future recruitment of mathematics teachers and for monitoring progress towards meeting the shortfall.**

0.20 The serious magnitude of the current problem can be appreciated from the fact that to solve the problem of the shortfall we would need to attract into teacher training over 40 per cent of the annual UK output of mathematics graduates for each of the next several years.

0.21 Such a solution is not, of course, available. However, there are many current schemes and initiatives in place aimed at boosting the numbers entering mathematics teacher training. These include enhancement courses, which enable those without appropriate existing mathematics qualifications to acquire these as a first step to training as a mathematics teacher. They also include schemes for encouraging more undergraduates to consider a teaching

career. **The Inquiry strongly supports all such measures undertaken by the Teacher Training Agency and supported by the DfES and makes recommendations for increased funding, where appropriate, to further encourage the expansion of mathematics teacher training places. The Inquiry also recommends further support for schemes aimed at fast track careers for outstanding mathematics teachers.**

0.22 We acknowledge the concerns of respondents to the Inquiry that schemes involving enhancement courses will necessarily be attracting potential entrants to the teaching profession with very varying levels of mathematical knowledge. In this connection, we have identified one area where we think a radical re-think in the approach to the certification of teachers could both help to increase the supply of those able to teach some part of the mathematics curriculum and also allay the fears of those who are concerned about the possible lack of mathematical knowledge of entrants to teaching coming through this route. **The Inquiry recommends that consideration be given to the introduction of new mathematics teacher certification schemes which award certification to teach mathematics only up to certain specified levels, eg Key Stage 3.**

Current mathematics pathways (chapter 3)

0.23 These are reviewed in some detail as necessary background to our subsequent discussion of concerns expressed to the Inquiry about current provision and the steps that might be taken to improve the situation.

Action on current and future pathways (chapter 4)

0.24 The work of the Post–14 Mathematics Inquiry has proceeded in parallel with deliberations of the Working Group on 14–19 Curriculum and Qualifications reform in England and similar initiatives in Wales. The Inquiry has not regarded itself as constrained by the thinking emerging from the Progress and Interim Reports of the Working Group, but it has clearly been of interest to the Inquiry to keep in mind the issue of the compatibility of its own thinking with that of the Working Group. We do not believe that any of the short-term or long-term changes we recommend will cause any problems when it comes to designing detailed pathways in mathematics compatible with the kind of framework envisaged by the Working Group. More positively, we strongly support the Working Group's wish to see a move away from rigid, age-related, one-size-fits-all arrangements.

0.25 It is clear that the overwhelming majority of respondents to the Inquiry no longer regard current mathematics curricula, assessment and qualifications as fit for purpose.

0.26 So far as GCSE is concerned, public perception, in line with school and college league tables, regards a Grade C as the "success" threshold. However, within the current three-tier arrangements for mathematics the lower (Foundation) tier can only lead to at most the attainment of a Grade D. As a result, the 30 per cent of the age cohort entered for this tier are pre-destined to "fail".

The Inquiry believes this to be a perverse arrangement and would wish to see a new structure in place as soon as possible. A two-tier GCSE is currently being piloted. **The Inquiry recommends that, subject to successful piloting, we move as soon as possible to a two-tier system for GCSE mathematics in England, Wales and Northern Ireland.**

0.27 Respondents to the Inquiry also report the universal perception among teachers and pupils that the amount of effort required to obtain the single GCSE in mathematics is similar to that needed to obtain the two awards in English or the double award in science. This further reinforces pupils' view of mathematics as a disproportionately hard subject and undoubtedly influences pupils' subject choices post–16. **The Inquiry recommends that immediate consideration be given to re-designating GCSE mathematics as a double award.**

0.28 There is much concern and debate about the positioning of Statistics and Data Handling within the current mathematics GCSE, where it occupies some 25 per cent of the timetable allocation. On the one hand, there is widespread agreement that the Key Stage 4 curriculum is over-crowded and that the introduction of Statistics and Data Handling may have been at the expense of time needed for practising and acquiring fluency in core mathematical manipulations. Many in higher education mathematics and engineering departments take this view. On the other hand, there is overwhelming recognition, shared by the Inquiry, of the vital importance of Statistics and Data Handling skills both for a number of other academic disciplines and in the workplace. **The Inquiry recommends that there be a radical re-look at this issue and that much of the teaching and learning of Statistics and Data Handling would be better removed from the mathematics timetable and integrated with the teaching and learning of other disciplines (eg biology or geography). The time restored to the mathematics timetable should be used for acquiring greater mastery of core mathematical concepts and operations.**

0.29 In addition to the anxiety referred to above about the undesirable effects of the current arrangements for the lower attaining 30 per cent of the age cohort, respondents to the Inquiry have expressed considerable concern that we do not sufficiently stretch and motivate the top 10 per cent. The Inquiry agrees and believes it to be vitally important that we nurture and encourage the very best mathematical talent. **The Inquiry therefore recommends that attention be given to making special provision in mathematics for these more able pupils, both at GCSE and GCE levels.**

0.30 Towards the more vocational end of the spectrum, respondents to the Inquiry have expressed considerable concerns regarding mathematics provision and the delivery of mathematics teaching within and relating to the Government's Key Skills agenda. There is a widespread feeling that it would be timely to consider rationalising the provision available through Application of Number, Free Standing Mathematics Qualifications, AS Use of Mathematics and Adult Numeracy qualifications. **The Inquiry agrees and recommends that such a review be undertaken as soon as possible.**

0.31 There is widespread recognition that the Curriculum 2000 reforms which led to a new post–16 structure based on AS and A2 levels have been a disaster for mathematics. The original AS/A2 split simply did not work. Students could not cope with the material within the laid down timetable and in the first year of operation the pass rate for AS mathematics was only just over 70 per cent, compared with over 90 per cent in many other subjects. The consequence was that the image of mathematics has suffered badly again and entries in the following two years have been some 20 per cent down on pre–2000 numbers. Given the UK's long-standing concern about the small numbers continuing with mathematics post–16, this further serious decline in the supply chain is very serious indeed. There are also concerns about the nature and frequency of assessment for AS/A2. **The Inquiry supports the remedial measures that are being put in place to try to mitigate the AS/A2 problems in mathematics and recommends reconsideration of the frequency and style of assessment. However, the Inquiry regards it as vitally important that numbers of entries in future years be closely monitored and, if there is no significant improvement, we recommend that radical measures – including financial incentives – be considered to address the issues of increasing post–16 take up of mathematics.**

0.32 So far as the longer-term re-design of mathematics 14–19 pathways is concerned, we explore a number of ideas encapsulating differing suggestions emanating from the mathematics community. We have set out a number of principles that we are clear should inform the design of new pathways in order to avoid the perceived defects of the current arrangements. We do not believe that a one-size-fits-all model is appropriate. We wish to see a highly flexible set of interlinking pathways that provide motivation, challenge and worthwhile attainment across the whole spectrum of abilities and motivations, but avoid the danger of returning to the O-level/CSE "sheep and goats" divide. We are clear that the new design should be underpinned and supported by extensive trialling and piloting and that a wide cross-section of the mathematics community be given maximum opportunity to participate in and influence the process of re-design. **The Inquiry therefore recommends that an open bidding process be adopted to identify and commission several groups to carry out curriculum and assessment development studies as a preliminary to identifying a preferred pathways model to form part of the eventual reformed 14–19 structure in England.**

Support for the teaching and learning of mathematics (chapter 5)

0.33 The Inquiry believes that whatever the longer-term prospects of increasing the supply of specialist mathematics teachers, we must do everything possible to support and nurture those teachers currently teaching mathematics in schools and colleges. They need and deserve the very best support we can provide. Much of this chapter therefore focuses on the need for various forms of Continuing Professional Development (CPD) for teachers of mathematics and the need to radically change our culture of expectations in relation to CPD

in England, Wales and Northern Ireland. The situation in Scotland is already changed. **The Inquiry recommends that formal responsibility for and entitlement to fully funded CPD be introduced as soon as possible into the professional terms and conditions of service of teachers of mathematics in schools and colleges in England, Wales and Northern Ireland. The Inquiry further recommends that additional remuneration be linked to successful completion of accredited CPD activities.**

National and regional support infrastructure (chapter 6)

0.34 We present detailed arguments in favour of delivering CPD and other forms of support for teachers of mathematics through a national and regional infrastructure. We believe this provision to be of the utmost importance in sustaining, nurturing and enhancing current provision of mathematics teaching. **The Inquiry strongly recommends that in England this support infrastructure take the form of a National Centre for Excellence in Mathematics Teaching, together with nine Regional Mathematics Centres. The Inquiry recommends that this infrastructure incorporate existing CPD provision, including the mathematics strand of the current Key Stage 3 Strategy.**

0.35 In addition to supporting the delivery of CPD, the Inquiry believes that such an infrastructure should provide both strategic co-ordination of and local support for a wide range of other important networking and resource provision for the support of the teaching and learning of mathematics. **The Inquiry makes firm recommendations relating to: the provision of an expert resource for dissemination of educational research and development findings, including those relating to the use of ICT; networking and mentoring relationships involving local schools, colleges, higher education and business; the incorporation of relevant existing mathematics support activities and initiatives, including the work of the Open University, the Learning and Teaching Skills Network, the Specialist Schools Network and the National Research and Development Centre for adult literacy and numeracy.**

Conclusion

0.36 The Inquiry has identified three broad areas of considerable concern:

- the shortage of specialist mathematics teachers;
- the failure of the current curriculum and qualifications framework to meet the requirements of learners, higher education and employers, and to ensure that sufficient numbers of young people continue with mathematics post–16;
- the need to support, sustain and enhance current teachers of mathematics through CPD and other teaching and learning resources.

0.37 The recommendations set out in this report provide a series of practical measures designed to begin to reverse the problems and concerns we have identified. The Inquiry believes that implementing these recommendations will provide a crucial first step towards ensuring a future supply of sufficient young people in the UK with appropriate mathematical skills.

1 THE IMPORTANCE OF MATHEMATICS

Mathematics for its own sake

1.1 Mathematics provides a powerful universal language and intellectual toolkit for abstraction, generalization and synthesis. It is the language of science and technology. It enables us to probe the natural universe and to develop new technologies that have helped us control and master our environment, and change societal expectations and standards of living. Mathematical skills are highly valued and sought after. Mathematical training disciplines the mind, develops logical and critical reasoning, and develops analytical and problem-solving skills to a high degree.

Mathematics for the knowledge economy

1.2 Mathematics is of central importance to modern society. It provides the vital underpinning of the knowledge economy. It is essential in the physical sciences, technology, business, financial services and many areas of ICT. It is also of growing importance in biology, medicine and many of the social sciences. Mathematics forms the basis of most scientific and industrial research and development. Increasingly, many complex systems and structures in the modern world can only be understood using mathematics and much of the design and control of high-technology systems depends on mathematical inputs and outputs.

Mathematics for science, technology and engineering

1.3 Ensuring an adequate supply of people with science, technology, engineering and mathematics skills is at the heart of the UK Government's strategy for innovation and productivity and was the subject of the recent important Roberts report (April 2002), SET *for Success: the supply of people with science, engineering and mathematics skills*.

1.4 The report documents the declining numbers of young people continuing post-16 with education in subjects with high mathematics content other than in Scotland, where numbers have increased substantially in recent years as a result of the introduction of new National Qualifications in 1999, which provided a wider range of qualifications. The UK is almost alone in Europe in not making some form of mathematics a compulsory part of the post-16 curriculum. Currently, less than 10 per cent of the age cohort in England continues with mathematics post-16; and less than 10 per cent of those who do continue go on to do a mathematics degree.

1.5 Against this background, the Roberts report provides a wealth of data and analysis in support of the need for greater numbers of trained young people with appropriate mathematical skills. In particular, it provides evidence from employment rates, salary levels and surveys of employers' recruitment

experience that demonstrates that graduates and postgraduates in strongly mathematical subjects are in increasing demand in the UK economy. The report concludes that skills shortages in areas requiring high levels of mathematical knowledge are resulting from the disparity between the growing demand for such skills and the declining numbers of graduates in the relevant disciplines. These shortages constitute a threat to the Government's innovation and productivity strategy and to the future strength and success of the UK economy.

Mathematics for the workplace

1.6 Although the role of mathematics in underpinning science, technology and engineering is reasonably well recognized and acknowledged in the UK, the fundamental and all-pervasive role of mathematics throughout the rest of the economy is typically not well understood. To the layman it can appear that mathematics for the workplace has become less important because "everything is now done by computers". The clear message to the Inquiry from a wide range of leading industries and businesses is that this is absolutely not the case.

1.7 Major employers in the engineering, construction, pharmaceutical, financial and retail sectors have all made clear to us their continuing need for people with appropriate mathematical skills. In particular, employers highlight the shortage of statisticians. Advanced economies need an increasing number of people with more than minimum qualifications in mathematics to stay ahead in international competitiveness and, in particular, to effectively exploit advances in technology. An adequate supply of young people with mastery of appropriate mathematical skills *at all levels* is vital to the future prosperity of the UK.

1.8 Requirements for mathematical skills in the workplace have been examined in detail in a recent report, *Mathematical Skills in the Workplace* (Celia Hoyles, Alison Wolf, Susan Molyneux-Hodgson and Philip Kent – June 2002, Institute of Education and STMC). A key finding of the study was that although the ubiquitous use of information technology in all sectors has changed the nature of the mathematical skills required, it has not reduced the need for mathematics. The authors of the report refer to these mathematical skills and competencies, framed by the work situation and practice and the use of IT tools, as "mathematical literacy". The term partly reflects the skills needed by individuals in relation to business goals, but also reflects the need to communicate mathematically expressed decisions and judgements to others. On the basis of detailed case studies, the report concludes that there is an increasing need for workers at all levels of organisations to possess an appropriate level of mathematical literacy.

Mathematics for the citizen

1.9 The acquisition of at least basic mathematical skills – commonly referred to as "numeracy" – is vital to the life opportunities and achievements of individual citizens. Research shows that problems with basic skills have a continuing adverse effect on people's lives and that problems with numeracy lead to the greatest disadvantages for the individual in the labour market and in terms of general social exclusion. Individuals with limited basic mathematical skills are less likely to be employed, and if they are employed are less likely to have been promoted or to have received further training.

Increasing mathematical skills

1.10 From all perspectives, the UK needs more young people with greater mastery of higher levels of appropriate mathematics skills than is currently the case. To achieve this, we need three things to happen:

- first, that more young people continue longer with the study of mathematics;
- secondly, that we have a clear view of what are, at any given level, the appropriate mathematical skills to be acquired and what constitutes mastery of these skills;
- thirdly, that, having agreed the latter, the teaching and learning process and environment effectively encourages and promotes the mastery of these skills.

1.11 In the current non-compulsory environment, the first requirement in paragraph 1.10 leads us to consider the issue of the numbers of students choosing to continue with mathematics post-16. This leads us to consider the factors that influence student choice post-16 and how these might be modified. Factors influencing student choice are complex and not well understood, although certain themes emerge anecdotally from focus groups:

- the influence of the teacher is clearly important; in particular, poor teaching is likely to turn students off mathematics;
- the perceived difficulty of mathematics relative to other subjects is also important both to schools (concerned with league tables) and to individual students (concerned with university entrance);
- separate from perceived difficulty, the content of the course may be perceived to be boring or irrelevant, or insufficiently stimulating or challenging;
- lack of awareness of the link between career options and subject choices may also play a role, both for teachers and students.

1.12 The second requirement leads us to consider issues of curriculum, assessment and qualifications and whether these are currently fit for purpose.

1.13 The third requirement leads us to consider issues relating to learning pathways, teaching resources and pedagogy (including the use of ICT) and whether these are currently fit for purpose.

This report

1.14 In this report, we address these issues in the following way.

- Chapter 2 reviews problems related to the supply of specialist mathematics teachers and makes a number of recommendations;
- Chapter 3 sets the scene for a discussion of curriculum, assessment and qualifications issues with a detailed account of current 14-19 mathematics pathways in the UK;
- Chapter 4 reviews in detail a number of the concerns expressed to the Inquiry about the fitness for purpose of current pathways and makes a number of recommendations for short- and medium-term improvements and changes;
- Chapter 4 goes on to make a longer-term recommendation about preparation for a more radical re-think of mathematics pathways in the context of the kinds of overall changes to the 14-19 landscape that might emerge, for example in England, from the Working Group on 14-19 curriculum and qualifications reform;
- Chapter 5 considers the issues of how we could better support, in the very broadest sense, the teaching and learning of mathematics; in particular, how we could better support those involved in the teaching of mathematics at all levels through various forms of Continuing Professional Development;
- Chapter 6 presents a blueprint for a national infrastructure to oversee and deliver such support for the teaching and learning of mathematics.

The special position of mathematics

1.15 In considering these issues, the Inquiry has inevitably had to relate the concerns of mathematics both to other disciplines and to the wider concerns of schools and the education system. This has led us to become increasingly concerned that there is insufficient recognition, in many quarters, of the fact that mathematics is in many respects "special" and that we must be prepared to consider, particularly in terms of organisation, structures, and investment, that different approaches and prioritisation may be required for mathematics.

1.16 There are positive senses in which mathematics is special. First, by virtue of its fundamental nature as a universal abstract language and its underpinning of the sciences, technology and engineering, mathematics has a claim to an inherently different status from most other disciplines. Secondly, as we have set out above, mathematics is fundamentally important in an all-pervasive way, both for the workplace and for the individual citizen.

1.17 But there are also negative senses in which mathematics is special. In particular, in the UK there is a widespread view, among both parents and students, that the subject itself is "difficult" and "boring" and presents disproportionate challenges in the school and college setting, both in terms of the workload and the achievability of high grades. Another, unfortunate, negative sense in which mathematics is special derives from the very serious shortage of specialist mathematics teachers, particularly in maintained secondary schools and colleges in England and Wales.

Territorial responsibilities

1.18 Within the territories of the UK, there is a varied pattern of devolution of responsibilities for different aspects of mathematics education. Scotland has a completely devolved system and all responsibilities lie ultimately with the Scottish Executive. Northern Ireland also has fully devolved responsibilities, but its curriculum and qualification structure is very similar to that of England and Wales and it has historically approached issues of teachers' pay and conditions with a view to generally maintaining parity with England and Wales. Wales no longer has a common curriculum with England, although the current arrangements are still very similar to the previous joint arrangements. It has responsibilities for its own targets for teaching training and for Continuing Professional Development, but responsibility for teachers' pay and conditions remains with the Department for Education and Skills (DfES). Engalnd, Wales and Northern Ireland share a common qualifications system.

Government departments and agencies

1.19 This report makes a number of detailed recommendations. However, we are necessarily addressing our recommendations to existing government departments and agencies and have inevitably been led to reflect on whether these are currently organised and constituted in a manner best suited to acknowledging and taking forward our very special concerns about mathematics. We have outlined above the complex division of devolved responsibilities among the four territories of the UK but restrict our further discussion of this issue to England.

1.20 In particular, respondents are concerned about what they see as current obstacles in England to taking forward subject-specific agendas within the education system. For example, the Inquiry has observed, with considerable concern, that there is no high-level post in the DfES in England with dedicated subject-specific responsibility for mathematics. We are also very concerned that in England the split of responsibilities between secondary schools (DfES) and Sixth Form and FE Colleges (LSC) presents a potential obstacle to joined-up thinking and action regarding 14-19 mathematics educational strategy. This prompts our first recommendation.

Recommendation 1.1

The Inquiry recommends that in England a high-level post be created in the DfES with dedicated subject-specific responsibility for mathematics. The Inquiry further recommends that in England a joint forum be created between the DfES and the LSC through which high-level officers in the DfES and LSC with subject-specific responsibilities for mathematics are charged with overseeing coherent strategy for 14-19 mathematics education.

The mathematics education community

1.21 It has also become clear during the course of this Inquiry that although almost everyone can be regarded as an important stakeholder in mathematical education, there are currently very few forums for effective communication among major stakeholders. We make some recommendations in Chapters 5 and 6 that attempt to address this issue at a local level, but a broader issue remains.

1.22 The Advisory Committee for Mathematics Education (ACME) is a recently formed body, empowered by the Royal Society and the mathematics professional bodies and learned societies that come under the umbrella of the Joint Mathematics Council to speak on behalf of the mathematics community on matters in England pertaining to mathematics education. In any particular case, the involvement of ACME, augmented by professional representatives from the territories as and when appropriate, could provide a direct and manageable mechanism for involving a large part of the professional stakeholder community. We believe this to be an important and valuable role for ACME to play and have make explicit suggestions for ACME's involvement in a number of the Inquiry's recommendations. However, the current scale of funding for ACME would not support this expanded role. This prompts our next recommendation.

Recommendation 1.2

The Inquiry recommends that, in order to enable ACME to play an important extended role, including taking forward a number of the Inquiry's recommendations, substantial Government funding be made available to ACME. We recommend that this be channelled, as is existing funding, through the Royal Society, in order to enable ACME to retain its standing as an independent voice acting on behalf of the mathematics education community.

The wider mathematics community

1.23 However, the Inquiry is aware that ACME is empowered only to represent the wider mathematics community on matters of mathematics education. Respondents to the Inquiry have covered a much wider constituency of stakeholder interests; in particular, those in the mathematics community primarily concerned with mathematics research and/or the outreach of mathematics to business and industry.

1.24 Many of these respondents to the Inquiry have noted the lack of a single high-level body – comparable, say, with the Science Council or the Engineering and Technology Board – that could make representations to the DfES, or to Ministers when appropriate, on strategic level issues relating to the discipline of mathematics and its role in the economy and society. The Inquiry believes that such a body would be invaluable in advising on taking forward the issues and recommendations presented in this report and in sustaining subsequent strategic discussions on the future of mathematics in the UK. This prompts the following recommendation.

Recommendation 1.3

The Inquiry recommends that the UK mathematics learned and professional societies form an Advisory Committee on Mathematics Research and Industry (ACMRI), which would be empowered to speak on behalf of the community to Government and others on strategic level issues concerning the role of mathematics in the economy and society, complementing ACME's role in relation to mathematics education. The Inquiry suggests that it would be valuable to also have a joint Advisory Committee for Mathematics (ACM), formed from representatives of ACME and ACMRI, to speak on behalf of the community on general strategic issues concerning mathematics.

2 THE SUPPLY OF TEACHERS OF MATHEMATICS

The need for qualified teachers of mathematics

2.1 The Inquiry has sought and received input from a wide range of stakeholders. Not surprisingly, not everyone agrees on every issue relating to post–14 curriculum, assessment, pedagogy and qualifications. But we have identified one issue on which all stakeholders agree: the absolute necessity of ensuring adequate provision of appropriately qualified and supported mathematics teachers in schools, Sixth Form and FE colleges. This is seen by the overwhelming majority of respondents to the Inquiry to be the essential prerequisite for delivering long-term future improvements to post–14 mathematics education. The Inquiry also sees this as the highest priority.

2.2 We recognise in relation to our recommendations in this chapter and in Chapters 5 and 6 that devolved responsibilities for teacher recruitment, retention, and employment terms and conditions vary across the four territories of the UK. Responsibilities for teacher supply, training, employment terms and conditions and Continuing Professional Development (CPD) are fully devolved to Northern Ireland and Scotland (although Northern Ireland has historically approached issues of pay and conditions with a view to generally maintaining parity with arrangements in England and Wales). Wales determines its own intake targets for Initial Teacher Training and incentives paid to student teachers, and has devolved responsibility for CPD, but responsibility for teachers' terms and conditions remains with the DfES. In relation to teacher supply, further summary discussion in relation to Wales, Northern Ireland and Scotland is given at the end of this chapter.

2.3 It is also clear that the perception of the problem of mathematics teacher recruitment and retention varies considerably across the four territories of the UK. In summary, respondents have raised very serious concerns about England and Wales, significant concerns about some aspects of the situation in Northern Ireland, but no serious current concerns about Scotland. Much of our discussion and analysis will therefore be addressed to the situation in England and Wales (often, for convenience, using larger volume England data sources), but often we believe with some relevance to Northern Ireland.

2.4 The consensus view of what is an appropriately qualified mathematics teacher at secondary school and college levels seems well captured by the categorisations adopted in the 1982 Cockcroft Report, *Mathematics Counts*, which are set out in Table 2.1 below. To the categories of those with good or acceptable qualifications, we would now add those undertaking the new pre-ITT mathematics enhancement courses (see below paragraphs 2.65–67).

Table 2.1: Categories of qualifications of teachers used in the Cockcroft report

Good	Trained graduates, or equivalent, with mathematics as the first, main or only subject of a degree course. Bachelors of Education (BEd) with mathematics as a main specialist subject. Teachers whose general qualifications were of either of these types with mathematics as a subsidiary subject provided their main specialism was in a related subject, such as computer studies, physics or engineering.
Acceptable	Trained graduates, graduate equivalents, or BEd with mathematics as a second or subsidiary specialism if their first subject was not related. Untrained graduates with mathematics as first, main or only subject. Teachers holding the Certificate in Education, having followed a secondary course in which mathematics was their first, main or only specialism. Teachers with no initial mathematical qualifications who had a further qualification resulting from a course of at least one year in which mathematics was the main subject.
Weak	Teachers holding the Certificate in Education, having followed a secondary course with mathematics as a second or subsidiary subject, provided their first or main subject was related. Teachers holding the Certificate in Education having followed a Junior or Junior /Secondary course with mathematics as their first or main subject. Teachers in the immediately preceding category with subsidiary mathematics, provided their main subject was related. Graduates in any subject provided their course included a related subject.
Nil	Qualified teachers without any recorded mathematics (qualifications) and not covered by any previous specification. Teachers holding the Certificate in Education with mathematics subsidiary to an unrelated subject. Teachers without any initial qualification possessing a further qualification which did not lead to graduate status and in which mathematics was not the main subject.

Cockcroft, W.H. (1982) *Mathematics Counts*. London, HMSO.

2.5 Ensuring adequate numbers of appropriately qualified mathematics teachers clearly involves both issues of recruitment and retention. This chapter of the Inquiry report will review the evidence available to us about current numbers, qualifications and recruitment trends. So far as retention issues are concerned, respondents to the Inquiry believe that the key issue is that of professional support, particularly Continuing Professional Development (CPD). We see this as an important topic in its own right and we will separately discuss professional support issues in Chapters 5 and 6.

Teacher shortages and their effect on students' performance

2.6 Despite a recent small decline in advertised teacher vacancies and numbers of temporary teachers employed, a number of respondents to the Inquiry have reported that many secondary schools and further education colleges in England and Wales still have considerable difficulty in recruiting and retaining specialist mathematics teachers. According to the 2000/1 annual report (HMI 0–10–291358–7) of Her Majesty's Chief Inspector of Schools:

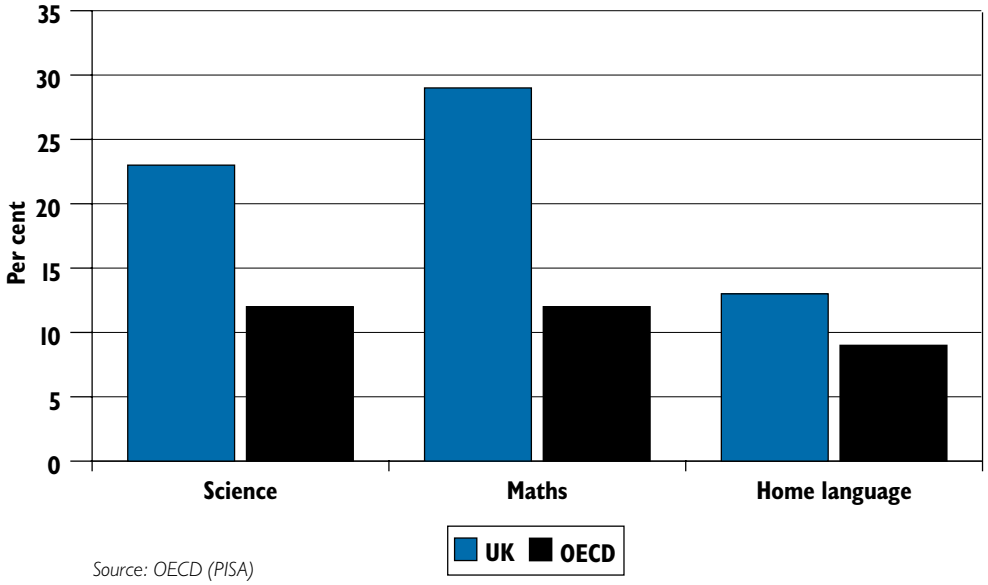
> *"In Mathematics: there are insufficient teachers to match the demands of the mathematics curriculum in one school in eight, a situation that has deteriorated from the previous year."*

The Chief Inspector's report for 2001/2 (HMI 0-10-292032-X) states that:

> *"Across secondary schools there remain significant difficulties in the recruitment of specialist teachers, particularly, but not exclusively, in mathematics … These recruitment difficulties are having an adverse impact on pupils' standards of achievement. For example: the quality of mathematics teaching at Key Stages 3 and 4 suffers in many schools because the limited amount of specialist teachers' expertise is deployed largely on post–16 courses. As a result, non-specialist teachers undertake a significant minority of the teaching at Key Stage 3, where they find it difficult to respond effectively to the demands of the Key Stage 3 Strategy."*

2.7 The Inquiry notes with concern the Chief Inspector's view in 2001/02 that shortages of specialist teachers in mathematics are having an adverse effect on pupils' performance. This is a view echoed by many respondents to the Inquiry and further supported by data presented in the *SET for Success* report. Figure 2.1 below (which reproduces Figure 2.14 of the *SET for Success* report), shows the proportion of head teachers in an OECD study who believe that teacher shortage or inadequacy is hindering the learning of pupils in different subjects. The Inquiry notes that, according to this survey, the position of mathematics is strikingly worse in the UK than in other OECD countries.

Figure 2.1: Proportion of schools in which teacher shortages/inadequacy are adversely affecting pupils



Source: OECD (PISA)

2.8 This concern about the effect of the shortage of specialist teachers on students' learning of mathematics has been echoed by almost all respondents to the Inquiry. In England, Ofsted, the Teacher Training Agency (TTA), headteachers and mathematics teaching professionals have all communicated their concern. The General Teaching Council for Wales (GTCW) has expressed concern that in Wales secondary school posts in mathematics attract significantly fewer applicants than for many other subjects. Surveys in Northern Ireland have shown there to be significant concerns about the situation in non-grammar schools and even some concern regarding

recruitment to grammar schools The Inquiry shares these concerns. In our view, the very highest priority in tackling the mathematics problem is to increase the supply of mathematically qualified, effectively trained specialist mathematics teachers. There are considerable difficulties in addressing this supply problem and we can fully understand that those confronting the problem must sometimes despair and be led to seek other solutions, which involve the deployment of non-specialist staff. We note, however, the contrast with the view taken in Scotland, where, since 2000/01, teachers of mathematics have been required to have studied the subject for three years at university.

2.9 The Inquiry urges the DfES and the LSC to continue to acknowledge the importance of specialist teachers in mathematics and to accept that increasing the supply of specialist teachers of mathematics is an essential component of any strategy for tackling the mathematics problem in English schools (DfES) and colleges (LSC). We similarly urge the relevant authorities in Wales and Northern Ireland to give the issue the very highest priority and to consider, where appropriate, whether they might wish to implement their own versions of recommendations made for the English context. The rest of this chapter of the report focuses on what we perceive to be the scale of the problem of under-supply in England and ways in which we believe, over time, that supply can be increased.

The shortfall of specialist mathematics teachers in secondary schools

2.10 Official estimates of the numbers, age, profile and qualifications of teachers of mathematics in secondary schools in England are based on the Secondary Schools Curriculum and Staffing Survey (SSCSS). Until 1996, the Secondary SSCSS was conducted at four-yearly intervals. However, the Inquiry has noted with concern that the most recent SSCSS took place after a six-year interval, with a closing survey date of 21 November 2002. Some preliminary findings on qualifications and age profile have been released from the 2002 SSCSS and will inform our attempts to analyse trends. However, these findings are in the form of percentage breakdowns and we regret that key data on absolute numbers are not available for inclusion in this report.

2.11 From the 1996 Survey, it was estimated that there were 27,100 full-time and 3,700 part-time teachers in secondary schools with a post A-level qualification in mathematics. Not all of these were engaged in full-time mathematics teaching, but of the 25,200 full-time teachers actually teaching mathematics in years 7–13, 20 per cent had no post A-level qualification in mathematics. The number of teachers with a post A-level qualification teaching mathematics was 20,160 in 1996.

2.12 One interesting inference from these figures is that in 1996 there appear to have been nearly 7,000 teachers in secondary schools with a post A-level qualification in mathematics who were not teaching mathematics. This is of the order of 25 per cent of the qualified cohort within schools. Some of these teachers may, of course, have moved to teach other subjects – for example,

computer studies. However, it seems very unlikely that this accounts for more than a fraction of the large numbers of qualified teachers no longer teaching mathematics. This seems to the Inquiry to raise serious issues about current school level resource management and the incentives for qualified subject teachers to remain teaching their subject rather than moving into other posts.

Recommendation 2.1

The Inquiry recommends that the DfES undertake a review of school level resource management of qualified mathematics teachers in England. This review should include an assessment of whether current career paths and rewards provide appropriate incentives for qualified mathematics teachers to continue teaching mathematics. The LSC might wish to consider a similar exercise regarding the deployment of qualified mathematics teachers in colleges.

2.13 It has been suggested to the Inquiry that, in considering issues of qualified teacher supply in secondary schools, we should base our analysis solely on those actually teaching mathematics rather than on the total numbers with a post A-level qualification, since the latter include many teachers who are not currently teaching mathematics. This seems to us to ignore two important points. First, it disregards the potential for increasing the pool of qualified mathematics teachers actually teaching mathematics within schools by making suitable changes to school level resource management practices and incentives for teachers to remain teaching their subject. Secondly, it does not take on board that if future trends continue to reflect the fact that something like a quarter of post A-level qualified mathematics teachers eventually end up not teaching mathematics this needs to be factored into projections and strategies for mathematics teacher recruitment.

2.14 The 1996, 1992 and 1988 surveys revealed a worrying trend in the number of teachers qualified in mathematics as shown in Table 2.2. Some of the decline from 1992 will be due to the transfer of Sixth Form Colleges from the Schools to the FE Sector during the period after the 1992 survey. However, even allowing for this, the figures suggest a significant decline over the period in the number of qualified mathematics teachers in secondary schools. It is therefore a cause of considerable concern to the Inquiry that up to date numbers are not available to us from the 2002 SSCSS.

Table 2.2: Survey numbers of qualified mathematics teachers in maintained secondary schools in England and Wales

Survey	Teachers qualified in Mathematics (full and part-time)
1996 Survey	30,800
1992 Survey	43,900
1988 Survey	46,500

2.15 The Inquiry believes that a clear understanding of trends in the provision of qualified mathematics teachers is a key prerequisite to informed policy making regarding mathematics teacher recruitment and retention. The Inquiry therefore has further serious concerns about the low response rates in these recent surveys. The 1996 survey was based on a sample of 553 secondary schools and achieved a response rate of 60 per cent. The 2002 survey was based on a sample of 883 schools and achieved a response rate of 24 per cent. The DfES response to the Inquiry's concern regarding these low response rates has been to argue that they are a direct consequence of the excessive burdens that such surveys place on schools. The Inquiry notes this argument, but regards it as defeatist and unhelpful. We are absolutely convinced that policy making in this area requires good quality data and we urge the DfES and the LSC to accept and take forward Recommendation 2.2 below.

2.16 In the absence of key numbers from the 2002 survey, the Inquiry has examined alternative approaches to quantifying the current situation regarding numbers of qualified mathematics teachers. Estimates supplied to the Inquiry by the DfES suggest an outflow from maintained secondary schools in England and Wales in the period 1996 to 2003 of just over 8,900 teachers with a post A-level mathematics qualification actually teaching mathematics. Over the same period, the total inflow with a post A-level mathematics qualification has been just over 7,300. As we have seen from the 1996 figures, we can infer that something like 25 per cent of the teacher cohort qualified to teach mathematics ends up not actually teaching mathematics. Applying this to the inflow figure of 7,300 given above, we would estimate that this corresponds in the steady state to an addition of around 5,500 to the cohort of qualified mathematics teachers who will actually be teaching mathematics, The decline over the period of qualified mathematic teachers actually teaching mathematics is likely therefore to have been of the order of around 3,400.

2.17 It is not clear how schools have been able to cope with the shortfalls without an increased use of unqualified teachers. The 2002 Curriculum Survey, published in April 2003, shows mathematics still being taught to 100 per cent of pupils in Years 7–11, with no apparent change in the time allocated to the subject in any of the year groups. We note that the survey does not provide information on the number of pupils in teaching groups. Overall in secondary schools, class sizes seem to have remained relatively constant, but anecdotal evidence to the Inquiry suggests that class sizes in many sixth forms and FE Colleges have been increasing significantly. There are other changes that have impacted further upon the numbers of qualified mathematics teachers in schools and colleges. In particular, respondents to the Inquiry have estimated that the mathematics strand of the KS3 Strategy has resulted in at least some 300 experienced secondary mathematics teachers being taken out of schools since 2001 to support this initiative.

2.18 It is clear that the non-occurrence of the SSCSS survey in 2000 and the need to place continued reliance on the 1996 data has caused considerable concern to the many stakeholders already worried about the supply of qualified mathematics teachers. This has led in the interim to several attempts at unofficial surveys of the position. In 2001, a joint group from The Open University, King's College London and the National Association of Mathematics Advisors (NAMA) carried out a survey[1] of all NAMA members in a mix of metropolitan, unitary and shire counties across England. A total of 228 schools responded from 22 LEAs, involving a mixture of 1,571 full-time and part-time teachers of mathematics.

2.19 In addition, Willis (2002)[2] surveyed 54 schools involving 364 mathematics teachers on behalf of the Secondary Headteachers Association (SHA) and Roper (2002)[3], using the same definitions as the NAMA survey, surveyed 158 schools involving 536 mathematics teachers. The Inquiry has significant reservations about the unofficial and small-scale nature of these surveys. We also have a concern about response rates, a concern that also applies to the SSCSS 2002 survey, as noted above. However, to the extent that response bias in this context is felt by many respondents to be likely to lead to an understatement of the problem, the surveys may be indicative and we feel, on balance, that the outcomes are worth reporting. To facilitate comparisons with earlier studies, the data from the NAMA survey were analysed by the authors using the same categories as in the Cockcroft report (see Table 2.1).

2.20 The OU/KCL/NAMA report makes clear that it is not the intention of the authors that the terms 'good', 'acceptable', 'weak' be seen as necessarily applicable to every individual teacher whose qualifications fall in the relevant category. The assumption is rather that the overall picture based on this categorisation provides a meaningful measure of the extent of the shortage of specialist mathematics teachers. The Inquiry agrees that the measures used in these surveys do provide a reasonable aggregate basis for quantifying the shortage of appropriately qualified mathematics teachers.

2.21 Results of the OU/KCL/NAMA survey (see Table 2.3) show that, in the schools responding, nearly 24 per cent of those teaching mathematics had 'weak' or 'nil' qualifications in mathematics. The survey also revealed a number of school mathematics departments with large numbers of part-time teachers teaching mathematics. Overall, the schools reported that 8 per cent of mathematics teachers were about to retire. Of the 504 teachers who taught AS or A-level, 34 (nearly 7 per cent) had A-level as their highest mathematics qualification and 3 had no higher qualification than GCSE.

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[1] Shortage of Mathematics Teachers: a report of the survey of secondary mathematics departments carried out in the academic year 2001–2002: Sue Johnston-Wilder, Barbara Allen *The Open University*, Gillian Thumpston, Heather Cooke *National Association of Mathematics Advisers*, Margaret Brown, Leone Burton *King's College London.* In *What Progress? Proceedings of a National Day Conference* (Centre for Mathematics Education: The Open University).

[2] Willis P (2002) *Trained to Teach?* London: SHA

[3] Roper T (2002) Who is Teaching Secondary Mathematics? In S Johnston-Wilder, *Key Stage 3 mathematics teachers: the current situation, initiatives and visions: Proceedings of a National Day Conference* 113-128 Milton Keynes: The Open University

Table 2.3: Qualifications of mathematic teachers

Good	916	58.3 per cent
Acceptable	230	14.6 per cent
Weak	100	6.4 per cent
Nil	275	17.5 per cent
Not reported	51	3.3 per cent

2.22 There are a significant number of part-time teachers of mathematics in secondary schools. In order, therefore, to get an estimate of how much teaching is carried out by teachers with 'weak' or 'nil' initial mathematics qualifications it is necessary to consider the percentage tuition time rather than just teacher numbers in each category. This results in the estimates given in Table 2.4. These estimates suggest that, among the schools responding, 14.6 per cent (one in seven) of secondary mathematics lessons in England are taught by teachers with 'weak' or 'nil' mathematics qualifications.

Table 2.4: Qualifications of mathematic teachers by hours of teaching

Good	17570	69.2 per cent
Acceptable	4116	16.2 per cent
Weak	1221	4.8 per cent
Nil	2480	9.8 per cent

2.23 Willis (2002) also estimated that 14 per cent of mathematics lessons (one in seven) were taught by a teacher not qualified to teach mathematics, although we note that his definition of "qualified" was not as stringent as the OU/KCL/NAMA definition. Roper (2002) also estimated that 14 per cent of mathematics teachers were not properly qualified to teach mathematics. This latter survey, unlike the other two, also included independent schools. Assuming a pupil to teacher ratio of 17.0 in maintained secondary schools in England (the January 2003 figure reported in SFR 23/2003) and assuming that around 13 per cent of the curriculum is devoted to mathematics, the OU/KCL/NAMA report calculates that some 25,900 full-time equivalent mathematics teachers are needed for the secondary school sector. The OU/KCL/NAMA report concludes, therefore, that just under 3,800 mathematics teachers need to be trained or brought into the system to cover the posts currently filled by teachers with 'weak' or 'nil' mathematics qualifications. Notwithstanding concerns about the unofficial nature of the surveys, sample sizes and response rates, the Inquiry believes that the analyses summarised above provide a prima facie case for estimating there to be a current shortfall of 3,400–3,800 qualified mathematics teachers teaching mathematics in secondary schools in England.

2.24 The OU/KCL/NAMA survey also collected data, Table 2.5 below, on the experience of schools trying to recruit teachers of mathematics. Respondents clearly felt that the number of applicants for mathematics teaching posts with 'good' or 'acceptable' mathematics qualifications continues to decline. Some schools reported advertising for five or six teachers during a single year. Over a quarter advertised for three or more mathematics teachers during the year. Overall, only 37.1 per cent of the appointments made by those schools responding to the survey were considered to be of teachers with 'good' mathematics qualifications.

Table 2.5: Results of advertisements in the year 2001–2002

Good appointment	136	37.1 %
Satisfactory appointment	70	19.1 %
Appointment needing support	40	10.9 %
Unsatisfactory appointment – no choice	39	10.6 %
No appointment made – staff moved	77	21.0 %
Vacancy	5	1.4 %

2.25 The SSCSS also collects data on teacher qualifications. However, the Inquiry is concerned that current categorisations used in the SSCSS survey do not permit clear inferences to be drawn. The SSCSS estimated the percentages of teachers of mathematics who hold no qualifications in mathematics higher than A-Level to be around 20 per cent in 1996 rising to 26 per cent in 2002. However, the categorisation used in the survey only indicates the lack of a mathematics degree. It does not distinguish between other degrees with a high mathematical content (eg physics) and those with low mathematical content. This ambiguity is reflected in the Secretary of State's 25 September, 2003, press statement regarding the 2002 SSCSS:

> "*A proportion of mathematics teachers are listed in the survey as having 'no qualification in mathematics'; but this does not mean they are unqualified. Most of these teachers are likely to be qualified and graduates in subjects such as physics .... They may only teach one or two periods of mathematics a week.*"

2.26 The Inquiry would be considerably reassured to know that this was the case, although we might have concerns about these teachers' knowledge of and exposure to mathematics pedagogy if their specialist training had been in a different subject. However, we find it frustrating and unsatisfactory that such issues are currently matters of speculation rather than being clearly evidence-based. To achieve the latter, we need clearer categorisation in the survey, perhaps based on the Cockcroft categorisation, in order to distinguish qualifications with appropriate mathematics content from those lacking such content (see Recommendation 2.2 below).

The shortfall of specialist mathematics teachers in colleges

2.27 We also note that the SSCSS relates solely to teachers of mathematics in maintained secondary schools. However, there are a significant number of teachers of mathematics in independent schools and Sixth Form and FE Colleges. In relation to colleges, the Inquiry notes that the LSC currently has no equivalent of the SSCSS data on numbers and qualifications of teachers of mathematics. Data in colleges are currently collected in the categories used for Ofsted inspections, for which mathematics numbers are subsumed within the science category and are not separately identifiable. We view this absence of data with some concern in view of a number of developments that are likely to increase demands on mathematics teaching resources in colleges. For example, DfES evidence to the Inquiry acknowledges that progress on the adult numeracy strategy could be undermined by the limited pool of competent and confident teachers of mathematics and numeracy currently available in the adult sector. This task of addressing the lack of numeracy skills among a large section of the adult population will require additional staff with mathematics qualifications to provide support to trainers, even if they are not used to deliver the programme. There is also the risk that any shortage might be met by further leakage from the secondary and FE sectors. It has also been suggested to the Inquiry that teaching interested adults may seem more appealing to some current schoolteachers than working with sceptical adolescents. This might result in further losses of mathematics teachers from the secondary school sector.

2.28 However, as there appear to be no national targets for lecturer supply and training in colleges, it is difficult to quantify the effects of these additional pressures on the demand for mathematics educators. The Inquiry regards it as extremely unhelpful that in the key area of mathematics teacher supply there is currently no coherent overall understanding of numbers and qualifications (see Recommendation 2.2 below).

The shortfall of ITT mathematics trainers

2.29 Respondents to the Inquiry have also expressed anxieties about the future capacity and availability of suitably qualified mathematics educators in higher education to deliver quality ITT and provide ongoing CPD. Trainers themselves clearly need to be appropriately academically qualified and to continue to update their own knowledge and skills in order to properly train future teachers. The Inquiry has therefore noted with considerable concern that there does not seem to be an evidence base relating to the numbers and profile of those delivering mathematics teacher training.

2.30 The results of an informal survey carried out in May 2002, by the University Council for the Education of Teachers suggest that there are serious problems ahead. Higher Education Institutions with ITT provision were asked to return the numbers and ages of staff working in mathematics education. Of the trainers covered by these responses, 63 per cent trained primary teachers,

40 per cent trained secondary teachers and 17 per cent trained post–16 teachers (with some overlap). The age profile of those trainers covered by the providers responding to the survey is shown in Table 2.6. Given the relatively low response rate (58 per cent) and some problems with inconsistencies in responses, the Inquiry is not sure how much weight to attach to these figures. However, if they are at all representative, the Inquiry has concerns for the future of a system in which 50 per cent of the current trainers are over 50 years of age.

Table 2.6: Age profile of teacher trainers

Age	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65
No. of staff	4	10	9	14	25	40	24	2

The need for up-to-date comprehensive data

2.31 At all levels, the Inquiry has serious concerns about the current evidence base regarding the numbers and profile of those teaching post–14 mathematics in schools, Sixth Form Colleges and FE Colleges and providing mathematics ITT. This evidence base is crucial for understanding current and future supply needs for teachers of mathematics at all levels and for monitoring progress towards meeting these needs. This prompts the following recommendation, expanding on Recommendation 2.1, which we would wish to be taken on board by relevant bodies, including the National Statistics Strategic Review of School Workforce Statistics, which we understand is due to report in 2004.

Recommendation 2.2

The Inquiry recommends that the DfES and the LSC work together and with the TTA to review the frequency and scope of data collection relating to mathematics teacher and teacher trainer numbers and qualifications. They should seek to agree a data collection strategy that will provide the evidence base for a coherent policy approach to the supply of appropriately qualified teachers for the teaching of mathematics across all secondary schools, sixth form and further education colleges, and of appropriately qualified ITT mathematics trainers. In particular, the Inquiry recommends that:

(i) a revised form of SSCSS, requiring a mandatory response, should be designed and undertaken as soon as possible to cover not only secondary schools, including those in the independent sector, but also sixth form and further education colleges and providers of mathematics ITT;

(ii) categories of response be redefined, along similar lines to the Cockcroft categorisation, to provide a clearer indication of teacher qualifications;

(iii) the breakdown of qualifications should be available separately for the those teaching key skills, KS3, KS4 and post–16;

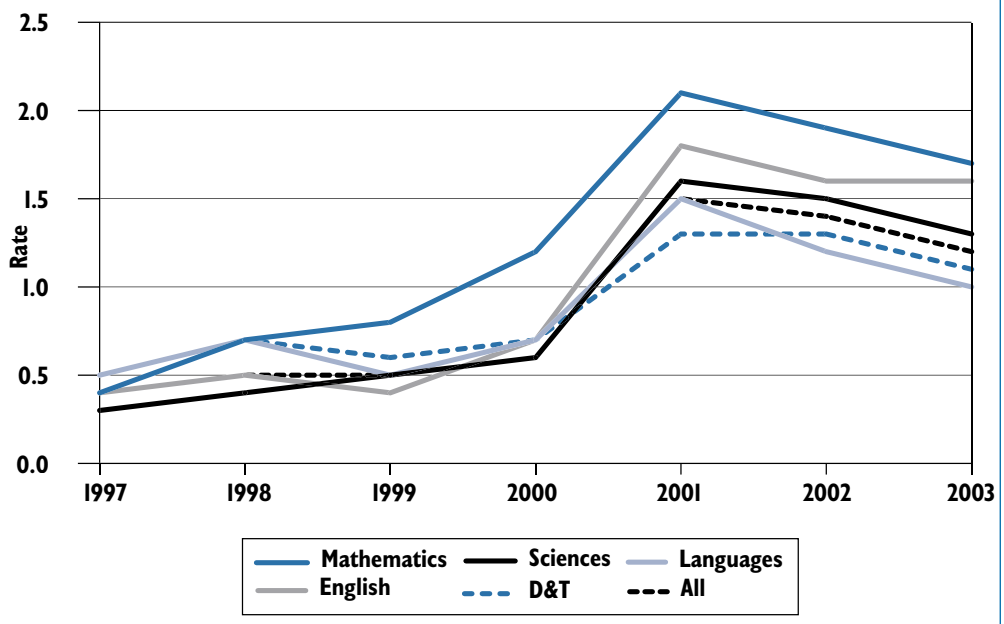
(iv) in view of the current critical position in regard to provision of teachers of mathematics and the need for close monitoring of policy initiatives to improve recruitment and retention, at least the first three new surveys should be undertaken every two years.

Teacher vacancies

2.32 Vacancy rates provide another source of data for assessing the extent to which there is a shortage of specialist mathematics teachers. Technically, a vacancy is defined as a post that has been advertised for a full-time permanent appointment (or appointments of at least one-term's duration) but has not been filled. This includes posts that are being filled on a temporary basis of less than one term. Part-time posts and fixed-term posts that are unfilled are not counted as vacancies, nor are posts that are filled on a temporary basis for one term or more, for example by agency staff.

2.33 Despite recent improvements, analysis of data on vacancies as a percentage of teachers in post confirms that the shortage in teachers of mathematics is more acute than for many other subjects. Concerns about the supply of mathematics teachers in the period 1997–2003 are reflected in evidence provided to the Inquiry by the DfES. Figure 2.2 below illustrates trends in vacancy rates for mathematics compared with a selection of other subjects, and with the aggregate over all subjects in maintained secondary schools in England since 1997. The graph for mathematics reveals an overall rise in the vacancy rate from a level of just under 0.5 per cent of the 1997 mathematics teacher stock, to a peak rate of 2.1 per cent in 2001. In 2002, there was a small decline to 1.9 per cent and in 2003, a further decline to 1.7 per cent. This recent downward trend is encouraging. However, the Inquiry notes that the 2003 rate is still the third highest vacancy rate for mathematics teachers in the past decade and also the second highest for all the other subjects in 2003.

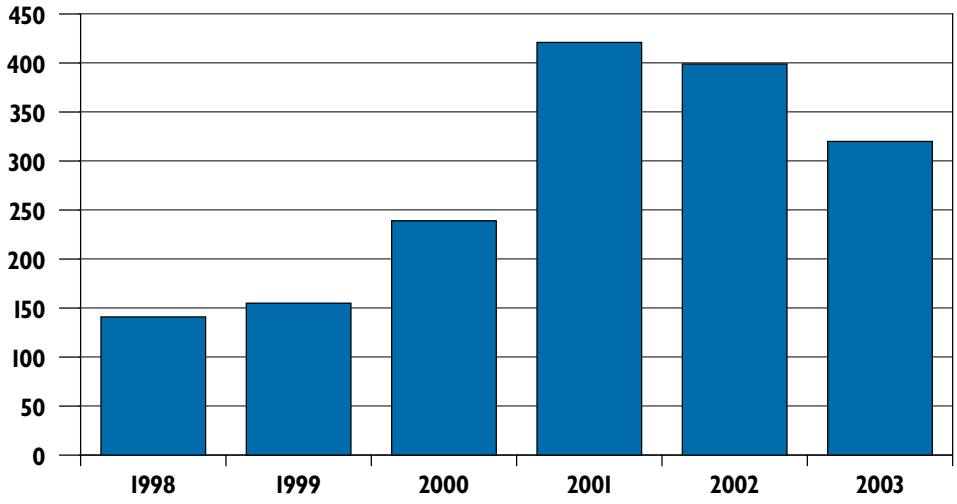
Figure 2.2: Vacancy rates by subject



Source: DfES

2.34 Reported numbers of vacancies provided by the DfES to the School Teachers Review Body (STRB) are shown in Figure 2.3. The Inquiry welcomes the recent downward trend but again notes that the current numbers are still well above the average of the 1990s, even as a proportion when increased teacher numbers are taken into account.

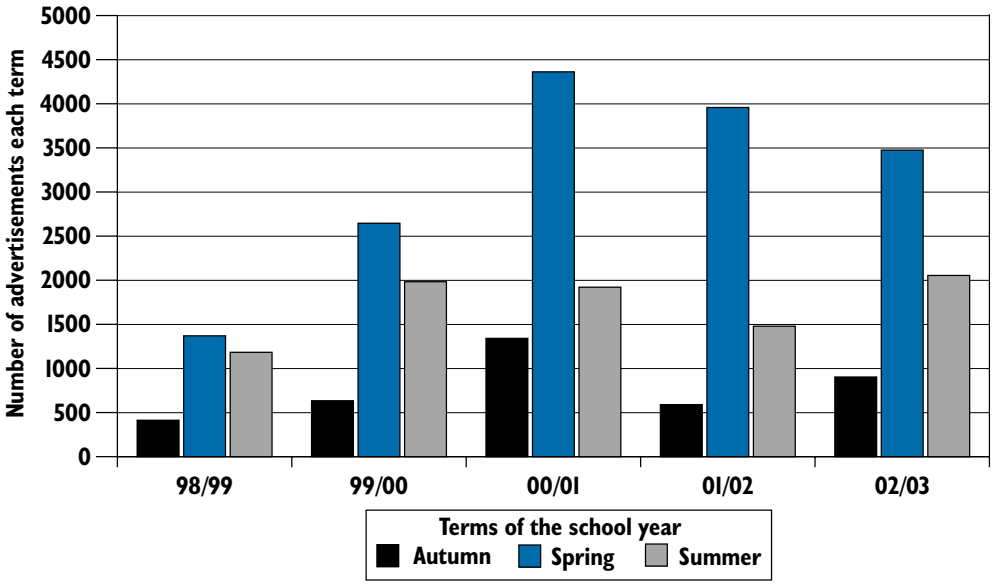
Figure 2.3: Reported Vacancies



Source: DfES Evidence to STRB + SFR April 2003

2.35 Figure 2.4 shows the number of advertisements for mathematics teachers in England that have appeared in the Times Educational Supplement (TES) in the past five years. This prima facie evidence further supports the view that unfilled teacher vacancies have been reducing in number; certainly, there are fewer advertisements than two years ago. The Inquiry again welcomes this trend but remains concerned that the data do not show the extent to which there is still a latent demand for more qualified mathematics teachers in schools where a significant proportion of lessons are taken by unqualified teachers.

Figure 2.4: Number of Advertisements for Mathematics Teachers in the TES

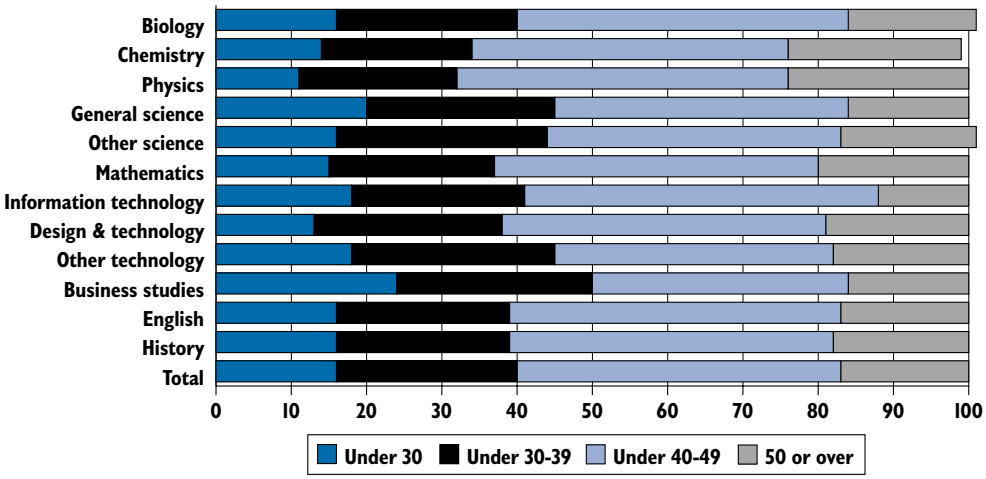


2.36 So far as turnover of staff is concerned, surveys conducted by the National Employers' Organisation for School Teachers, with support from the DfES and the teacher unions, collect information on resignations by teaching subject. This, combined with information about the number of staff by main teaching subject from the SSCSS, provides the basis for calculating turnover rates. In 2001, the turnover rate for secondary mathematics teachers in England was 15.3 per cent. The Inquiry notes with concern that this was twice that of 1991 (7.6 per cent) and higher than the 13.5 per cent average turnover rate for secondary teachers. Provisional data for 2002, supplied to the Inquiry by the DfES, suggest a small improvement in turnover rate for secondary mathematics teachers of 13.6 per cent against an average for all subjects of 12.5 per cent.

Teacher age-profiles and forecasts of future supply requirements

2.37 International comparisons reported in the Roberts report (*SET for Success*, paragraph 2.44) suggest that although other countries also experience more shortages of teachers in science and mathematics than in other subjects, the shortages in the UK are considerably worse than elsewhere. Furthermore, teacher shortages in mathematics (as well as physics, chemistry and design Technology) could well worsen over time, since, as shown in Figure 2.5 (Figure 2.13 of *SET for Success*), fewer teachers whose main qualification is in these subjects are under 30 and more are over 50 compared with their counterparts in other subjects.

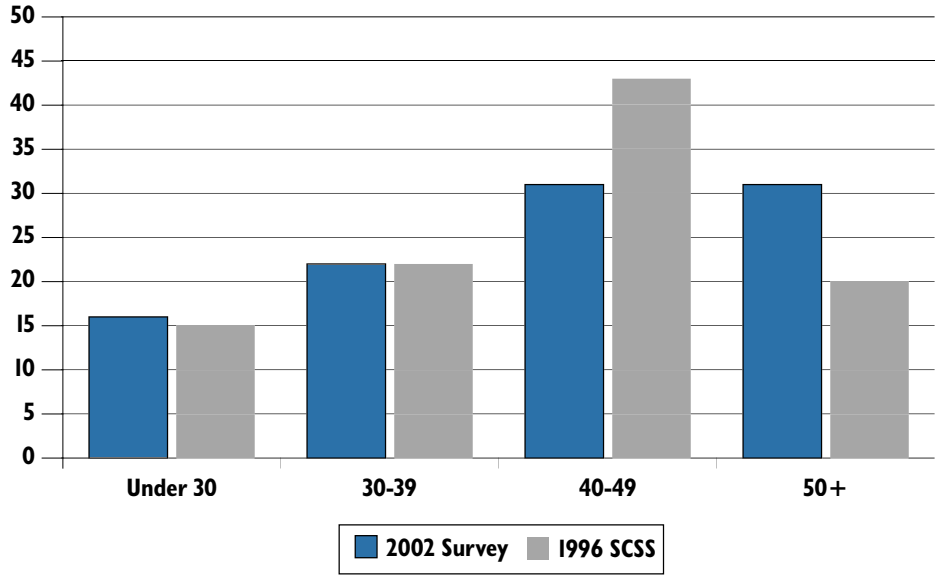
Figure 2.5: Teacher Demographics



Source: 1996/97 Secondary Schools Curriculum and Staffing Survey

2.38 A further serious problem for the future arises from trends in the age profile of the mathematics teaching profession. Data from the SSCSS revealed that the position was already worrying in 1996. However, provisional data released from the 2002 SSCSS shows a further marked deterioration in the age profile of mathematics teachers. Of the full-time teachers surveyed in 1996, 63 per cent were over 40 compared with 60 per cent of all secondary teachers; 20 per cent were over 50, compared with 17 per cent of all secondary teachers; 15 per cent were under 30 compared to 16 per cent overall. According to the 2002 SSCSS, 62 per cent were over 40, compared with 56 per cent of all secondary teachers; 31 per cent were over 50, compared with 27 per cent of all secondary teachers; 16 per cent were under 30, compared with 20 per cent overall. Figure 2.6 provides a comparison of the 1996 and 2002 age profiles.

Figure 2.6: Age Profile of Mathematics Teachers



2.39 The shift in age profile of the population of full-time mathematics teachers in secondary schools revealed by the 2002 SSCSS is a cause of major concern to the Inquiry. In particular, we would like to be reassured that this demographic shift is being fully taken into account in modelling future demand and calculating future mathematics teacher training requirements for the whole system in England. As indicated earlier, we cannot see how coherent forecasts can be made at present given the apparent lack of age profile data for those teachers of mathematics working in Sixth Form and FE Colleges. We are also concerned that even existing surveys only cover the maintained secondary school sector and do not factor in the numbers of mathematics teachers required in the independent sector.

Recommendation 2.3

The Inquiry recommends that at the earliest possible opportunity forecasts of future teacher training number requirements for mathematics teachers be re-examined in the light of:

- the estimate we have suggested of a current shortfall of at least 3,400 qualified mathematics teachers in secondary schools;
- the age profile findings from the 2002 SSCSS;
- and taking into account the current position and future needs of independent schools, Sixth form and FE Colleges, in addition to secondary schools.

The decline in post–16 take up of mathematics

2.40 Perhaps the cause of greatest concern to many respondents to the Inquiry, and not only in the context of teacher recruitment, has been the dramatic decline in A-level mathematics entries since the Curriculum 2000 changes were introduced. This is shown in Table 2.7.

Table 2.7: Total A-level entries (all UK, all ages)

Year	Numbers of candidates
2003	55,917
2002	53,940
2001	65,891
2000	65,836
1999	68,502
1998	68,846
1997	68,853
1996	67,022

Source: JCGQ.

2.41 The decline in the number of candidates in the period 2000–2003 is of the order of 15 per cent. Respondents have seen this as having serious potential consequences for recruitment into mathematics and other degree courses with high mathematics content, with subsequent problems in two and three years time for recruitment into mathematics teacher training. However, data on numbers entering into undergraduate mathematics courses, shown in Table 2.8 below, present some mixed messages.

Table 2.8: Entry to undergraduate mathematics (all UK)

Year	Applicants	Acceptances, including clearing applications
2003	3825	4329
2002	3325	3840
2001	3863	4006
2000	3925	4052
1999	3989	4158
1998	3887	4147
1997	3816	4255
1996	3839	4159

2.42 There was, indeed, a sharp drop in applications in 2002, of around 14 per cent, which translated into a subsequent 4 per cent drop in numbers entering mathematics degrees. However, in 2003 the number of applications has increased back to around the 2001 level and, perhaps surprisingly, the number of entries to degree courses actually increased significantly to one of the highest levels for a decade, although we note that this still only represents a return to the level of the mid–1990s. The figures for 2003 have only become available as this Inquiry was completing its work. We have therefore had no opportunity to investigate the rather volatile movements in numbers over the past couple of years. Some respondents to the Inquiry have suggested that this sudden increase may be explained by internal funding issues within HEIs linked to student recruitment problems in some mathematics departments. This may have led to changed (ie a lowering of) entry requirements in some institutions. The Inquiry has not been able to follow up on this suggestion, but we suggest that it would be valuable for someone to investigate further these patterns of applications and acceptances. We suggest that the Committee of Heads of Departments of Mathematical Sciences in Higher Education (HoDMS) might undertake such an investigation, perhaps in conjunction with the Council for the Mathematical Sciences.

Teacher recruitment

2.43 Evidence to the Inquiry from the TTA shows that, in recent years, newly qualified teachers have made up 45 per cent of the total inflow of all teachers into the secondary maintained sector. Overall, in secondary schools in 2001 there was a staffing inflow of 9 per cent and an outflow of 8 per cent. This fine balance between inflow and outflow makes it essential to ensure that a good supply of newly qualified teachers is maintained and therefore that able and committed trainees are recruited to fill all allocated training places. We are aware that the DfES is currently consulting on proposals for reform of ITT in FE, following a critical review by Ofsted. We urge that careful consideration is given to ensuring that, where appropriate, the recommendations we make in this chapter are also implemented in that context.

2.44 Teachers working in maintained schools in England normally hold Qualified Teacher Status (QTS), which is usually obtained through completing ITT. There are three main routes for achieving QTS:

- as part of an undergraduate degree BEd, BA or BSc (mostly used for primary school teachers);
- through a postgraduate training course, often combined with study for a Postgraduate Certificate in Education (PGCE);
- for trainees via employment in schools on the Graduate Teacher Programme (GTP) or the Registered Teacher Programme (RTP) (for those without a first degree but with two years' study in higher education).

2.45 Postgraduate trainee teachers in England and Wales on an eligible ITT course receive a £6000 training bursary as a recruitment incentive. The TTA also administers a Secondary Subject Shortage Scheme. An additional £4,000 is available for eligible postgraduates who go on to teach in shortage subjects in England[4], and some further training awards are available to secondary school teacher trainees in shortage subjects based on financial need[5]. Some of these incentives are also available in Wales. The following table (Table 2.9) shows the kinds of routes and financial provision available to potential mathematics teachers.

[4] An additional £4,000 is available for eligible postgraduates teaching mathematics, science, English, modern languages, design and technology or ICT in England. It can be claimed by those successfully completing induction within 5 years of the start of the first academic year after gaining Qualified Teacher Status and, within 12 months of completing induction, working in a relevant teaching post in the maintained sector.

[5] These awards are for secondary school teacher trainees on undergraduate and postgraduate ITT courses studying one of the following subjects: mathematics, science, modern foreign languages, design and technology, ICT, religious education, music or geography. The maximum payment in any one year is £7,500. These maximum amounts are only awarded in exceptional circumstances and there is no automatic entitlement to any level of payment.

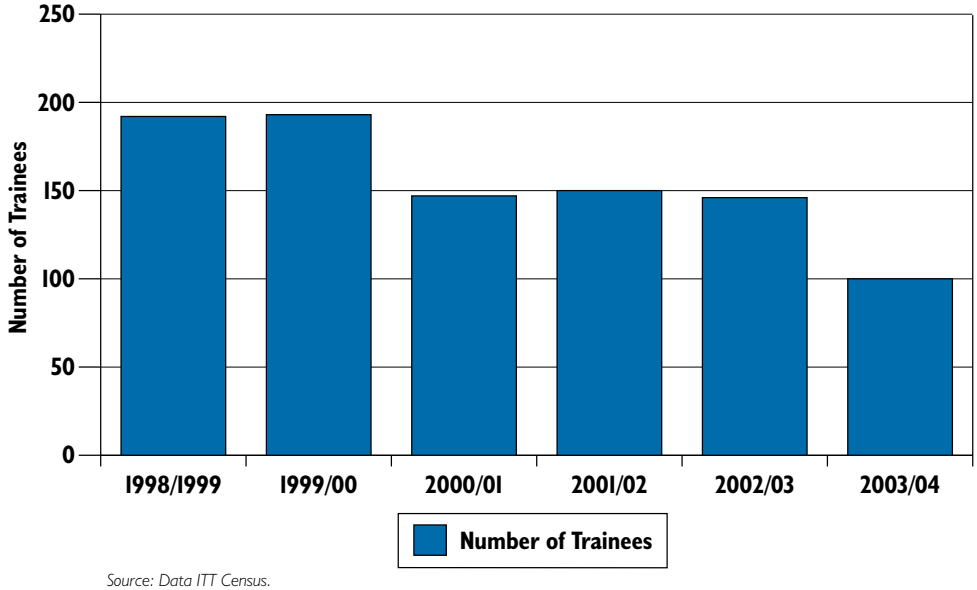
Table 2.9: A summary of current training routes

Route	Time	Training bursary
Undergraduate routes		
BA with QTS or BSc with QTS	1 term – 1 year (QTS)	
Postgraduate routes		
Postgraduate Certificate in Education (PGCE)	1 year full-time. Part-time varies	£6,000
PGCE (flexible)	10 weeks – 2 years	£6,000 max
PGCE (2-year)	2 years	£6,000 in final year only
Fast track	1 year enhanced PGCE with extended development in school	£6,000 + additional £5,000
Employment based routes		
Graduate Teacher Programme (GTP)	1 term – 1 year	£13,266 salary
Registered Teacher Programme (RTP)	1 – 2 years	£13,266 salary
Overseas Trained Teachers Programme (OTTP)	Up to 1 year	£13,266 salary

Undergraduate routes

2.46 The Inquiry notes that undergraduate teacher training courses are now of declining importance as a route for training secondary mathematics teachers (Figure 2.7 below).

Figure 2.7: Number of new undergraduate trainees in secondary mathematics since 1998/99



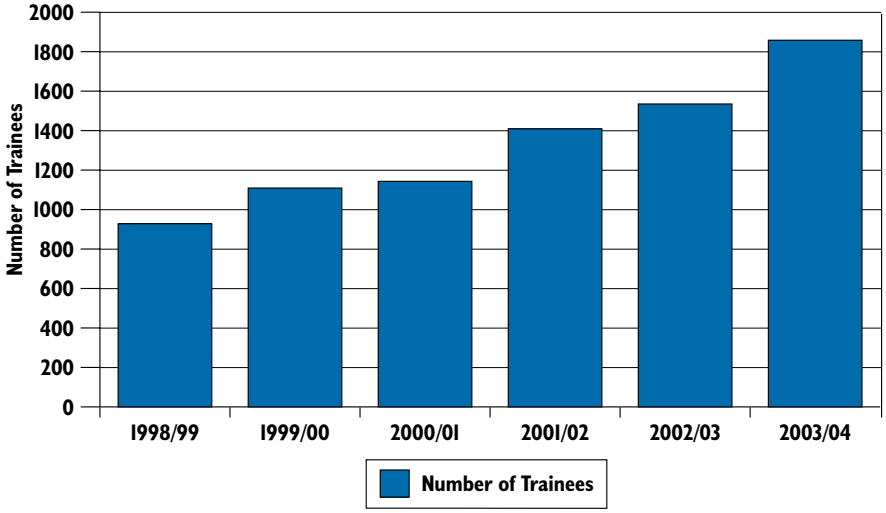
Source: Data ITT Census.

Postgraduate routes

Mainstream PGCE recruitment

2.47 The mainstream ITT PGCE courses continue to be the most important route, with improved recruitment in recent years as shown in Figure 2.8. In 2003/04 95 per cent of entrants to secondary mathematics ITT (excluding the employment-based routes) were postgraduates. The Inquiry very much welcomes the increased mathematics teacher training enrolment over the past five years. The postgraduate recruitment in 2002/3 was the highest since 1994/5. However, we are also mindful that the recruitment level is only just recovering to that of 1996/97 (1,653), which itself represented a significant decrease compared to the level of the previous year, 1995/96 (1,795).

Figure 2.8: Number of new postgraduate trainees in secondary mathematics since 1998/99 (including Fast Track)



Source Data: ITT Census

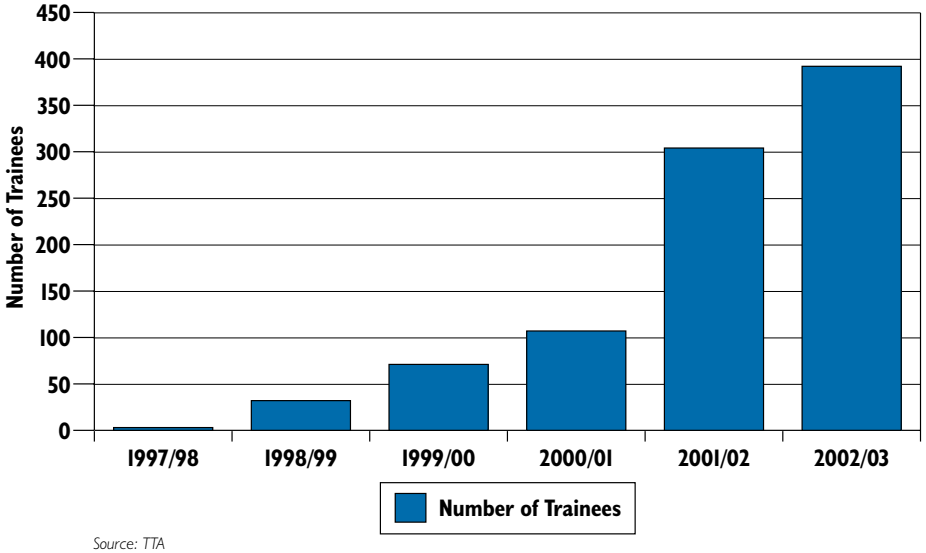
Flexible PGCE recruitment

2.48 In addition to the standard, usually one-year and full-time, PGCE course, a flexible or modular PGCE has been recently introduced, designed to meet the needs of trainees with commitments that preclude other than a part-time route. The course can be taken over a period of up to two years but may be completed in a shorter time (a minimum of six weeks) by trainees with suitable relevant prior experience. The distinctive feature of courses designated as flexible is that they have variable start and finish points. Over the last three years, the number of flexible mathematics ITT places in England has increased by 23 per cent (from 212 places in 2001/02 to 260 in 2003/04). From September 2003, there will be around 40 HE providers offering such courses.

Employment-based routes

2.49 Employment-based routes are beginning to make a significant contribution to the number of people training to teach mathematics (see Figure 2.9). The Graduate Teacher Programme (GTP) is a programme that allows graduates to earn a salary while they train to be a teacher. Since September 2003 GTP has been open to applicants of any age. The GTP enables schools to employ, as supernumeraries, people who do not yet have QTS and train them through an individual training programme leading to QTS. Schools are funded to pay GTP trainees as unqualified teachers, a minimum of £13,266 a year, whilst they are training. The programme is designed for individuals who want to change to a teaching career but need to continue earning while they train. The Registered Teacher Programme (RTP) offers individuals the opportunity to work as an unqualified teacher in a maintained school in England whilst completing the final year of a degree and undertaking teacher training. Individuals who have qualified as a teacher outside the European Economic Area may gain QTS through the Overseas Trained Teacher Programme (OTTP) while working as a teacher. While on the OTTP trainees follow an individualised training programme leading to QTS while working in a school as an unqualified teacher.

Figure 2.9: Number of new entrants to employment based routes training programmes in secondary mathematics since 1997/98



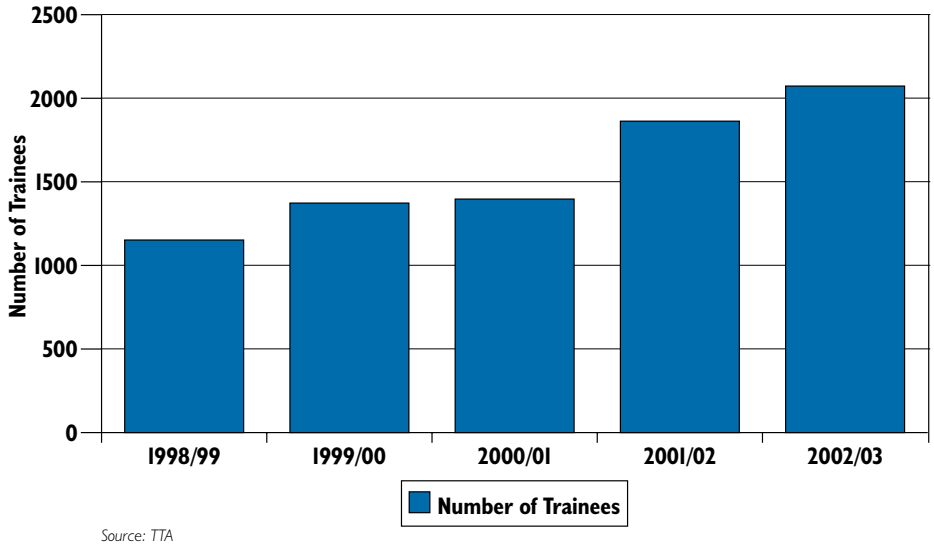
Source: TTA

The GTP is the most significant of the employment-based routes. In response to the increases in recruitment through this route, Ministers have agreed to double the size of the GTP by 2005/06. In addition to the GTP numbers, the RTP has contributed 19 new teachers of mathematics and the OTTP has contributed 175. The Inquiry very much welcomes this response and would wish to see further increases if demand for this route continues to grow and quality is assured.

Overall recruitment

2.50 The total annual number of new mathematics trainees from 1998/99 to 2002/3 is shown in Figure 2.10.

Figure 2.10: Number of new trainees to initial teacher training in mathematics (including employment based routes) Since 1998/99



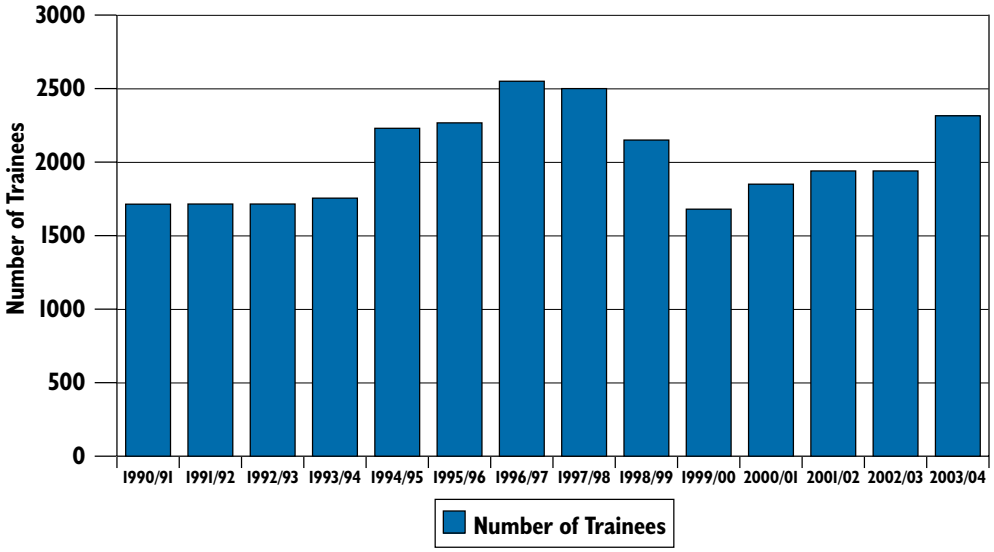
Source: TTA

2.51 Factors that the TTA believes have contributed to the increased interest in and subsequent rise in postgraduate recruitment numbers in recent years include:

- the introduction of training bursaries and 'golden hellos';
- the penalties imposed for under-recruitment;
- a more vigorous communications and marketing campaign;
- impressing on ITT providers the importance of recruiting to all the allocated places;
- a wider range of teacher training opportunities.

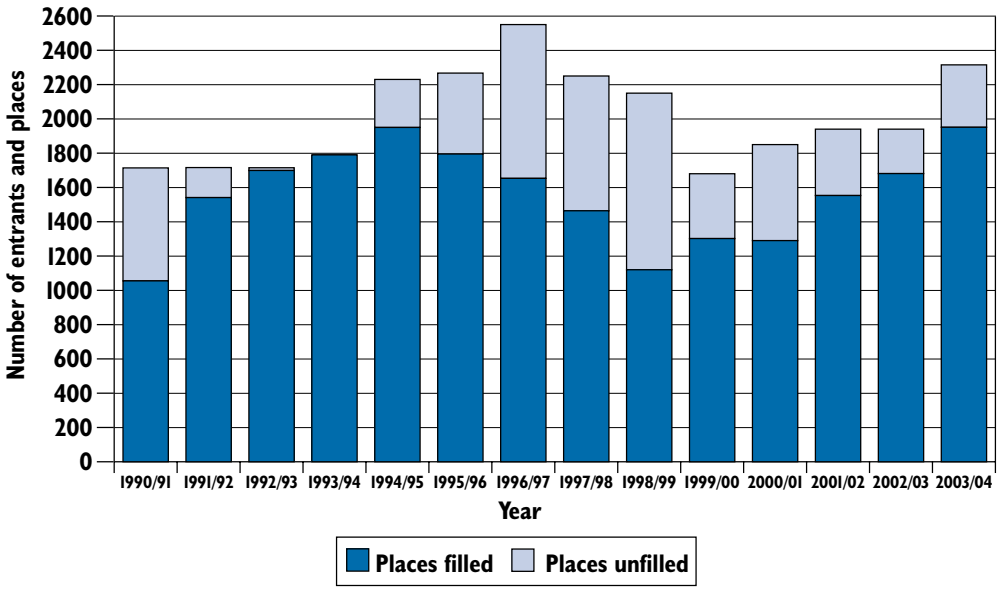
2.52 The Inquiry welcomes these recent increases in numbers entering teaching training in mathematics as well as the upward trend in the number of training places available. However, we note that there remains a considerable shortfall in recruitment compared with the training places available. Figure 2.11 below shows the number of mathematics training places available each year from 1990/91 and Figure 2.12 shows the percentage of places filled, the latter clearly reflecting the effects of the economic cycle. The number of ITT places for mathematics in 2003/04 is 2,350.

Figure 2.11: Number of places for mathematics ITT courses in England 1990/91 to 2003/04



Source: DfES

Figure 2.12: Number of places filled and unfilled for secondary mathematics courses



Comparisons with recruitment in other subjects

2.53 Tables 2.10 and 2.11 indicate the considerable difficulties experienced in recruiting to mathematics teacher training compared with some other subjects. These recruitment figures exclude fast track trainees.

Table 2.10: Places and actual recruitment for Initial Teacher Training in England, 2002/03

Subject	Actual recruitment	Places	Proportion of places filled
Mathematics	1,673	1,940	86 per cent
Science	2,701	2,850	95 per cent
Modern Languages	1,732	2,050	84 per cent
English & drama	2,479	2,350	105 per cent
History	985	950	104 per cent

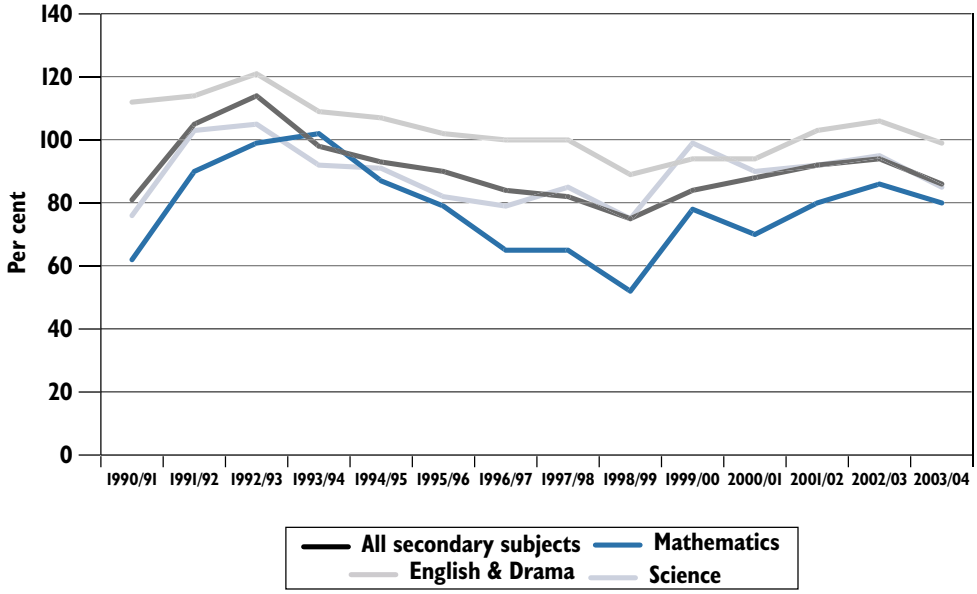
Table 2.11: Places and actual recruitment for Initial Teacher Training in England, 2003/04

Subject	Actual recruitment	Places	Proportion of places filled
Mathematics	1,951	2,315	84 per cent
Science	2,854	3,225	88 per cent
Modern Languages	1,815	2,050	89 per cent
English & drama	2,440	2,350	104 per cent
History	994	950	105 per cent

Sources: Recruitment – TTA ITT trainee number census, 2003

2.54 Figure 2.13 below shows trends in the percentage of available teacher training places filled in secondary mathematics along with those for English, science and the aggregate over all secondary subjects.

Figure 2.13: Recruitment as a percentage of places in mathematics, English & Drama and science



Source: DfES places and TTA ITT Census

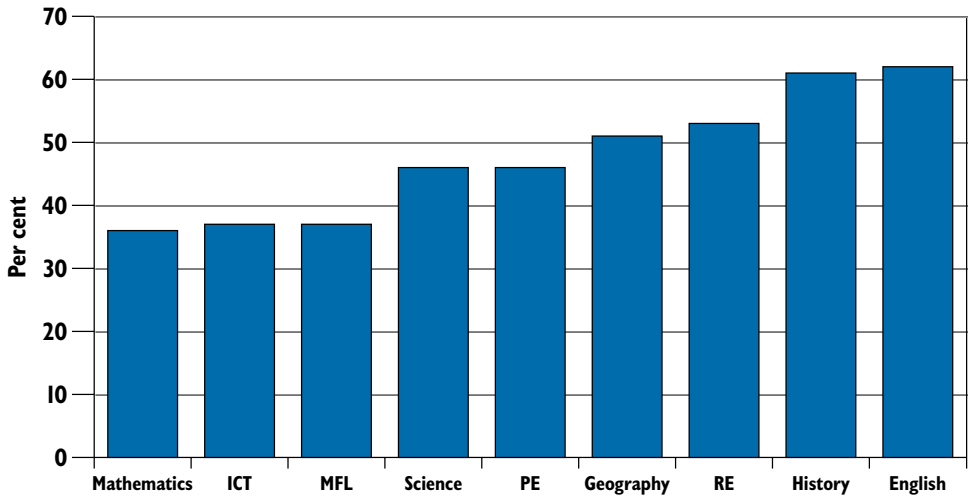
2.55 The Inquiry notes that, according to figures supplied by the DfES, at present only around 66 per cent of applicants in mathematics make it onto PGCE courses. This compares, for example, with 98 per cent on design and technology, 82 per cent on music and 79 per cent on RE courses. Mathematics has a conversion rate from applicant to trainee that is closer to subjects such as English (53 per cent), where there is a plentiful supply of applicants. This raises the question of whether ways could be found to enable more of the 1,000 applicants who are currently turned away, or withdraw their applications, to become mathematics trainees and eventually teachers. We suggest that the TTA, together with ITT providers might investigate this relatively low conversion rate from mathematics PGCE applicant to trainee.

Comparisons with qualifications of trainee teachers in other subjects

2.56 So far as the academic qualifications of entrants to mathematics teacher training is concerned, over the period 1996/97 to 2001/02, the proportion of mathematics trainees with a 2:1 degree or better remained fairly constant at below 40 per cent, varying between 33 and 38 per cent.

2.57 Figure 2.14 presents comparative data for a range of subjects showing the proportion of recruits to ITT with a degree class of 2:1 or better over the period 1996/97 to 2001/02. The proportions are calculated as a percentage of all first year trainees, including trainees who do not have a UK degree and for whom degree classification is unknown. For modern foreign languages (MFL), the proportion of trainees with non-UK degrees is higher and this goes some way to explain the lower percentage of trainees with a 2:1 or higher in this category. However, we are not aware of a similar mitigating factor for mathematics. We therefore note, with considerable concern, that the proportion of entrants with a 2:1 or higher entrants for mathematics teacher training is the lowest of all the subjects.

Figure 2.14: Percentage of all first year postgraduate trainees with a 2:1 or higher degree classification



Source: TTA Performance Profiles Note: includes trainees with non-UK degree equivalent qualifications

2.58 This clearly suggests that teaching is not as attractive to the pool of students who could teach mathematics as it is for potential teachers of many other subjects and that, among entrants to the teaching profession, subject-specific competence may not be so high in mathematics as in many other subjects. This suggests that, in general, many teachers of mathematics may be in more need of subject-specific CPD than teachers in other subjects. We shall return to this issue in Chapters 5 and 6.

Returners to the profession

2.59 *SET for Success* drew attention to the small but growing number of returners to the science teaching profession, as well as the increase in mature entrants to the profession. Given the relatively small number of graduates in mathematics, late entrants to the teaching profession in these subjects are likely to become increasingly important and the Inquiry was interested to learn of the Government's "Welcome back bonus" scheme for teachers returning to the profession that existed between Easter and Christmas 2001. Teachers returning in a shortage subject such as mathematics received £1,000 shortly after returning, plus £3,000 around a year later. We understand that there are currently no plans to reintroduce this scheme, but would wish to encourage this to be reconsidered.

Advanced Skills Teachers and Fast Track Schemes

2.60 The Advanced Skills Teacher (AST) grade was introduced in 1998 and offers a new career route with an enhanced salary scale for excellent teachers who do not wish to take up management posts. ASTs continue to work mainly as classroom teachers but also spend time working with teachers in their own and other schools to raise teaching and learning standards. To qualify for an AST post teachers have to pass a rigorous assessment process. Schools receive a grant jointly funded by the DfES and the Local Education Authority to cover the additional cost of creating an AST post. The Inquiry believes that a substantial increase in the number of mathematics ASTs is required, not least to lead on the CPD agenda which we discuss in detail in Chapters 5 and 6 (see Recommendation 2.4 below).

2.61 The DfES has introduced a Fast Track Scheme aimed at improving career progression for individuals with the greatest leadership potential. It aims to identify and develop those teachers who will eventually become an AST, or part of the senior management team of a school. A total of 340 people joined the programme in September 2003 either as trainees or existing teachers and it is planned that numbers will continue to grow to several hundred a year. The long-term aim is for 5 per cent of the teaching profession to be on (or to have been through) the Fast Track programme. Teachers on the Fast Track receive enhanced salaries. New entrants to the programme who come through Fast Track initial teacher training receive an additional spine point on the Main Pay Scale and a £5,000 bursary. All Fast Track teachers receive a Recruitment and Retention allowance (about £2,000) once they have completed their induction year in a maintained school.

2.62 There is a separate fast track scheme for London. Teach First is a general initiative to attract high quality graduates to teach in London. Teach First has attracted investment by industry and commerce and in its first year has attracted a relatively high proportion of mathematics graduates. The Inquiry encourages the TTA and the DfES to monitor and evaluate this and similar schemes and to be prepared, if appropriate, to provide resources to help expand and sustain such initiatives. We would also encourage the LSC to work with the DfES and TTA on these and other issues relating to teacher recruitment (see, also, Recommendation 2.1).

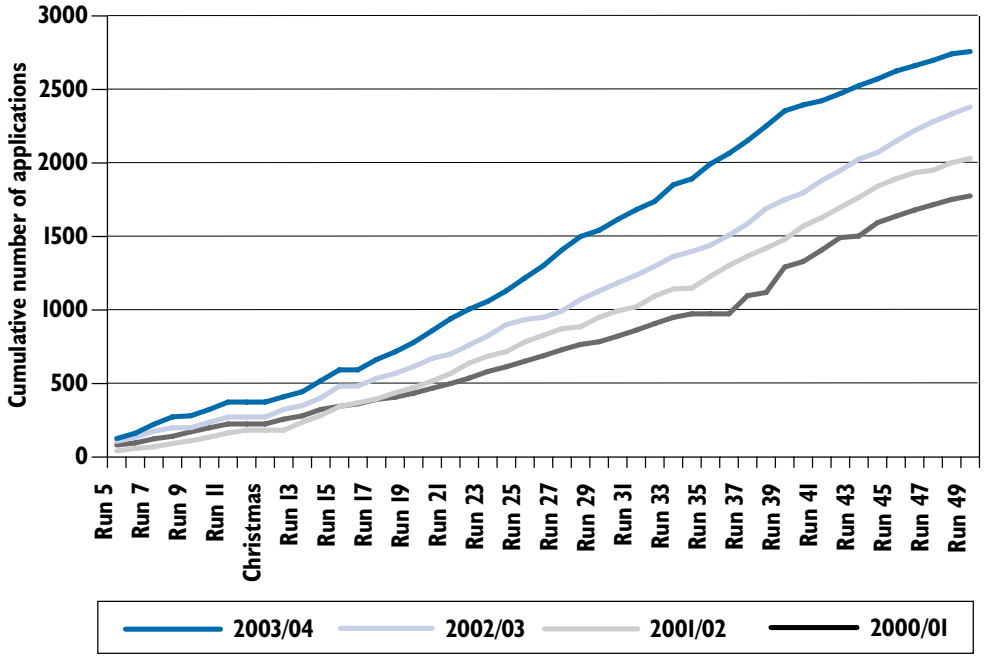
Recommendation 2.4

The Inquiry recommends that the DfES give high priority to encouraging and funding a significant increase in the number of mathematics graduates admitted to the Fast Track Scheme and, in particular, a significant increase in the number of mathematics ASTs.

Incentives and the rise in PGCE applications in mathematics

2.63 Respondents to the Inquiry have expressed the view that Golden Hellos and the introduction of the training bursaries in September 2000 have had a significant effect on PGCE applications. Cumulative applications for mathematics PGCE course are shown below in Figure 2.15.

Figure 2.15: Cumulative number of applications to mathematics PGCE courses in England and Wales since 2000



Source: Graduate Teacher Training Registry (GTTR)

2.64 The Inquiry welcomes these incentives and believes they are likely to have contributed to the increased number of people on initial teacher training courses. However, the financial inducements have now remained at the same monetary level for three years and need reviewing. We believe it to be important to ensure that the real value of these incentives is at least maintained.

The need to look beyond the pool of mathematics graduates

2.65 The Inquiry has noted with concern the data in Table 2.12 showing that it would require 40 per cent of the current output of UK mathematics graduates to fill all the allocated ITT training places in mathematics. With 2,350 allocated places for mathematics for 2004/05 the pressure to recruit mathematics graduates is significantly greater than in 2000.

Table 2.12: Percentage of mathematics graduates needed to fill allocated mathematics ITT places

Academic year	Number of graduates	Number of allocated places	per cent of graduates required to meet allocation
2002/03	3,380	1,759	52
2001/02	3,375	1,075	52
2000/01	4,235	1,876	44
1999/00	4,060	1,710	42
1998/99	4,214	2,126	50

Source: TTA

2.66 It is clear to the Inquiry that the supply of mathematics graduates applying for ITT will be insufficient to meet the demand for trainee teachers for many years to come. It is important therefore that the TTA and ITT providers work together to try to identify and attract a wider pool of people to recruit from. This includes finding ways of enabling people from a wider degree base to train as teachers of mathematics. Suppose we assume that 40 per cent of students achieving an A-level mathematics pass progress to higher education. Even with the current drop to around 55,000 entries, which is likely to translate to around 40,000 passes, this would imply a future population of close to 16,000 graduates per year (in practice, the percentage progressing to higher education may be even higher than this figure) each with at least an A-level in mathematics. Around 4000 obtain mathematics degrees. There is therefore a potential pool of around 12,000 without a mathematics degree, but with an A-level in mathematics. These include many graduates who may be capable of enhancing their mathematics knowledge to allow them to teach to at least Key Stage 3. At present, those in this group could gain access to courses leading to primary teacher training, but would be unlikely to be able to join a secondary PGCE course in mathematics (see Table 2.1).

2.67 Where a trainee's previous degree does not cover the spectrum of knowledge required to teach a particular subject, pre- and in-course study courses and subject support courses are available with access to help from specialist tutors. These are currently being evaluated to assess their impact. Some providers offer two-year PGCE courses that provide more time for trainees to develop their subject knowledge. The TTA also has plans to pilot a Pre-Initial Teacher Training Mathematics Enhancement Course from January 2004. This initiative will target graduates from a wider range of non-mathematics degree backgrounds, to develop their knowledge and deepen their understanding of mathematics prior to a PGCE or GTP course. From January 2004, the course

will be piloted in two regions each year, for two consecutive years. Each course will have 20 allocated places. A working group of ITT providers, undergraduate course tutors and schoolteachers has developed the course specification for mathematics. Contracts will be awarded to provide enhancement courses as a service to all providers of graduate routes to QTS within the region. Course participants will receive a bursary of £150 a week for the twenty-six weeks of the course. On successful completion of the course participants will progress to available QTS bearing courses of their choice within the region.

2.68 These enhancement courses will be evaluated fully to identify action for DfES, TTA, enhancement course providers and ITT providers and to inform any ministerial decisions about national availability of enhancement courses. The Inquiry believes that the enhancement routes being piloted by the TTA may be of considerable importance in identifying new sources of students for recruitment into mathematics teacher training. This prompts the following recommendation, which we would like to see also taken into account by those responsible for the supply of mathematics teachers in colleges.

More specific certification of mathematics teachers

Recommendation 2.5

The Inquiry recommends that the current TTA enhancement programmes for graduates be evaluated carefully and that additional resources be made available to support and reinforce successful programmes in mathematics. The Inquiry further recommends that the TTA should consider introducing enhancement programmes that offer non-graduate career changers opportunities, including bursaries, to complete graduate mathematics course and secure QTS. The Inquiry recommends that, subject to appropriate quality assurance, the DfES give high priority to providing any extra resources required by the TTA in expanding mathematics enhancement programmes.

2.69 In considering the need to provide enhancement to attract non-mathematics graduates into mathematics teacher training, the Inquiry has been led to consider whether there should just be a single certification scheme for QTS, as at present, or whether instead there should be new routes which make it possible to gain specific certification to teach mathematics up to specific levels; for example, KS3, KS4 and post–16 levels. We believe this could be extremely helpful in ensuring the supply of sufficient numbers of mathematics teachers across all stages of learning and we therefore make the following recommendation.

Recommendation 2.6

The Inquiry recommends that consideration be given to the introduction of new mathematics teacher certification schemes, aimed at increasing the overall supply of teachers appropriately qualified to teach at least some part of the curriculum.

Career Exploration

2.70 The TTA operates a range of programmes to enable prospective applicants to become more informed about teaching and training to teach:

- The Open Schools programme provides opportunities for people at an early stage of exploring teaching as a career to spend an observation day in school;
- The Teaching Advocates programme harnesses the enthusiasm of serving teachers to support the TTA in various recruitment activities;
- The Taster Courses programme aims to provide an in-depth taste of teaching and teacher training. The courses last three days and include one full day in school.

2.71 The Inquiry welcomes the fact that the TTA is now working to ensure that the provision of these services is focussed on the need to improve recruitment to priority subjects. Approximately 10 per cent of those making use of the programmes are people interested in teaching secondary mathematics. Another scheme managed by the TTA is the Student Associates Scheme. This is designed for undergraduates currently uncommitted to a teaching career to enable them to explore the possibility of teaching and give them a taste of life in school. Universities pay a small bursary to the undergraduates for the time they spend in schools. The second stage of the Scheme is only open to those who have the qualifications required for entry into ITT and 40 per cent of the Scheme is targeted at students from secondary shortage areas. It is anticipated that 5,000 undergraduates will participate in the Scheme in the academic year 2003/04. The scheme allows them to build up a portfolio of evidence towards the standards for QTS, with a view to having that evidence taken into account either in relation to the overall time spent on a PGCE course, or in relation to the work required on specific parts of the course.

2.72 Evaluation of the Scheme so far and of the experiences of a sample of 60 students from the academic year 2001/02 has been undertaken. Student reaction to the Scheme has been very positive overall. There is also evidence from training providers that students who had experience of the scheme were better prepared for the PGCE interview process and more confident and better prepared for their first teaching placement. The Inquiry welcomes the introduction of this Scheme and is pleased to note that it has recently been expanded to 5,000 places a year. However, we would like to see more targeted use of the Scheme for mathematics students.

Recommendation 2.7

The Inquiry recommends that a significant number of places in the Student Associate Scheme be earmarked for undergraduates on degree courses in mathematics or courses involving a substantial component of mathematics. We encourage the TTA to work closely with the Committee of the Heads of Departments of Mathematical Sciences (HoDMS) and others in higher education to continue to raise the level of awareness of the scheme among relevant undergraduates.

2.73 The TTA Student Associate Scheme also supports the Undergraduate Ambassadors Scheme pioneered by the writer and broadcaster, Simon Singh. The scheme operates across all science, technology and engineering areas, as well as mathematics. This is a further possible route to encouraging students into teaching, as well as providing additional teaching resource in schools. The scheme operates through higher education departments creating an undergraduate module in which undergraduates acquire academic credit for time spent in schools and for acquiring transferable skills in the context of their work in the classroom. There are no financial payments. The scheme began in 2002 with a total of twenty-eight students; this increased to around one hundred students in 2003 and four hundred in 2004. We provide further discussion of this and possible related schemes in paragraphs 6.19-21 and in Recommendations 6.3 and 6.4.

Teachers' Remuneration

2.74 From 1 September 2002, teachers in maintained secondary schools have been paid on a new six-point salary scale. Once at the top of the scale, they may apply to "cross the threshold" and move to a higher, performance-related pay scale. One of five management allowances may be awarded in addition to pay scale points to teachers on either of these scales, for example to heads of department and other teachers with significant specialised management responsibilities. In addition, any teacher may apply to become an Advanced Skills Teacher and, if successful, will move to a new higher pay scale.

2.75 Schools in theory have considerable freedom over the pay of their teachers. Schools are also able to use recruitment and retention allowances to attract and keep key members of staff. At present, DfES evidence to the Inquiry suggests that around 3 per cent of all teachers receive such an allowance. In relation to the use of this flexibility for teachers of mathematics, the 2001/02 Annual Report of Her Majesty's Chief Inspector of Schools notes that

> *"Despite the flexibility that schools have to award recruitment and retention allowances to attract high-quality teachers, many, particularly in the primary sector, are reluctant to use them as they regard them as divisive and unfair to existing staff. In secondary schools, use of recruitment and/or incentive allowances to attract and retain staff, especially subject specialists in mathematics and science is, however, increasing."*

2.76 *SET for Success* regarded the issue of teachers' remuneration as critically important and recommended that more needs to be done to address pay and other incentives offered to teachers in shortage subjects. The Inquiry strongly endorses this view. There is a shortage of mathematically qualified graduates and schools and colleges are competing with other sectors of the economy. We therefore echo the recommendation made in *SET for Success*.

Recommendation 2.8

The Inquiry recommends that more must be done to address the issue of pay and other incentives to teachers of mathematics and other shortage subjects (see, also, Recommendation 5.2).

2.77 The Government has recently introduced a pilot scheme (from 2002/03 for three years) under which teachers in shortage subjects will also benefit from having their student loans written-off for them over a period of time. Current proposals would further increase the effective salaries of mathematics teachers, potentially by up to around £1,500 per year for the first ten years. The Inquiry welcomes this further attempt to provide incentives for the recruitment of mathematics teachers. However, we are concerned at the rather hit-and-miss and potentially unfair nature of the incentive, which clearly has no impact on students who, for whatever reason, did not take out loans (including those who may, at some personal cost, have worked to support themselves through university). More fundamentally, we note that the Government's current HE Bill, which received its second reading on 4 February 2004, proposes radical changes to future fee levels in higher education. The Inquiry believes that the proposed fee changes open up important new opportunities for substantial incentives through fee waivers and loan write-offs. The Inquiry urges the Government to consider how to exploit these opportunities to encourage teacher recruitment in shortage subjects.

A summary of additional comments on teacher supply in Wales, Northern Ireland and Scotland

Wales

2.78 The 2002 General Teaching Council for Wales (GTCW) survey of teacher recruitment indicated that secondary mathematics posts attract significantly fewer applicants than other subjects. In addition the number of applicants per mathematics post is declining. In Welsh medium schools the situation is worse. Recruitment is likely to be affected by the limited pool of Welsh speaking teachers available. Mathematics and English are the posts most difficult to fill in Welsh secondary maintained schools, despite a low overall teacher vacancy rate of 0.4 per cent. Over ten per cent of mathematics teachers at key stage 4 and above do not have a degree in mathematics or a closely related subject.

2.79 However, there are a number of incentives being provided to both postgraduate and undergraduate trainee teachers. Encouragingly, the number of graduates accepted onto PGCE ITT mathematics courses in Wales has risen by 15 per cent in 2002–03, with a further increase in applicants for courses starting in September 2003.

Northern Ireland

2.80 Responses to the Inquiry from Northern Ireland have expressed the view that mathematics teachers in Northern Ireland are more likely to be qualified mathematicians than their colleagues in England. However, respondents felt that there is a need to ensure the effective professional development of mathematics specialists (see Chapters 5 and 6).

2.81 A recent recruitment survey of all Northern Ireland post-primary schools was conducted by some of Northern Ireland's Education and Library Board Officers. There was a high response rate of around 89 per cent. So far as full-time posts were concerned, Grammar schools indicated that mathematics is for the most part taught by teachers with appropriate training. Posts are filled on time and without additional inducements. However, around 45 per cent had experienced some form of difficulty with recruitment. Grammar schools also highlighted a lack of teachers qualified to cover Additional Mathematics, AS and A2. Integrated schools met more problems in recruiting full-time mathematics teachers and enhancements were typically used when recruiting Heads of Department. Non-grammar schools found it the most difficult to recruit appropriately qualified mathematics specialists. As a result, schools often have to appoint under-qualified teachers and despite this some posts need to be re-advertised. Enhancements are used both to recruit and to retain teachers. This lack of teachers and appropriate skills are felt to have a negative impact on students. In terms of substitute teacher recruitment, most schools had experienced difficulties. Substitute teachers prove even harder, if not impossible to recruit. Although some schools are able to call on retired teachers for additional cover, there is a concern that this may result in out of date teaching. In outlying areas, such teachers are often simply not available.

Scotland

2.82 In Scotland, since 2000/01 mathematics teachers have been required to have studied the subject for three years at university. Responses to the Inquiry indicate that although there is no overall shortage of teachers in Scotland, mathematics is among the secondary school subjects in which it is hardest to fill vacancies. The Scottish Executive has developed a three-tier prioritisation system to ensure an adequate supply in all subjects: mathematics is in the first category. However, overall, in November 2003 only 35 posts in mathematics (2 per cent) were vacant and only 10 of those had been vacant for more than three months.

2.83 The teaching workforce in Scotland is ageing, which necessitates an ongoing annual increase in the number of new teachers. This may become a problem. Currently, there are no major shortages, however mathematics is one of the more difficult areas. Scotland is currently among the handful of European countries with a reasonable equilibrium between teacher supply and demand. According to the Scottish Executive national statistics publication *Results of Teacher Workforce Planning for 2003–2004*, five per cent of the overall workforce joined or re-joined the workforce during 2000–2001, and five per cent left during this time.

2.84 It is the responsibility of Education Authorities and head teachers to deploy staff as effectively as possible to meet local needs. Scotland currently has no plans to make use of HE resources, such as using students as teaching assistants.

3 CURRENT MATHEMATICS PATHWAYS

The National Curriculum (pre-16)

3.1 Progression through the school system in England and Wales is described in terms of four Key Stages: Key Stage 1 (pupils 5–7 years); Key Stage 2 (pupils 7–11 years); Key Stage 3 (pupils 11–14 years); Key Stage 4 (pupils 14–16 years). Although the focus of this Inquiry is post–14 mathematics education, in practice we cannot fully discuss post–14 pathways (Key Stage 4 and beyond) without a clear overview of mathematics pathways in Key Stages 1–3. Mathematics is a core subject of the National Curriculum (NC) in England and Wales throughout Key Stages 1–4. The expectation is that every student is taught some, or all, of the NC until aged 16. The NC was last revised in 1999, with the new curriculum in place from September 2000. Until 1999, England and Wales had a common curriculum in mathematics. Northern Ireland has always had its own curriculum and its own definition of key stages. The expectation is that every student is taught some, or all, of the Northern Ireland Curriculum (NIC) until age 16. The structure post–14 is essentially that of GCSE and GCE AS and A-level Mathematics, with some take up of Application of Number. Scotland has always had its own completely different structure.

3.2 Overwhelmingly, the concerns of respondents to the Inquiry have related to the English system. Unless otherwise stated, therefore, details in the text mainly refer to England. For completeness and comparison, detailed descriptions of the systems and recent developments in Wales, Northern Ireland and Scotland are provided at the end of this chapter.

3.3 The new curriculum for Wales is very similar to the previous joint curriculum for England and Wales, but in England the revisions to the mathematics curriculum were extensive. The content of the NC was not greatly changed, but the presentation of topics and the idea of progression was made much more explicit than before. These changes were made in response to widespread concerns about growing evidence of many pupils' poor facility with the basic processes and calculations of mathematics, concerns which also led to the approval of adult numeracy and application of number qualifications for Key Stage 4 and older students. There was also concern that many pupils exhibited an inability to reason logically in mathematics, particularly in the areas of algebra and geometry. The curriculum changes were designed to help teachers emphasise important points in common areas of difficulty and misconception.

3.4 The full range of mathematics that should be taught in England at key stages 1, 2, 3 and 4 is set out in detail in the Programmes of Study (PoS) for Mathematics in the National Curriculum. All pupils are taught from a common curriculum to the end of Key Stage 3. There is a degree of differentiation at Key Stage 4 with two overlapping Programmes of Study called Key Stage 4 (Foundation) and Key Stage 4 (Higher). The PoS provide the basis for school

planning and individual schools decide how to organise their school curriculum to include the programmes of study for mathematics. These decisions have been influenced in recent years by the impact of the National Numeracy Strategy and the Key Stage 3 Strategy, which have produced Frameworks for Teaching Mathematics for both the primary phase and for Key Stage 3, respectively.

3.5 The knowledge, skills and understanding sections in the PoS in England and Wales identify the main strands of mathematics in which pupils should make progress (Northern Ireland has its own PoS structure). The strands at each key stage are shown below. In Wales, an additional MA1 strand, Using and Applying Mathematics, is taught at each key stage.

Strand	Key Stage 1	Key Stage 2	Key Stages 3 & 4
MA2	Number	Number	Number & algebra
MA3	Shape, space & measures	Shape, space & measures	Shape, space & measures
MA4		Handling data	Handling data

3.6 Following the curriculum review in England in 1999, the Qualifications and Curriculum Authority (QCA) has carried forward a major programme of proactive development work in algebra and geometry with a view to producing guidance to teachers of mathematics at Key Stages 3 and 4. This programme is also intended to help inform future changes to the mathematics curriculum. The PoS describe the intended content of the curriculum and the learning opportunities that teachers should provide for all pupils. In addition, there are four Attainment Targets, which set out expected standards of pupil's performance:

- AT1 Using and applying mathematics (which pervades all the strands MA2-MA4);
- AT2 Number and algebra;
- AT3 Shape, space and measures;
- AT4 Handling data.

The Attainment Targets consist of eight level descriptions of increasing difficulty, plus a description for exceptional performance above level 8. Each level description indicates the types and ranges of performance that pupils working at that level should characteristically demonstrate. These level descriptions remained largely unchanged in the 1999 revision of the National Curriculum. The level descriptions provide the basis for making judgements about pupils' performance in the National Tests at the end of key stages 1, 2 and 3. At Key Stage 1, it is expected that pupils will be working within the range of levels 1–3; in 2003, 90 per cent reached level 2 or above by age 7. At Key Stage 2, it is expected that pupils will be working within the range of levels 2–5; in 2003, 73 per cent reached level 4 or above by age 11. At Key Stage 3, it is expected that pupils will be working within the range of levels 3–7; in 2003, 70 per cent reached level 5 or above or above by age 14 and 49 per cent reached level 6 or above.

3.7 Evaluation of pupils at the end of Key Stage 4 (14–16) is normally through the externally assessed General Certificate of Secondary Education (GCSE) examination. GCSE assessment is the norm for all pupils who have achieved higher than NC level 3 by the end of Key Stage 3. Those who have not yet achieved at this level may take Entry Level qualifications, including, in England, the Certificate in Adult Numeracy.

3.8 GCSE and Entry Level qualifications are suites of qualifications within the National Qualifications Framework (NQF) for England, Wales and Northern Ireland. The NQF is managed jointly by three regulatory authorities – QCA for England, ACCAC for Wales and CCEA for Northern Ireland. These three regulatory authorities set the criteria for the development of specifications for GCSE Mathematics and Entry Level qualifications in mathematics. As we have indicated, Scotland has an altogether different structure. The GCSE examinations in England, Wales and Northern Ireland are administered by five awarding bodies, AQA, London Qualifications (Edexcel), OCR, the WJEC and the CCEA. Performance on GCSE Mathematics is determined, from the highest to the lowest grade, on an eight grade scale: A*, A, B, C, D, E, F and G. In the National Qualifications Framework (NQF), GCSE results grades A*– C are classified as a level 2 qualification, whereas grades D–G are classified as a level 1 qualification. GCSE therefore encompasses levels 1 and 2. Entry Level is below level 1. Level 3 mathematics qualifications are above the GCSE level 2 standard in terms of mathematics content and difficulty. Higher Education undergraduate degree courses are defined as level 4 and postgraduate courses as level 5.

The curriculum post–16

3.9 There is no statutory curriculum in England, Northern Ireland and Wales beyond the age of 16. Qualifications primarily for use post–16 are all externally assessed on a range of specifications developed to mathematics criteria set by the three regulatory authorities of England, Wales and Northern Ireland and all accredited by these authorities. Again, Scotland has a different structure. Significant changes to the curriculum and qualifications framework were made in the Curriculum 2000 reforms, which followed the extensive 1997 Qualifying for Success consultation with schools, colleges, universities and industry on proposals that were originally recommended in Lord Dearing's Review of Qualifications for 16–19 Year Olds, published in 1996. At the time, there was a widespread consensus that change was required. The traditional programme of full-time study was increasingly seen as a less than adequate preparation for work or for the increasing number of generalist courses in Higher Education, which required a broader range of knowledge and skills than was hitherto the case. In addition, considerable concern was expressed – in particular, by the mathematics, physics and engineering communities – about the lack of mathematical fluency of those entering Higher Education courses requiring more specialist mathematics skills.

3.10 The five key elements of Curriculum 2000 were the introduction of:

- AS qualifications;
- New A level specifications;
- Advanced Extension Awards;
- New Vocational A levels;
- Key Skills.

3.11 There were five main principles underlying Curriculum 2000 reform:

- *Progression*: AS was intended not only to allow for better progression from GCSE to A-levels but also to have its own internal coherence;
- *Flexibility*: The reforms were intended to offer schools and colleges the opportunity to teach AS alongside A level. In most cases, this would mean having common teaching programmes;
- *Breadth*: A key aim of the restructuring was to encourage greater breadth of study for full-time 16–19 students and to reduce wastage for those who did not continue to the full A-level after completing the first year of post–GCSE study. Students would be encouraged to study four or five subjects at AS in year 12, before specialising in two or three of these subjects in year 13;
- *Better key skills*: as one of the new Government's manifesto commitments, Curriculum 2000 encouraged the incorporation of key skills in all post–16 programmes, with the intention of helping students prepare better for both higher education and employment. The expectation was that all students be helped to achieve level 2 in communication, number and computer skills by age 19 (through a good GCSE or the corresponding key skills qualification). Those going on to Higher Education or professional study would be expected to achieve at least one level 3 qualification in these skills;
- *Greater Status*: Curriculum 2000 aimed to bring vocational qualifications in line with academic qualifications, by creating parity of esteem between the qualifications.

Mathematics qualifications: current progression routes within mathematics

3.12 At present, secondary mathematics qualifications split into two age-related clusters: 14–16 qualifications (to the end of compulsory schooling) and then 16–19 qualifications in the phase of post-compulsory schooling. There are six main families of qualifications:

- 14–16 GCSE mathematics and GCSE Statistics (encompassing levels 1 and 2);

- 14–18+ The Certificate in Adult Numeracy (available at Entry level and levels 1 and 2) and the key skill qualification in Application of Number (available at levels 1–4);
- 16 –18+ GCE AS and A level Mathematics and related courses (all at level 3);
- 16 –18+ Free Standing Mathematics Qualifications (separate levels 1, 2 or 3);
- 16 –18+ GCE AS Use of Mathematics (level 3);
- 18+ Advanced Extension Award in Mathematics (level 3).

With the exception of Free Standing Mathematics Qualifications at levels 1 and 2, all the qualifications listed are approved and available for use pre–16 and post–16. FSMQ levels 1 and 2 are currently only approved for use post–16. In addition, there are mathematical units within a number of vocational qualifications.

3.13 Progression within mathematics is currently characterised by a potential chain of courses from the age of 14 onwards, students moving on from one level to take one or more qualifications in the next level up. Most students enter the chain from Key Stage 3 working mostly at level 1. Some aim to achieve a level 2 qualification in mathematics beyond the age of 16, having achieved a level 1 qualification by age 16. Others who have not achieved a level 1 qualification at age 16 try to reach level I by the age of 17 or 18. We shall discuss Free Standing Mathematics Qualifications (FSMQs) and AS Use of Mathematics in more detail later (paragraphs 3.32–38). Most students take these qualifications within the age ranges specified. A few may take GCSEs or GCEs at an earlier age than those specified. Some will take them at a later age than specified, and some will resit qualifications in an attempt to improve their grade. In the following sections, we provide a brief discussion of each available mathematics qualification.

3.14 The Inquiry has noted with considerable concern that very few students in England progress to level 3 qualifications in mathematics. A large proportion of the age cohort 16–19 in England choose programmes of study post–16 that do not include mathematics. The scale of the problem is typified by the progression rates of the cohort sitting GCSE in 2001: nearly 564,000 students (93 per cent of the age cohort) entered GCSE Mathematics, with nearly 51 per cent obtaining grades A* to C, and a 97 per cent overall pass rate; but in 2002, only just over 41,000 (6.5 per cent of the age cohort) entered for AS level.

GCSE Mathematics

3.15 The GCSE was introduced in 1986 and the first examination was in 1988. It replaced the General Certificate of Education Ordinary Level (O-level) and the Certificate of Secondary Education (CSE), which had run in parallel.

3.16 Originally, GCSEs were graded from A–G. From 1994, the A* grade was introduced into the examinations to discriminate the very best performance.

With one exception, all GCSE Mathematics specifications are now assessed through a combination of terminal examination and coursework. Northern Ireland's GCSE in Additional Mathematics does not have coursework. The subject criteria for mathematics specify the balance between internal assessment (which must be externally moderated) and external assessment to be a ratio of 20:80.

3.17 GCSE Mathematics has had overlapping tiered papers since its first examination in 1988. Pupils cannot be entered for more than one tier in any given examination period. From 1998, most major entry subjects, with the exception of mathematics, have been examined through a Higher Tier covering grades A*–D and a Foundation Tier covering grades C–G. Mathematics is the only subject to have retained more than two tiers. A small number of subjects, including art, music, PE, and history, have one tier. The intent of the three-tiered papers in mathematics was to cover a range of GCSE grades, so that candidates can attempt questions that are matched to their broad ability and enable them to demonstrate positive achievement.

- the Foundation Tier awards grades D, E, F and G;
- the Intermediate Tier awards grades B, C, D, E;
- the Higher Tier awards grades A*, A, B, and C.

3.18 Schools base their decision on which tier to enter pupils for on their Key Stage 3 results and on their expected level of achievement in the examination. In the revised National Curriculum, there are two underpinning PoS at Key Stage 4: Key Stage 4 (Foundation) and Key Stage 4 (Higher). At present, this two-tier structure of the curriculum in England is not mirrored in the structure of GCSE assessment. The Foundation PoS is the appropriate course for those pupils who expect to achieve up to grade C standard GCSE Mathematics, but not beyond. The appropriate grounding needed for progression to GCE AS and A level is only covered in the Higher PoS at Key Stage 4. This includes more abstract and formal mathematics than does the Foundation POS, which has more emphasis on everyday and more practical examples. The revised curriculum recommends that all pupils who have obtained a good level 5 or better in mathematics at the end of Key Stage 3 should be taught the Higher Key Stage 4 PoS for mathematics.

3.19 Table 3.1 shows the numbers entered for GCSE Mathematics in England for each of the years 1999–2003, together with the percentage of the age cohort entered and the percentage of the age cohort attaining grades A*–C. For example; in 2003, 585,000 students out of a total cohort of 622,165 were entered for GCSE Mathematics (94 per cent) and 298,600 (48 per cent of the age cohort, 51 per cent of those entered) attained grades A*–C. A total of 562,000 attained grades A*–G (96 per cent of those entered). The percentage of those entered obtaining a pass grade has remained stable at around 96 per cent for the past few years. The percentage of those entered attaining grades A*–C has moved from just below to just above 50 per cent over the five-year period. The total percentage of the age cohort entered has increased slightly over the past decade from about 95 per cent to 97 per cent.

Table 3.1: GCSE entries and A*–C attainment for 15–year-olds in England, 1999–2003

Year	Numbers sitting GCSE Mathematics (thousands)	% of 15–year-olds* in schools in England attempting GCSE Mathematics	% of 15–year-olds-cohort gaining Grades A*–C
2003	585.0	94	48
2002	568.9	94	49
2001	563.8	93	48
2000	539.9	94	47
1999	536.8	92	45

** Age at 31 August prior to the start of the academic year*

Source: DfES Statistical Bulletins.

GCE AS and A-level Mathematics and Further Mathematics

3.20 General Certificates of Education (GCEs) are single subject qualifications. They were restructured for first teaching from September 2000 in response to decisions taken in April 1998 following the *Qualifying for Success* consultation. These revised GCEs are part of the *Curriculum 2000* reforms. GCE AS and A-level specifications are based on rules set out in the regulatory authorities' Common, GCE and subject criteria. The latter may specify some of the required content. In the case of GCE mathematics, this core of pure mathematics occupies 50 per cent of current specifications. All GCEs in Mathematics also contain at least 25 per cent of mechanics, statistics or discrete mathematics, or some combination of these applications. There are, nonetheless, significant differences in both the detailed structure and content of specifications offered by individual awarding bodies or across awarding bodies, and in the style of their examination questions, to provide an element of choice for centres.

3.21 Mathematics is unique at GCE level since candidates can obtain more than one A-level's worth of the subject. There are also qualifications in GCE AS and A-level Further Mathematics. These take the subject further than the study of GCE A-level Mathematics alone. Assuming that teaching resources are available, very able students will often be entered for both A-level Mathematics and A-level Further Mathematics. Some may even study and be examined in more than 12 modules, and so gain more than the equivalent of two full A-levels in Mathematics (which each correspond to 6 modules). In recent years, secondary schools have accounted for just below 70 per cent of A-level entrants in Mathematics, with Sixth Form Colleges providing just under 20 per cent and the rest being entered from FE/Tertiary Colleges. For AS levels, secondary schools are providing over 75 per cent of entrants, Sixth Form Colleges around 15 per cent and the rest are being entered from FE/Tertiary Colleges (JCGQ Inter-board Statistics).

3.22 Lord Dearing's review of 16–19 qualifications contained many references to qualifications in pre–16 mathematics, GCE Mathematics and Further Mathematics. Many of the key features of his remarks and recommendations for GCSE and GCE Mathematics, and about bridging the gap between them, were built into the 1999 National Curriculum review to age 16 and the Curriculum 2000 reforms for the post–16 age group. The Curriculum 2000 reformed GCE A-levels are modular with examinations that can be taken at various stages during, or at the end of, a two-year course. The qualification is designed in two parts. A first half – the GCE Advanced Subsidiary (AS) – that assesses the knowledge, understanding and skills expected of candidates half way through the course; followed by a second half (A2). AS and A2 together are intended to maintain the standard of the full A-level qualification prior to Curriculum 2000. The AS may be taken as part of the whole A-level or as a free-standing qualification. The full A-level normally comprises six modules, three each in the AS and A2 stages.

3.23 During 2000/01, serious difficulties with AS Mathematics were reported to the regulatory authorities. The overriding concern of teachers was that AS Mathematics appeared to be too difficult and was turning many students away from the subject. The results of the first cohort of candidates appeared to confirm this. The pass rate among the 17 year-old cohort was 71.8 per cent, very low compared to other mainstream subjects like English, history, geography, physics, chemistry and biology. Although in subsequent years, the AS pass rate in Mathematics had increased, it still remains conspicuously out of line with other mainstream subjects. Table 3.2 presents comparative figures for 2001–03. The Inquiry note with concern this considerable disparity and, in relation to student choice of subjects post–16, the perception problem this presents for the discipline of mathematics and the subsequent supply chain for mathematics, science and engineering.

Table 3.2: AS overall percentage pass rates for 17–year-olds in England, 2001–03

	Year		
Subject	**2001**	**2002**	**2003**
Mathematics	**71.8**	**75.6**	**76.3**
English	94.1	93.7	94.2
History	93.5	92.1	92.3
Geography	91.0	89.6	90.1
Physics	86.3	83.7	82.5
Chemistry	87.3	85.7	84.8
Biology	84.8	82.3	80.7

3.24 Detailed analysis of the AS Mathematics syllabus and assessment undertaken by the regulatory authorities in Autumn 2001 showed that in terms of both the specifications for AS and their associated examination papers the amount of content and the demand of the new papers was prima facie no greater than before. However, it was clear that what had worked well prior to Curriculum 2000 no longer worked.

3.25 With a 3 + 3 split of core pure mathematics plus applications for the full A-level, it was impossible for those teaching the material not to include some core A2 material in the AS. Retrospectively, it was therefore recognised that the content of the AS specifications was too great to be taught and mastered by students in the time available before May/June of their first year of post–16 study. There appears now to be an acceptance that students need time to mature into a two-year advanced course, and that learning is faster and material becomes more established in the second year of the course.

3.26 Whilst work was underway to revise the GCE Mathematics criteria, the regulatory authorities and the three administrations in England, Wales and Northern Ireland agreed that no changes could be implemented until an entire GCE cycle was completed and analysed. When the full Curriculum 2000 A-level was examined for the first time, and the AS had been through its second round, the 2002 summer results showed that:

- the AS pass rate had improved slightly to 75.6 per cent, but still lagged considerably behind other mainstream A-level subjects (see Table 3.2 above, which shows the gap between mathematics and other subjects continuing in 2003);
- there had been around a 10 per cent decline in the entries for the Mathematics AS level, a decline which persisted in the following year (see Table 3.3 below);
- the number of entries for the new A-level had reduced by around 20 per cent; (see Table 3.4 below);
- there had been over a 10 per cent decline in the number of entries for A-level Further Mathematics (see Table 3.5 below).

Table 3.3: AS entries and % pass rates by 17–year-olds in England, 2001–03

Year	Number of entries	Pass rate
2003	**41,556**	76.3
2002	**41,196**	75.6
2001	46,610	71.8

Table 3.4: A-level entries by 18–year-olds in England (Mathematics and Further Mathematics), 1993–2003

Year	Number of entries
2003	**42,897**
2002	**42,439**
2001	52,483
2000	51,455
1999	53,827
1998	54,707
1997	53,757
1996	51,601
1995	48,265
1994	48,680
1993	49,575

Table 3.5: Further Mathematics entries by 18–year-olds in England, 1993–2003

Year	Number of entries
2003	**4,030**
2002	**3,927**
2001	4,524
2000	4,461
1999	4,607
1998	4,686
1997	4,523
1996	4,413
1995	3,809
1994	3,753
1993	3,988

Source: DfES Statistical Bulletins

3.27 Faced with these serious declines in take up of AS and A-level Mathematics and Further Mathematics following the Curriculum 2000 reforms, the decision was made to proceed with the development of new specifications to the revised criteria for GCE Mathematics. These had been developed during the year by QCA, ACCAC and CCEA in conjunction with an expert panel of stakeholders. The revised criteria have now been approved. They retain the existing core content, but now spread over four units instead of three (2 AS and 2 A2). This means that:

- there will be no A2 core material in AS; it is hoped that the AS content will therefore be much more manageable;
- the number of applied units (statistics, mechanics or discrete mathematics) has been reduced from three to two in any mathematics A-level;
- awarding bodies still have scope to select a range of approaches to applications according to their local circumstances and the needs and preferences of their centres;
- students may still study up to two applications, but if students wish to study two application units these changes technically may result in awards of GCE A-level with 4 AS and 2 A2 units;
- the flexibility of AS Further Mathematics has been increased to include up to three AS units;
- there will be a loss of some of the current titles: the only permissible ones will be Mathematics, Further Mathematics and Pure Mathematics; administratively, however, this is viewed as an improvement on what was allowed before these revisions;
- a qualification in statistics, using units from outside the mathematics suite, has been submitted to the regulatory authorities using one common unit from the mathematics suite; the regulatory authorities have agreed that the title will no longer exist within the mathematics suite.

The revised specifications have been available from autumn 2003, taught from September 2004, with first AS examinations in 2005 and first A2 examinations in 2006.

3.28 All GCE AS and A levels are certificated on a scale A to E, with U (unclassified) and X denoting a fail. A previous grade N, denoting a narrow failure, was discontinued after 2001. The breakdowns of grades awarded for A-level and AS level Mathematics for the past four years (A-level) and three years (AS level) are shown in Tables 3.6 and 3.7, respectively. The Inquiry has noted with interest the fact that the distributions of grades for mathematics do not follow the bell-shaped curve typically observed in many other subjects. Instead, grade A is the most commonly obtained grade. We shall comment further on this in paragraph 4.37.

Table 3.6 Breakdown of A-levels Mathematics Results (%) for 18–year-olds, 2000–03

	Grade							
Year	A	B	C	D	E	N	U	X
2003	39.0	20.9	16.2	12.1	7.7		3.9	0.2
2002	38.7	20.2	16.1	12.1	7.9		4.6	0.2
2001	30.1	18.9	16.2	14.1	10.7	5.6	4.1	0.3
2000	30.7	19.3	16.8	14.0	10.0	5.1	3.8	0.2

Table 3.7 Breakdown of AS level Mathematics Results (%) 18–year-olds, 2001–03

	Grade							
Year	A	B	C	D	E	N	U	X
2003	23.1	15.0	14.5	12.6	11.1		22.1	1.6
2002	23.4	14.0	13.9	12.8	11.5		22.6	1.8
2001	19.7	12.9	13.5	13.6	12.2		26.3	1.7

Advanced Extension Award (AEA)

3.29 As part of the Curriculum 2000 reforms, Advanced Extension Awards (AEAs) were introduced for advanced level students in England, Wales and Northern Ireland to provide challenge for the most talented students. AEAs, for which the first examination was in summer 2002, are externally assessed through written examination. They are awarded at merit and distinction grades and supersede what were previously called Special Papers. The AEA in Mathematics was developed and trialled from 2000 to 2001 and is assessed by a single three-hour paper. All questions are based on the common core of pure mathematics from the A-level mathematics subject criteria.

3.30 In 2002, nearly 40 per cent of the candidates for A-level Mathematics obtained a grade A result. The AEA in Mathematics is aimed at the top 10 per cent of the A-level Mathematics candidates nationally, ie. the top one third of the potential grade A cohort. It aims to enable students to:

- demonstrate their depth of mathematical understanding;

- draw connections from across the subject;
- engage with proof to a much greater extent than is required in A-level Mathematics.

3.31 Questions on the AEA paper are much longer and less structured than those in the modular papers. They require a greater level of understanding than for GCE A-level as well as the ability to think critically at a higher level. The AEA is not expected to require the teaching of additional content, but requires exposure to deeper forms of reasoning and rigour, and a less compartmentalised approach to problem solving. Students are awarded additional marks for their ability to develop creative, and perhaps unexpected, solutions to problems. The AEA has proved more accessible than the Special Paper it replaced. The initial take up of the AEA in Mathematics has been encouraging, with approximately 1000 candidates in each of the two sessions to date. Provisional data a combined merit and distinction pass rate of 32 per cent in 2002 and 42 per cent in 2003.

Free-standing Mathematics Qualifications (FSMQs)

3.32 In view of the widespread concerns expressed to us about current post–16 provision, the Inquiry has been particularly interested in the recent development of Free Standing Mathematics Qualifications, which were developed by the QCA as a specific response to perceptions of serious gaps in mathematics provision post–16. Important target groups that were felt to be overlooked included:

- those repeating GCSE Mathematics (often with little success);
- students on vocational courses;
- A-level students not studying any mathematics to support their chosen subjects, even though the latter might implicitly require some mathematics.

3.33 FSMQs were developed at each of levels 1–3. The units were intended to meet individual student need at a level suited to the student's current level of mathematical understanding. Each unit is completely self-contained and students are directed to titles that complement their other study programmes. The level 1 FSMQs are designed for students on vocational courses, including some of those pursuing level 3 qualifications, who do not possess a level 1 qualification in mathematics including a GCSE grade D–G. The level 2 FSMQ qualifications are designed for those who have achieved GCSE at Foundation Tier and want to aspire to some mathematics at level 2, but wish to follow a route different from the GCSE route. The level 3 qualifications are designed for those wanting some form of focused mathematical study beyond the upper end of GCSE. In size terms, each unit was conceived as 60 hours of teacher contact time. FSMQs are intended to provide a different approach to studying and learning mathematics, designed to fit into the individual student's study programme. They aim to increase mathematical competence and develop transferable mathematical skills by using mathematics in a range of contexts. The use of ICT is integral to the units and real data is used wherever possible.

3.34 As an integral part of the learning and assessment process, students produce a portfolio of mathematics work, applying mathematics in contexts familiar from their study programme, work or leisure interests. This is intended to give the mathematics an immediate relevance and help motivate students to learn. In addition, FSMQs aim to test process skills more than just content knowledge. Students are encouraged to think about mathematics and present clear arguments in their work. They are also encouraged to read mathematical scenarios, presented in a variety of styles.

3.35 12 FSMQs were developed from 1997 and piloted from 1998–2000; 11 of these became nationally available qualifications from 2001. The original set of eleven FSMQs are:

- at level 1 (Foundation): *Working in 2 and 3 dimensions; Making sense of data; Managing money;*
- at level 2 (Intermediate): *Solving problems in shape and space; Handling and interpreting data; Making connections in mathematics; Using algebra, functions and graphs; Calculating finances*;
- at level 3 (Advanced): *Working with algebraic and graphical techniques; Using and applying statistics; Modelling with calculus*.

3.36 Most of the units deal with generic topics and skills, although some of them are clearly aimed at specific knowledge and skills needs. For example: *Making connections in mathematics* is designed for students who may apply for primary Initial Teacher Training; *Using and applying statistics* supports, in particular, teaching in A-level Psychology or in A-level Geography; *Managing money and calculating finances* support vocational business studies courses. The original units are all assessed through 50 per cent portfolio and 50 per cent written examination, both assessed externally. FSMQs are graded A–E: A being the highest pass grade and E the lowest.

3.37 Two further FSMQs have been accredited recently, which differ in format from the earlier set. *Foundations of advanced mathematics* is a level 2 qualification designed to bridge intermediate GCSE Mathematics and AS Mathematics. *Additional mathematics* is a level 3 mathematics qualification, not involving portfolio component, designed for year 11 students who gain GCSE Mathematics with high grades in year 10 and want to continue mathematics whilst doing other GCSEs in year 11. Northern Ireland has the distinctive feature of a GCSE in Additional Mathematics, which is a level 2 rather than a level 3 award, even though its content goes beyond the Key Stage 4 Programme of Study. (see, also, paragraph 3.63).

3.38 The Inquiry notes that since 2001 the number of candidates taking FSMQs has grown substantially, from around 2000 in 2001, to around 4,500 in 2002, to just over 6000 in 2003.

AS – Use of Mathematics

3.39 The AS Use of Mathematics qualification was introduced in September 2001. This qualification is designed for students who achieve at least GCSE Grade C at the end of compulsory schooling and who wish to continue with a general mathematics course post–16 without taking a full A-level. It focuses on developing process skills of application, understanding, reasoning, explanation and communication of mathematics. Currently, this qualification is only available at AS level. AS Use of Mathematics has three components (where (*) indicates that the component is a level 3 FSMQ): two are mandatory units, *Working with algebraic and graphical techniques* (*) and *Applying mathematics* (the terminal unit); for the remaining component, there is a choice between *Modelling with calculus* (*) and *Using and applying statistics* (*). The AS Use of Mathematics aims to develop:

- a working understanding of the significance of a range of mathematical models using algebraic, graphical and numerical techniques;
- mathematical comprehension, explanation and reasoning;
- mathematical communication.

Learning is assessed through written examination and a coursework portfolio, with the terminal unit wholly assessed through written examination. This differs from the assessment of AS Mathematics in that the weighting of student portfolio work to external written examination is 1:2. AS Use of Mathematics is the only full proxy for level 3 Application of Number. In 2003, there were just over 500 entries for this qualification.

Key Skills Qualifications in Application of Number

3.40 Application of Number qualifications, as part of the key skills portfolio, are available at levels 1–4 in England, Wales and Northern Ireland. In recent years, there has been a clearly expressed view from employers and others that GCSEs often do not equip learners with useful number skills, or the ability to use number in the contexts of other subjects, or the workplace. The call from employers and others has been for individuals to be enabled to acquire applied, transferable number skills, which will support them in work and beyond. These views have informed the design of the Application of Number qualifications and the development of keys skills teaching and learning approaches. The Inquiry has noted that in response to these views the development of the Application of Number strand has taken place completely separately from the development of mathematics provision for GCSE and AS/A–levels.

3.41 Current Government policy in England identifies key skills as a range of essential generic skills that underpin success in education, employment, lifelong learning and personal development. The recent DfES publication 14–19: *opportunity and excellence – volume 1*, (DfES 0744/2002) included the following statement (paragraph 3.8): "*To help ensure that all young people are well equipped in literacy, numeracy and computer skills we will introduce an*

entitlement for them to continue studying up to age 19 until they reach the standard of a good GCSE or the corresponding level 2 key skill qualification. Those going on to higher education or professional study after 19 should be encouraged to achieve a level 3 qualification in at least one of these skill areas." This expectation in England is supported by the LSC entitlement funding for full-time learners in schools and colleges. In work-based training, level 1 achievement in number (and communication) is the minimum requirement for Foundation Modern Apprenticeships (FMA). The requirement for Advanced Modern Apprenticeships (AMA) is achievement at level 2. The Skills White Paper (paragraph 5.27e) announced that a level playing field in basic and key skills funding would be established between the work-based and full-time FE routes from 2004/05 onwards (although, of course, the work-based route still relies on employers being willing to release students for appropriate study periods).

3.42 National standards for the suite of six key skills (then titled "core skills") were initially developed in the early 1990s, following joint work by the National Council for Vocational Qualifications and the Schools Examination and Assessment Council. The national key skills canon comprises: *Application of Number, Communication, Improving Own Learning and Performance, Information Technology, Problem Solving, Working with Others*. Their development represented a response to the nationally recognised need for applied and transferable skills in the global labour market of the late 20th century, and the case for a common core or entitlement curriculum post–16. They formed an explicit component of GNVQs (introduced in 1992) and of Modern Apprenticeship frameworks (introduced in 1995).

3.43 Prior to the introduction of Curriculum 2000, the Application of Number, Communication and IT key skills qualifications were only available through Advanced and Intermediate GNVQs, assessed solely through an externally verified/moderated portfolio of coursework evidence. Candidates had to show that they could apply the skills in a range of contextual and practical situations. With the introduction of Curriculum 2000, a short external test was added to this portfolio component with the intention of providing corroboration that candidates had genuinely achieved the underpinning skills. There is no compensation between the two assessment components: candidates have to pass each component separately to pass the qualification. There are no grades other than pass or fail. Following the implementation of the Curriculum 2000 reforms, the provision and acquisition of revised key skills qualifications for all students became a central goal of Government policy in the training and development of a numerate, literate and ICT skilled workforce for a modern economy. Funding incentives were provided to schools, colleges and other training institutions to promote key skills and achievement for all post–16 year olds, in line with Government policy. As recommended in the Cassels Review, all Modern Apprenticeship frameworks require achievement in communication and number skills, through good GCSEs or the corresponding key skills qualifications. Additional key skills requirements are included in frameworks at the discretion of the responsible sector body.

3.44 The key skills standards are centrally developed by the QCA, CCEA and ACCAC and offered as qualifications by 18 awarding bodies (representing the wide variety of candidates that need to acquire key skills). Student portfolios have to reflect accurately the specific requirements of each specification. The key skills qualifications in Application of Number, like those in Communication and IT, are free-standing qualifications formally available at levels 1–4 of the NQF. They are intended to serve a number of target audiences: eg those with good GCSEs who need or wish to develop their applied number skills further post–16, through the level 3 and 4 qualifications, without specialising in mathematics; those who have secured less good grades at GCSE and need or wish to achieve a level 2 qualification in number skills post–16; those who wish to progress from basic numeracy skills, developed through Entry level qualifications or the national numeracy tests. The Application of Number external tests at levels 1 and 2 serve also as the sole tests for Adult Basic Numeracy qualifications at these same levels. All publicly funded qualifications in adult basic numeracy are based on the national standards set by the regulatory authorities. Entry Level achievement can be certificated at each of the three sub divisions of Entry Level. For Entry Level qualifications, external assessment contributes a minimum of 50% to the overall award, but at levels 1 and 2, assessment is entirely by the external AoN tests at these levels.

3.45 Proxy qualifications are those qualifications that have been agreed by the regulatory authorities to assess the same knowledge and skills as aspects of the key skills qualifications. Candidates can claim exemption from all or part of particular key skills qualifications for up to three years from the date of the award of the specific accredited proxy qualification. GCSE mathematics at grades A*–C acts as a proxy for the external test of AoN at level 2 and a pass in AS or A-level Mathematics acts as a proxy for the external test of AoN at level 3. AS Use of Mathematics, comprising two of the FSMQ units together with one unit unique to the qualification, acts as a full proxy for both the portfolio work and the external test of AoN at level 3. All nationally accredited qualifications (including GCSE and GCE) are required to signpost opportunities for the learning and demonstration of key skills, including Application of Number. As result of the Skills White Paper in England, QCA have asked awarding bodies to improve their guidance in this area. For example, each FSMQ has a detailed map showing exactly how that qualification contributes to AoN portfolio assessment.

3.46 Students on many level 3 courses are awarded UCAS points for all level 3 qualifications that they pass. Each of the key skills qualifications at level 3 carries a UCAS tariff of 20 points; however, level 3 students also can be awarded a key skill at level 2 and for each of these they are awarded 10 UCAS points. This is the only instance where a level 2 qualification is awarded UCAS points. Thus, for example, a student who is awarded Communication and IT key skills qualifications at level 3 and AoN at level 2 will be awarded 50 UCAS points; a student with all three key skills at level 3 will be awarded 60 UCAS points, the same tariff award as an A grade for GCE AS Mathematics.

3.47 The external tests for AoN at levels 1 and 2 are available monthly, on-demand (weekly or higher frequency) and, via selected awarding bodies, on-line. Calculators are not allowed in these tests. The format of the tests is multiple-choice and lasts for 1¼ hours. Teachers may at their own discretion extend the duration of the test by as much as 25 per cent if they feel that their candidates need extra time. The level 3 test of AoN is available six times a year. It is a free response and calculator allowed test with six or seven multi-part questions. This test lasts 2 hours. The pass mark for each test is set jointly by the awarding bodies. Work is nearing completion on preset pass marks, which will further support the current high frequency testing opportunities and speed learner feedback.

3.48 The Statistical First Release covering the period between October 2000 and September 2002 showed that 296,000 key skills qualifications had been awarded to 206,300 candidates. Of all the key skills qualifications awarded in that period, 60 per cent of awards were obtained in FE/Tertiary Colleges, 20 per cent in secondary schools and 12 per cent in Sixth Form Colleges; 90 per cent of awards were to those aged 19 and under. We also note that 46 per cent of qualifications were obtained at level 2, 37 per cent at level 1 and 17 per cent at levels 3 and above. The majority were awarded in England (88 per cent), with 8 per cent awarded in Wales and 3 per cent in Northern Ireland. Of the 296,000 qualifications awarded, 25 per cent were for Application of Number compared with 39 per cent for Communication and 36 per cent for IT. A greater proportion of candidates gaining awards in Application of Number gained their highest qualification at level 1 compared to those only gaining level 1 in the other qualifications (46 per cent compared to 31 per cent in Communication and 38 per cent in IT). A review of the key skills specifications by the regulatory authorities reported to ministers in December 2003. The revised specifications for Application of Number and other key skills are due to take effect from September 2004.

Adult basic numeracy

3.49 *Skills for Life*, the national strategy for improving adult literacy and numeracy skills in England was launched by the Government in March, 2001, and aims to improve the basic skills of 750,000 adults by 2004 and 1.5 million adults by 2007. The all-age National Basic Skills Strategy for Wales was launched in 2001. It is estimated that 7 million adults (1 in 5) in England cannot read or write at the level expected of an average 11–year-old. It is estimated that even more (perhaps 1 in 4 adults) have problems with numbers. Labour market studies show that having level 1 numeracy skills are associated with having up to a 4 percentage point higher likelihood of being in employment than someone without level 1 skills, and that an individual with at least level 1 numeracy skills will earn on average between 6–10 per cent more than an individual with numeracy skills below level 1.

3.50 The provision of mathematics education for adults up to level 2 has been a key component of the Skills for Life strategy. The LSC makes numeracy provision available free to all adults irrespective of their starting point, geographical location or learning context or setting.The strategy sets out four strands to address numeracy deficiencies:

- to boost demand for numeracy skills by employers, providers and learners;
- to secure the capacity to deliver improved numeracy skills underpinned by the necessary financial resource;
- to raise standards of provision through high quality teaching and learning;
- to ensure learner achievement in the full range of numerical skills that underpin mathematical problem solving.

3.51 The new Adult Numeracy qualifications, which are part of the strategy, are available at three stages of Entry level and levels 1 and 2, while AoN key skills qualifications start at level 1. The Adult Numeracy qualifications at levels 1 and 2 are only available by taking the same external tests as those for AoN at levels 1 and 2, respectively. In contrast, the Adult Numeracy Entry Level qualifications have more flexible assessment procedures, offering a range of options for different types of learners. In general, the recent unification of the different examinations in adult numeracy seems to have been welcomed.

3.52 LSC actions so far to secure improvements in adult numeracy skills in England include:

- with QCA, publishing national standards for adult numeracy, which relate closely to both the key skills and the national curriculum levels in schools;
- in 2001 publishing the national adult core curriculum for numeracy, developed following wide consultation with key partners, teachers and managers; it provides, for the first time, consistent interpretations of the numeracy skills, knowledge and understanding required in order to achieve the national standards for adult numeracy;
- delivering a teacher training programme which has so far trained 6,378 numeracy teachers to use the new curriculum; responsibility for the teacher training contract has now been successfully transferred to the national LSC;
- developing a new diagnostic assessment tool for numeracy, together with training for 6,000 teachers, with the aim of supporting teachers in making accurate diagnostic assessments of numeracy skills;
- developing new numeracy learning materials mapped to the national curriculum, together with training in their use;
- setting up a national strategy to encourage volunteering in a range of roles, include mentoring and classroom support;

- setting up a Pathfinder project across the English regions during 2001–2 in order to test out elements of the new teaching and learning infrastructure.

Family programmes can also play a significant role in improving adult numeracy skills and in fostering greater involvement between children, their parents and their communities. The Adult Basic Skills Strategy Unit (ABBSU) is working with the LSC, who now fund family programmes, to expand and extend family literacy, language and numeracy provision.

3.53 In addition to the role of ICT in assessment, work has been done with Ufi/learndirect to support the development of both literacy and numeracy skills through e-learning. Evaluation of the experiences of adult learners who have participated in these programmes shows that 92% find the use of ICT motivating and most feel that ICT enables them to produce a higher standard of work more quickly. 64 per cent of learners said that ICT helped them to learn and in particular to concentrate. The ABBSU is continuing to work with other agencies to develop and disseminate e-learning methods and resources to support the development of a range of skills including numeracy.

A summary of structures, qualifications and developments in Wales, Northern Ireland and Scotland

WALES

Lower secondary – age 11–16

Assessment at Key Stage 3 (age 11–14)

3.54 The main aspects of the National Curriculum at Key Stages 3 and 4, the means of assessment, the structure of the National Curriculum attainment targets, the attainment level descriptions and the expectations for attainment by the end of Key Stage 3 are the same in Wales as in England. In the 2002 Key Stage tests, 62 per cent of pupils achieved level 5, or above, in mathematics. In Wales, the tests, together with guidance on their use and mark schemes are produced by the Qualifications, Curriculum and Assessment Authority for Wales (ACCAC), which is also responsible for evaluating the effectiveness of the assessment arrangements. The tests are marked by external markers appointed by an external marking agency. ACCAC has also developed the optional assessment materials (OAMs) to support teacher assessment in selected subjects at any point during Key Stage 3. The aim of OAMs is to lead to greater coherence in teacher assessment and provide comparable information about pupils' progress.

Assessment at Key Stage 4 (14–16)

3.55 The assessment arrangements in Wales are currently the same as those in England, but we have noted that the Interim Report of the Daugherty Assessment Review Group envisages different arrangements for assessment of 11–14 year olds in the future.

Assessment 16–19

3.56 The arrangements in Wales are currently the same as those in England.

Developments

3.57 In October 2002, the Welsh Assembly Government published Learning Country: Learning Pathways 14–19, which set out proposals for 14–19 learning. This was followed by the publication of the Action Plan on 2 April 2003. One of the key proposals is that, subject to the outcome of piloting, the Welsh Baccalaureate, which has been in pilot post–16 since September, 2003, should become a national award at Foundation, Intermediate and Advanced levels from September 2007. Initially the Welsh Baccalaureate is being offered post–16 at levels 2 (Intermediate) and 3 (Advanced) of the NQF. It is being piloted with three cohorts beginning in successive years (2003, 2004 and 2005).

3.58 The Welsh Baccalaureate contains three elements: a common Core curriculum, with a notional time allocation of 4.5 to 5 hours per week, comprising the six key skills, Wales, Europe and the World (including language modules), Work-related Education (including work experience and entrepreneurship) and Personal and Social Education (including an element of community participation); Optional studies, with an allocation of 18 to 20 hours per week, comprising the main programme of learning selected from existing courses leading to qualifications in the NQF (eg GCSE, GCE, NVQ); and the tutoring/mentoring system that links programme and student.

3.59 The Intermediate Welsh Baccalaureate will require all students to complete the three core key skills (AoN, Communication and IT) and two of the other three wider key skills (Improving one's own learning and performance, Problem-solving and Working with others, although these have not yet been accredited to the NQF) at level 2 and obtain 5 GCSE grades A*–C, or the equivalent. For the Advanced Welsh Baccalaureate, the student must attain three key skills (including at least one of the core three) at level 3 and the other three at level 2 and 2 GCE A levels grades A–E or the equivalent. This means that all those aspiring to the Intermediate Welsh Baccalaureate will need to have achieved Application of Number at level 2 and all Advanced Baccalaureate students will need to have achieved it at either level 2 or 3. Students will also be able to choose mathematics qualifications at the appropriate levels as part of the 'options' component of their programme.

3.60 The Credit and Qualifications Framework (CFQW), which will offer credit for qualifications in the NQF, will continue to be developed with a view to progressive rollout from May 2003 until 2006 when the essential building blocks are expected to be in place. It will be extended to reflect achievement through prior and informal learning and of voluntary qualifications.

NORTHERN IRELAND

Post Primary – 11–16

3.61 The broad structure for the delivery of a statutory curriculum and assessment arrangements for 11–16 year olds is similar to those in England and Wales with some differences. We note, however, that schooling in Northern Ireland starts at the age of 4, with children completing 7 years in primary before transferring to post primary at the age of 11. Key Stages and years do not therefore match those for England. In the Northern Ireland system: KS1 is ages 4–8 and years 1–4; KS2 is ages 8–11 and years 5–7; KS3 is ages 11–14 and years 8–10; KS4 is ages 14–16 and years 11–12. The main strands of mathematics in which pupils should progress at each key stage are set out below:

Key Stages 1 and 2	Key Stages 3 and 4
Processes in Mathematics*	Processes in Mathematics*
Number	Number
Measures	Algebra
Shape and Space	Space, Shape and Measures
Handling Data	Handling Data

**This pervades all other strands*

Assessment at Key Stage 3 (11–14)

3.62 At Key Stage 3, statutory assessment of English, Irish (in Irish speaking schools), mathematics and science takes the form of teacher assessment (without moderation) and the end of key stage subject tests with parallel reporting of both the teacher assessment and test outcomes. For mathematics, for most tiers of entry, there are two written papers and a mental mathematics test. The written tests, each lasting an hour, are based on the related POS and address all the attainment targets except Processes in Maths. There are five tiers, covering Northern Ireland Curriculum levels 3–8, with five written papers of which two are used for each tier except tier A and two mental tests, 1 and 2 (ie: Tier A, written paper 1 only, plus mental test 1; Tier B, written papers 1 and 2, plus mental test 1; Tier C, written papers 2 and 3, plus mental test 2; Tier D, written papers 3 and 4, plus mental test 2; Tier E, written papers 4 and 5, plus mental test 2).

Assessment at Key Stage 4 (14–16)

3.63 Revised GCSE specifications, including those for mathematics, were examined for the first time in summer 2003. Northern Ireland has the distinctive feature of a GCSE in Additional Mathematics, which is a level 2 rather than a level 3 award, even though its content goes beyond the Key Stage 4 Programme of Study. This is unusual in having no coursework element and is accredited by the QCA for use in Northern Ireland only. The take up is mainly from stronger GCSE candidates, who sit the examinations in year 12 (corresponding to year 11 in England), sometimes in tandem with standard GCSE Mathematics, sometimes having taken the latter the year before.

Assessment 16–18

3.64 Northern Ireland implemented the Curriculum 2000 reforms alongside England and Wales. The CCEA worked with the other regulatory authorities to revise the mathematics specifications in response to early evaluations that indicated that the overall content of the AS Mathematics was too great. Northern Ireland will also introduce the revised specifications for first teaching from September 2004.

Examination Arrangements

3.65 The CCEA is both an awarding body providing, among others, GCSE, GCE and key skills qualifications and one of the regulatory authorities responsible for ensuring the continued availability of high quality qualifications that are fit for purpose, command public confidence and are understood both by those who take qualifications and those who use them. In order to ensure that a consistent and uniform approach is taken to regulation, it works closely with ACCAC and QCA.

Developments

3.66 A fundamental review of the Northern Ireland curriculum has been completed by CCEA. Proposals would limit the role of statute to specifying only the minimum entitlement of every pupil. At Key Stage 3, the statutory curriculum would be specified in terms of: curriculum areas and not individual subjects (although mathematics remains an area in its own right); and a common minimum entitlement for every pupil, irrespective of future intentions. Schools would have the flexibility to extend this entitlement to cater for the needs of different pupils. At Key Stage 4, the proposals would mean a statutory curriculum limited to: Skills and Capabilities (including Communication, Using Mathematics, ICT, Problem-solving, Self Management and Working with Others); Learning for Life and Work (including PSHE, citizenship and education for employability); and Physical Education. There would be no requirement in law for pupils to study any individual subject, but it would be expected that for most pupils their programme at Key Stage 4 would continue to consist of a range of GCSE courses, or courses leading to other appropriate qualifications and that a course in mathematics would be amongst these. Indeed it is proposed that all qualifications in mathematics offered to pupils in Key Stage 4 in Northern Ireland should provide all the learning opportunities identified for Using Mathematics and therefore that the accreditation criteria should be altered accordingly. Once these provisions are in place it will be necessary to change the specifications for mathematics accordingly. This will have the effect of making it no longer necessary for pupils to undertake additional qualifications such as Key Skills in order to demonstrate competence in Using Mathematics. (Similar arrangements will pertain to Communication and English). If accepted, it is likely that phased implementation of these changes will commence in September 2005.

3.67 The review of the statutory curriculum has been accompanied by a review of the statutory assessment arrangements associated with it. CCEA recommends that the current tests in English, mathematics and science for 14–year olds be discontinued. End of key stage tests would be replaced by a system of standardised annual reports. If the proposals are accepted, CCEA will work with schools to explore more collaborative approaches to the curriculum beginning with Key Stage 3 and possibly extending into Key Stage 4. Each "subject" will be asked to make relevant links to other areas. In this scenario the nature of the mathematics being learned could then be applied to different scenarios across the curriculum.

3.68 Arrangements are being put in place for a single managed service entitled 'Learning Northern Ireland (LNI)' covering all aspects of the use of ICT in schools both for administrative and curricular purposes. One of the items of work which may contribute to this in the future is a project in computer-based formative assessment, partly in the area of mathematics. In this project a facility has been developed that allows for the playback of stages of a pupil's work in a way that will help the pupil appreciate the processes involved.

SCOTLAND

3.69 There is no statutory national curriculum in Scotland. However, guidance is provided by the Scottish Executive Education Department and other national agencies.

Structure of school education

3.70 School curricula are divided into two phases: 5–14 and National Qualifications. Following transfer from primary to secondary (at the end of year 7), the various Scottish Qualifications Authority (SQA) examinations have traditionally been taken at possible exit points from the school system. These are: Standard Grade at the end of S4 (year 11), Access, Intermediate 1, Intermediate 2 or Highers at the end of S5 (year 12), and additional Access, Intermediate 1 or 2, Highers or Advanced Highers (AH) in S6 (year 13). These arrangements are reflected in Age and Stage Regulations, which determine the age at which students may be assessed and receive external certification for the National Units and Courses managed by the SQA. However, schools and other centres, if they wish, also apply to the SQA for exceptional entry in order to present the most able students for examination at an earlier age. These arrangements have and are being revised to introduce more flexibility within the education system. National Qualifications (NQs) now incorporate Standard Grades and new National Qualifications (Access, Intermediate, Intermediate 2, Higher and Advanced Higher), which were introduced through the "Higher Still" reforms. The Scottish Executive's response to the National Debate on Education (see paragraph 3.83) also contains the commitment to consult on the future of Age and Stage regulations.

3.71 National guidelines for the 5–14 curriculum and course arrangements for Standard Grade and new National Qualifications give guidance on course content. The new NQ courses offer a measure of choice at each level, although all courses are based on generic maths until more advanced levels (Higher and Advanced Higher) where specialisation is possible. University entrance requirements are normally framed in terms of Higher awards and it is common for school students during year S6 to gain unconditional entry to universities on the basis of the Higher awards achieved in S5. Other students will, during year S6, receive conditional entry to Higher Education. Conditions usually refer to outstanding Higher awards but also sometimes refer to Advanced Higher targets. Both schools and colleges may deliver new National Qualifications at levels ranging from Access 1 to Advanced Higher.

Scottish Credit and Qualifications Framework

3.72 The Scottish Credit and Qualifications Framework (SCQF) provides a structure that helps to relate qualifications at different levels ranging from Access to Postgraduate levels. In these ways it assists learners to plan their progress and to minimise duplication of learning. The SCQF provides a national vocabulary for:

- describing learning opportunities and making the relationships between qualifications clearer;
- clarifying entry and exit points, and routes for progression within and across education and training sectors;
- increasing opportunities for credit transfer.

3.73 In the SCQF, there are 12 levels ranging from Access level 1 (designed for learners with severe and profound learning difficulties) to level 12 (associated with postgraduate doctoral studies). The awards and their relationship to SCQF levels are illustrated in the table.

SCQF level	Schools	Schools and Colleges	Colleges and Universities
12			Doctorate
11			Masters degree
10			Honours degree
9			Ordinary degree
8			HND
7		Advanced Higher	HNC/Certificate Higher Education
6		Higher	
5	Standard Grade–Credit	Intermediate 2	
4	Standard Grade–General	Intermediate 1	
3	Standard Grade–Foundation	Access 3	
2		Access 2	
1		Access 1	

Assessment 14–16

3.74 Most pupils aged 14–16 (S3 and S4) will take a range of Standard Grade courses. National guidance recommends that mathematics is one of the courses that pupils study. Each Standard Grade course lasts two years and is generally taken at the end of S4 (year 11). It has two or three assessable elements. Assessments can take the form of an examination, coursework or performance. The mark for each element is aggregated to give the overall grade. Mathematics has two assessable elements: Knowledge and Understanding and Reasoning and Enquiry. Both elements are externally assessed by the SQA through an examination. Awards at Standard Grade are set at three levels: Credit (grades 1–2), General (grades 3–4) and Foundation (grades 5–6). Credit is the highest level of achievement

Assessment 16–18

"Higher Still" reforms

3.75 New National Qualifications were introduced as a result of the "Higher Still" development programme. They are intended to provide a coherent, progressive educational experience for all students within post–16 education. Pupils aged 16–18 (S5 and S6) take a range of National Qualifications courses. The number and subjects to be studied are agreed through a guided process of negotiation between pupil and school to ensure an appropriate curriculum. National Qualifications courses are offered at five levels:

- Access (Access 1–3),
- Intermediate 1,
- Intermediate 2,
- Higher, and
- Advanced Higher.

3.76 Advanced Higher is the highest level of achievement and normally studied in S6. Each course lasts one year although, as courses are unit-based, a longer period of study is possible. Almost all courses at Intermediate 1, Intermediate 2, Higher and Advanced Higher levels consist of 3 units. An internal assessment is carried out at the end of each unit (known as a National Unit). Each unit counts as a qualification in its own right. Pupils must pass internal assessments in all the relevant units and then, separately, an external assessment to attain an overall course award. The external assessment, carried out by SQA, determines the grade (A–C) of the course award.

3.77 National Qualifications courses in mathematics cover a range of knowledge, skills and understanding appropriate to each level of course. Topics include problem solving, applied mathematics and algorithms. For mathematics at Intermediate 1 and 2, students have a choice of the third unit of the course. The normal unit 3 is designed to allow progression to the next level (so, for example, a student with units 1, 2, 3 at Intermediate1 could go on to take Intermediate 2 the following year). Instead of unit 3, the student can take

an applications unit that gives opportunities to apply what has been studied in suitable contexts and undertake a short project – but this unit does not articulate with the next level. Not all schools will be able to offer pupils a choice as each unit requires direct teaching and therefore class composition and timetabling may also be relevant factors in the decision. At Higher level there is again a choice of the third unit. A small minority take a statistics unit instead of the main maths unit 3. At Advanced Higher level, there are two courses available. Advanced Higher Mathematics consists of three units covering a range of mathematical skills including algebra, geometry and calculus. Advanced Higher Applied Mathematics allows students the opportunity to study specialised areas of applied mathematics to greater depth. From 2004–05, Advanced Higher Applied Mathematics will consist of two units covering mechanics, numerical analysis and statistics and a third unit of broad content drawn from the Advanced Higher Mathematics course.

3.78 The Scottish Executive considers that the end result of the new NQ courses is that, at each level, schools and students have a wider range of awards available to them and an appropriate choice of courses, while at the same time users of the resulting awards can have confidence about the content of the courses that students will have studied. For mathematics, by far the most common routes for entry to Higher Education are Higher Maths and then, for some students additionally Advanced Higher Maths. Lecturers in HE should not therefore have to contend with a wide range of mathematical background if their classes consist mainly of school leavers.

Core Skills

3.79 Numeracy is one of five Core Skills within the Scottish Qualifications Framework: the others are Communication, Problem Solving, Working with Others and Information Technology. The core skill of numeracy is defined as follows: "To cope with the demands of everyday life, including work and study, people need to be comfortable with numbers and at ease with graphs, symbols, diagrams and calculators. The skills needed are essentially those of interpreting, processing and communicating quantifiable and spatial information." Numeracy is regarded as having two components. The first, *Using Graphical Information*, is described in terms of students progressing from working in familiar, everyday contexts to more abstract contexts where analysis is needed in order to arrive at decisions and communicate conclusions. The second, *Using Number*, involves the ability to apply a range of numerical and other relevant mathematical and statistical skills in everyday and more abstract contexts.

3.80 All National Qualifications have been audited against the SQA's Core Skills Framework to determine which core skills are embedded within the assessment arrangements for each unit and course and at what level. Students achieving unit and course awards are automatically certified for the core skills covered by those units and courses. Students also have the option of achieving core skills through dedicated core skills units. These can be achieved in a number of ways – by following a programme of study leading to assessment,

by developing a portfolio of evidence or by taking specially designed assessments at an agreed or negotiated time. SQA will be consulting stakeholders in summer 2004 on the future development of all arrangements for assessing and certifying core skills.

Pace and Progression

3.81 As indicated in paragraph 3.70, the Scottish Executive is encouraging schools to think imaginatively and flexibly about how to maximise educational gain for all students. A circular issued in 2001 noted that new National Qualifications offer coherent progression routes between qualifications, some schools may decide to replace some or all Standard Grade provision with these course if appropriate and in accordance with Age and Stage regulations. So far, most schools have not taken full advantage of these new opportunities although some are planning to improve progression routes, for example by moving to Intermediate in S3/4 to improve chances of progression in S5/S6. Initiatives tend to be aimed at mathematically weaker pupils with a view to improving the phasing of work and letting pupils reach a higher level of attainment than previously, albeit at a relatively slow pace. There is less interest in accelerating the most able students as Higher in S5 is still seen as a challenging level for most pupils to reach only a year after Standard Grade in S4.

Examination Arrangements: Role of SQA

3.82 The SQA is the national body in Scotland responsible for the development, accreditation, assessment, and certification of qualifications – other than degrees – and was established under the Education (Scotland) Act 1996, as amended by the Scottish Qualifications Authority Act 2002.

SQA's functions are to:

- devise, develop and validate qualifications, and keep them under review;
- accredit qualifications;
- approve education and training establishments as being suitable for entering people for these qualifications;
- arrange for, assist in, and carry out, the assessment of people taking SQA qualifications;
- quality assure education and training establishments which offer SQA qualifications;
- issue certificates to candidates;
- provide the Scottish Ministers with advice in respect of any matter to which its functions relate.

SQA is also responsible for developing and distributing 5–14 National Tests to schools as part of the Government's 5–14 Programme.

Developments

3.83 Overall, evidence to the Inquiry suggests there is thought to be congruence between stages with the new National Qualification awards in S5/S6 as they have been designed to articulate well with each other and with Standard Grade courses in S3/S4. There is thought to be a lack of congruence between levels A–F within the 5–14 curriculum and Standard Grade/NQs. Level F was designed to articulate to an extent with Intermediate 2, and early in the life of 5–14 some 'mapping' was done to identify overlaps between 5–14 and Standard Grade, but this was never completed. Action is underway to address this. The Scottish Executive issued in 2002 National Statements for Improving Attainment in Literacy and Numeracy in Schools. Two national Development Officers have been appointed to support education authorities and schools in making most effective use of the Statements and working with them to improve literacy and numeracy. The remit of the new Numeracy Development Officers includes assisting in the monitoring of good practice in improving progression routes from S1/S2 mathematics courses through S3/S4 and into S5/S6.

3.84 A National Debate on Education was held in Scotland in 2002. The Scottish Executive's response to the National Debate includes establishing a single set of principles and a framework for the whole curriculum through pre-school, primary and post-primary, looking forward to lifetime learning. Other commitments include consulting on the future of the Age and Stage regulations, addressing the relationship between Standard Grade and new National Qualifications and reducing the amount of time spent on external examinations, including the option of sitting examinations only when leaving school instead of every year from S4.

4 ACTION ON CURRENT AND FUTURE MATHEMATICS PATHWAYS

The Working Group on 14-19 Curriculum and Qualifications Reform

4.1 The Post-14 Mathematics Inquiry has proceeded in parallel with the work of the Working Group on 14-19 Curriculum and qualifications reform in England, chaired by Mike Tomlinson. In its Interim Report in February 2004 (DfES/0013/2004), the Working Group outlined broad proposals for the phase of 14-19 learning, including the development of a new diploma framework that would cover the whole of the 14-19 learning programme. The Interim Report includes proposals to move away from the existing age-related qualifications to a system offering more opportunities for students to achieve qualifications in their own time and at their own ability and aptitude level, while offering coherent pathways of progression. Such a framework should provide candidates with opportunities to demonstrate and record specific mastery of skills and topics rather than recording overall levels of success or failure. A key feature of the Tomlinson proposals is a single 14-19 learning continuum in place of the current perception of 14-16 and 16-19 as two distinct phases.

4.2 The Working Group proposals will encourage more students to obtain level 3 qualifications. So far as mathematics is concerned, the proposals incorporate the possibility of more specialist study of mathematics beyond a mandatory core of foundational mathematics. Although the Mathematics Inquiry has proceeded independently from the Working Group on 14-19 Reform, the Inquiry has found there to be a strong consensus within the mathematics community in favour of a diploma type of approach to qualifications.

4.3 So far as mathematics is concerned, the Post-14 Mathematics Inquiry agrees with the 14-19 Working Group's conclusion that the present qualifications framework is in need of a radical overhaul. The first part of this chapter will discuss in detail the concerns expressed to the Inquiry about the current framework. This will lead us to make specific short- and medium-term recommendations regarding the current framework. We see these not only as important steps towards improving the current structure, but also as contributing to a longer term direction of travel, compatible with the Tomlinson notion of progressive pathways, each with its own mathematical components. We see some version of the latter as the key to providing a structure whereby all students have access to a relevant mathematics pathway appropriate to their learning needs, and relevant to end destinations in the workplace, or continuing education, post-19. In the view of the Inquiry, mathematics should be seen as an integrated whole when designing 14-19 pathways. We begin with a review of concerns with the current structure.

Current concerns over GCSE Mathematics in England

4.4 The Inquiry has no doubt that, compared with the previous O-level/CSE structure, GCSE Mathematics has been beneficial to many more students and has provided them with an adequate background for further study in the subject. However, respondents to the Inquiry have raised a number of serious concerns, which the Inquiry believes to be well founded.

4.5 In GCSE Mathematics, only about 50 per cent of the candidature achieves the iconic 'pass' grades A*-C. Many repeat GCSE to try to improve their grade, having failed to reach at least a C grade first time round at age 16. There do not appear to be easily accessible data on resit performance, but respondents to the Inquiry report that a significant number of resit candidates do not achieve an improved grade. More generally, far too few young people in England achieve level 2 qualifications in mathematics and England seriously lags behind its European competitors in this respect.

4.6 Whilst accepting that the decision to have a three-tier arrangement for mathematics was made with the best of intentions, respondents to the Inquiry have overwhelmingly expressed grave concern that GCSE mathematics is now the only GCSE subject where a grade C is not accessible on all the tiers. In the light of concern expressed about the three-tier structure, the regulatory bodies have given further consideration to appropriate assessment mechanisms and is running a pilot of a two tier GCSE examination in mathematics with OCR.

4.7 The pilot scheme has three examination papers and all candidates sit a combination of two of these. Candidates studying the Foundation PoS are entered for Paper 1 (targeting grades E-G) and for Paper 2 (targeting grades C-D). Those studying the Higher PoS are entered for Paper 2 and for Paper 3 (targeting grades A*-B), but could be entered for Papers 1 and 2 if they are having difficulty with the course. Every student therefore has access to a grade C and there will be only one route to each grade. The pilot will run through two complete cycles. The first examinations took place in June 2003 and there will be a second round in June 2004. Ministers will be notified of outcomes and advised of any proposed changes in December 2004. Any modification of the current arrangements in England will require Ministerial approval.

4.8 The Inquiry has been informed that the QCA would wish to see this two-tier assessment structure become the standard examination structure for GCSE Mathematics within a few years. The assessment structure would then mirror the revised curriculum structure, a correspondence that many respondents clearly believe to be important. We believe that this was the original intention at the time of the 1999 revision of the curriculum, but was shelved on the grounds that such additional change to the system would be have been too disruptive at that time. The majority of respondents to the Inquiry seem to believe that most teachers would now welcome the shift to two-tier examining as fitting in more naturally with their curriculum planning and

setting into cohorts for the Key Stage 4 Higher and Foundation Programmes of Study.

4.9 The three-tier assessment structure does not mirror the two-tier structure of the revised curriculum. Moreover, the existing three-tier arrangement for assessing GCSE Mathematics disbars about one third of candidates from having access to a grade C. Since grade D is the highest grade achievable on the Foundation Tier papers, respondents report that many students feel themselves to have been classed as "failures" by their teachers before they even start the course. The Inquiry shares this concern. Rightly or wrongly, public opinion – no doubt much influenced by school league tables – has come to regard a grade C at GCSE as a minimal acceptable level of attainment. It therefore seems to the Inquiry totally unacceptable to be entering some 30 per cent of the age cohort into a tier in which "externally perceived success" (ie grade C) is unattainable whatever the level of achievement.

4.10 The existing arrangements for assessing GCSE Mathematics allow raise issues regarding the interpretation of GCSE grade B. This grade can be awarded both on the Intermediate Tier papers and also on the Higher Tier papers. However, respondents are clear that the algebraic and geometric content associated with the Intermediate Tier is significantly less than the algebraic and geometric content associated with the Higher Tier and that this means that there cannot be an unambiguous interpretation of GCSE grade B in mathematics. In particular, there is concern in relation to preparedness for AS/A-level mathematics. Many clearly feel that, without some form of bridging course, candidates obtaining a grade B in mathematics on the Intermediate tier have an inadequate basis for moving on to AS and A2. They have had too little fluency in algebra and too little routine practice with reasoning about geometric properties and relations.

4.11 However, it has been put to the Inquiry that the tactical behaviour of schools and pupils is being influenced by the perception that it is easier to get a grade B for GCSE mathematics by being entered for the Intermediate Tier. We have been informed that when grade B was first introduced as a possible outcome on the Intermediate Tier, entries for the Higher Tier fell from nearly 30 per cent to about 15 per cent of the candidate cohort and have remained relatively stable since then. The Inquiry finds these consequences of the current arrangements to be worrying, both in terms of the interpretability of grades and the perverse incentives it provides for placing pupils on educationally inappropriate pathways. We suggest that those piloting the two-tier system take on board these concerns.

4.12 The GCSE Mathematics examinations in summer 2003 were the first to assess the revised two-tier curriculum. Anecdotal evidence to the Inquiry indicates that the new coursework regulations have caused some problems to some teachers and pupils. It may also be the case that teachers may not have fully acquainted themselves with the content of the Higher PoS. The Inquiry is not in a position to properly assess the new two-tier initiative or the two-tier assessment, but nevertheless believes that serious consideration should be given to moving to a two-tier structure.

Recommendation 4.1

The Inquiry recommends that, subject to the present pilot being fully and successfully evaluated, immediate consideration be given by the QCA and its regulatory partners to moving as soon as is practicable to a two-tier system of overlapping papers for GCSE Mathematics in England, Wales and Northern Ireland. The Inquiry recommends that the regulatory authorities try to recruit more schools and colleges to take part in pre-implementation piloting after summer 2004.

4.13 Many respondents clearly feel that mathematics is not rewarded sufficiently at level 2 in comparison to English and science and this is also reflected in responses given in focus groups organised by QCA on behalf of the Inquiry. It is widely believed by pupils and teachers that the amount of effort required to achieve a single GCSE award in Mathematics is similar to the amount of effort required to gain the two awards in English Language and Literature or to gain a Double Award in Science. There is a widespread concern that this is adding yet further to the perception of mathematics as a disproportionately hard subject and may be adversely affecting pupils' subsequent choices post-16. The Inquiry believes that this to be a serious issue and supports the view that serious consideration should be given to making a double award available for mathematics for the higher tier route (either in the current structure, or in a revised two-tier structure).

4.14 We acknowledge that consideration needs to be given as to how to do this so as to ensure that such a double award is on a par with the double award for GCSE Science. The Inquiry has not had the time or resources to provide detailed practical recommendations regarding the necessary curriculum and/or assessment adjustments required (in either the two-tier or three-tier structures). However, we would wish to make the following clear recommendation.

Recommendation 4.2

The Inquiry recommends that, at the earliest possible opportunity, consideration should be given by the QCA and its regulatory partners to re-designating GCSE Mathematics, appropriately modified if necessary, to merit a double award at level 2. This re-designation should be considered in tandem with the possible move to a two-tier system (see Recommendation 4.1).

4.15 Many respondents have expressed serious doubts about the value of GCSE mathematics coursework, in particular the data-handling component. There is concern that current requirements lead to a rather artificial approach to analysing and interpreting data, rather than encouraging substantive involvement with "real life" problems. There is also concern over the comparatively large amount of time spent on GCSE coursework in relation to the amount of timetabled time for the subject itself. We are aware that the QCA has amended the coursework marking criteria in response to perceived teething troubles, but the Inquiry still feels that there is sufficient concern to merit a review of current requirements. This needs to be considered alongside Recommendation 4.4.

Recommendation 4.3

The Inquiry recommends that there should be an immediate review by the QCA and its regulatory partners of the quantity of coursework in GCSE mathematics and, in particular, the data handling component, with a view to reducing the amount of time spent on this specific element of the course. (See, also, Recommendation 4.4)

4.16 More generally, there has been considerable disagreement among respondents regarding the appropriate treatment of the Handling Data strand of the PoS for Key Stage 4 (Higher). Basic Probability is clearly seen as part of the mathematics core, but some have argued that Handling Data should be absorbed into the using and applying mathematics strands in number and algebra and in shape, space and measures. Others have argued that the roles of Statistics and Data Handling are so fundamentally important, both in other disciplines and in the workplace, that, in the long term, these topics need to be found their own timetable niche – perhaps embedded in the teaching of other disciplines – rather than taking up a substantial part of the mathematics timetable that used to be available for practice and reinforcement of fluency in core mathematics techniques. In addition, the function of GCSE Statistics is thought by many respondents to be unclear. The majority view is that it is not sensible for pupils who achieve a good GCSE Mathematics pass in year 10, or earlier, either to discontinue the study of mathematics altogether in year 11 or to study GCSE Statistics as an additional GCSE replacing formal study of mathematics in this year. Conversely, it is suspected that some pupils are entered for GCSE Statistics because it is seen as a softer option than GCSE Mathematics itself in terms of grade attainment, rather than for sound educational reasons.

4.17 The Inquiry strongly believes that knowledge of Statistics and Data Handling is fundamentally important for all students and would wish to see these topics continue to be given due emphasis and timetable allocation. However, we believe it would be timely – in the context of a radical re-think of future 14-19 mathematics pathways within the general structure that may emerge following the 14-19 Working Group review – to reconsider the current positioning of Handling Data within the GCSE mathematics timetable, where

it occupies some 25 per cent of the timetable allocation. Many respondents believe the current mathematics curriculum at Key Stage 4 to be overloaded. We have no doubt that much of the concern expressed to us about the perceived decline of fluency with core mathematical operations reflects the pressure on the mathematics timetable that has resulted from the inclusion of this significant element of Handling Data.

4.18 We have also received a number of responses arguing that the teaching and learning of Statistics and Data Handling would be greatly enhanced if they were more closely integrated with the other disciplines that rely heavily on these topics, such as biology and geography. We support this view and believe it to be timely to begin to review this issue in the context of the general philosophy of the approach to 14-19 learning programmes emerging from the Tomlinson review. This prompts our next recommendation, which should also be considered in the context of our longer-term recommendations about future pathways set out later in this chapter.

Recommendation 4.4

The Inquiry recommends that there should be an immediate review by the QCA and its regulatory partners of the future role and positioning of Statistics and Data Handling within the overall 14–19 curriculum. This should be informed by: (i) a recognition of the need to restore more time to the mathematics curriculum for the reinforcement of core skills, such as fluency in algebra and reasoning about geometrical properties and (ii) a recognition of the key importance of Statistics and Data Handling as a topic in its own right and the desirability of its integration with other subject areas (see, also, Recommendation 4.11).

4.19 In terms of usable skills, although GCSE grade C is the minimum societal expectation, evidence to the Inquiry suggests that employers are often less than happy about the mathematical abilities of recruits with GCSE, even when the grade obtained is at least a C. The perception of the level of mastery signified by a grade C has been further damaged by the claim in an article in the Daily Express in the summer of 2003 that some students were achieving the grade on the basis of 15 per cent raw marks. More generally, evidence to the Inquiry and the findings of the report *Mathematical Skills in the Workplace* suggest that GCSE Mathematics itself now seems to many employers to be an inadequate preparation for the growing mathematical needs of the workplace. The perception is that students are learning most of their mathematics in a vacuum, with little attention given to any sort of mathematical modelling, or to a range of problems set in real world contexts and using real data. In addition, the report *Mathematical Skills in the Workplace* makes clear that there is serious concern that students have little exposure to how ICT can be used to enhance each of these aspects of mathematics, even though employers today increasingly want a combination of mathematical skills harnessed to ICT skills. In terms of the appeal of the subject to students, evidence from focus groups run by the QCA for the Inquiry reveals that for many students, GCSE Mathematics seems irrelevant and

boring and does not encourage them to consider further study of mathematics. At the same time, many respondents have impressed on us the dangers of also losing the attention and interest of some of the most able because of the perceived lack of depth and challenge in the standard curriculum.

4.20 The Inquiry is acutely aware of the dangers of diluting the essence of the discipline of mathematics by inappropriate attempts to make everything immediately "relevant" and by the use of clearly unrealistic versions of "real" problems. That said, we believe that the time has come for a radical re-look at longer-term options for 14-16 mathematics provision that do provide sufficient appropriate pathways for those who need motivating more through perceived practical relevance. We shall later make recommendations directed at beginning this process. In the meantime, we believe that there is an immediate action to be taken in relation to the needs of the most mathematically able.

4.21 The Inquiry believes that it is vitally important to provide appropriate challenge for the mathematically more able and motivated. We also accept the view of the overwhelming majority of respondents to the Inquiry that current provision is failing in this respect. Some respondents to the Inquiry have suggested that the more able students should be catered for by accelerating their exposure to material covered at higher qualification levels. The overwhelming majority of respondents disagree. The prevailing view is that what is required is deeper challenge and exposure to more open-ended problem solving with material from the student's *current* qualification stage. The Inquiry supports this latter view. We have an open mind about whether such provision should be statutory and whether it should lead to a formal qualification.

Recommendation 4.5

The Inquiry recommends that the QCA and its regulatory partners should be funded to develop an extension curriculum and assessment framework for more able pupils at Key Stages 3 and 4. This extension curriculum should be firmly rooted in the material of the current Programmes of Study, but pupils should be presented with greater challenges. These should involve harder problem solving in non-standard situations, a greater understanding of mathematical inter-connectedness, a greater facility in mathematical reasoning (including proof) and an ability to engage in multi-step reasoning and more open-ended problem solving (see, also, Recommendation 4.11).

FSMQs and AS Use of Mathematics: concerns over key skills and Application of Number (AoN)

4.22 The Inquiry also believes that the action is vital to provide appropriate challenge and motivation for those who need and want to continue the study of mathematics post-16, but are primarily motivated by seeing the relevance of mathematics in the context of a range of real-world applications. In this

connection, many respondents have indicated to the Inquiry that there is insufficient awareness and use of the FSMQs and AS Use of Mathematics qualifications. In particular, respondents have indicated that there is scope for more level 2 FSMQs, to cover a wider spectrum of mathematics. In particular, it is argued that a level 2 Use of Mathematics should be developed along lines similar to the existing AS Use of Mathematics. The Inquiry has not had the time or resources to consider this in depth. However, we do believe it would be timely to conduct a review of all these issues and we suggest a way forward in Recommendation 4.7.

4.23 Despite the rapidly increasing numbers making use of FSMQs, take up remains comparatively small. Despite some very positive reports, the Inquiry does not feel that there is sufficient experience of their use for it to be able to judge clearly the merits or otherwise of the current portfolio of FSMQs. However, the Inquiry has become aware of a number of seemingly unnecessary current obstacles to delivery and further take-up. These include:

- the difficulty of promoting FSMQs in institutions with small class numbers of students; currently, there is better take up in Colleges of Further Education and Sixth Form Colleges than in secondary schools;
- a lack of awareness of FSMQs among some parents, employers and admissions tutors in higher education institutions;
- the possible difficulty of obtaining funding for teaching; in FE colleges, it is not possible to claim funding for both Application of Number and FSMQs; the Inquiry is not able to judge whether reported shortages of funding for tutorials, key skills and enrichment reflect local management decisions, or result from national LSC funding rules.

4.24 The Inquiry accepts that prima facie FSMQs have much to offer, particularly in the context of a re-design of 14-19 mathematics pathways. It would therefore clearly be highly desirable to have greater experience of their use as part of the process of working towards a richer portfolio of 14-19 pathways. However, we accept that this is unlikely to happen without at the very least a concerted campaign to raise the profile and acceptance of these qualifications. More generally, we are concerned that provision of Application of Number has not been developed within a coherent framework together with FSMQs and AS Use of Mathematics. We are concerned about this potentially lack of coherence and believe that it would now be timely to review this whole portfolio of provision as a prerequisite to the re-design of more practically oriented pathways within a new 14-19 structure. A specific way forward is detailed in Recommendations 4.6 and 4.7.

4.25 The Inquiry has received a significant number of responses raising serious concerns about the implementation of the key skills agenda and particularly the AoN component. While there are doubtless instances where successful implementation is taking place, the messages we have received are overwhelmingly negative. The Inquiry is aware of the danger of being over-

influenced by strongly expressed views and is conscious of the fact that it has had neither the resources nor the expertise to conduct independent studies or surveys in relation to many of the issues raised. However, the messages have been consistent enough for us to be convinced that this whole area requires at the very least a thorough and radical review.

4.26 One key issue around the delivery of AoN has been whether delivery should be separate or integrated with the students' other courses, particularly those of a vocational nature. The Inquiry shares the view of many respondents that for many students at this stage of their education, particularly those who have made firm vocational choices, integration of the mathematics with the vocational subject would be highly desirable. In practice, however, evidence to the Inquiry makes clear that many teachers on non-mathematical courses have found it very difficult to provide satisfactory delivery of AoN. Many teachers of vocational subjects who are not mathematics specialists are not confident in their understanding of how mathematics can be used to enhance their own areas of work. They typically have even less confidence in teaching mathematics to their students, who also work from a very low level of mathematical understanding. This seems to be especially true of students on Modern Apprenticeships. Many of these students may need to address problems with their basic numeracy skills before moving on to AoN. The Skills White Paper in England announced that the services provided by the Key Skills Support Programme will continue to be available to practitioners in schools, colleges and work-based training from 2004-05. The Inquiry acknowledges the efforts that are being made here, but continues to be concerned that the issue of the vocational teachers' actual skills and confidence levels in mathematics are not being fully addressed.

4.27 We understand from respondents to the Inquiry that, in practice, in most FE Colleges the delivery of AoN is currently the responsibility of specialist mathematics staff, many of whom would regard themselves better employed teaching other aspects of mathematics where their specialist skills are more crucial. Where this is the case, this has clearly resulted in tensions for local managers in reconciling teacher preferences and learners' needs and effectively deploying specialist teaching resources. Such tensions have often been difficult to resolve, although in many cases local solutions have been found. In some cases, mathematics specialists have shared the teaching load with vocational or other subject specialists. In others, specialist teachers have provided a resource to support and advise other teachers. Overall, however, the Inquiry is clear that there is a continuing serious short-term problem with teaching delivery of AoN. We cannot see an immediate solution. However, longer-term we believe that effective support for integrated delivery and for enhancing the mathematical and mathematics teaching skills of specialists in vocational subjects can and should be provided through the national infrastructure for the support of teaching of mathematics. (See, Chapters 5 and 6.)

4.28 Separate from the issue of teaching delivery, many respondents to the Inquiry are concerned that the mathematical content of AoN is too narrow; in particular, there is concern about what is seen as the superficial approach to the component relating to collecting and interpreting data. The narrowness of the content doubtless reflects the original conception of limiting the mathematics to core numeracy in order not to burden students with unnecessary content. However, the concern has been raised that this may have resulted in the too rigid exclusion of closely related and relevant mathematics that in many cases would help individual students with their vocational specialisms and other studies. This, in turn, is seen as an obstacle to students fully appreciating the relevance of application of number element of key skills to their interests and course of study. The Inquiry notes this widespread concern, but has not had the resource or expertise to make a definitive judgement.

4.29 There has been some concern that some of the requirements of portfolios have made them difficult to complete. Also, there are concerns that the form in which evidence is required may often be too structured and inflexible. This current inflexibility, together with problems of integrated teaching delivery referred to above, is felt to lead in many cases to poor integration of key skills and to encourage stand-alone key skills activities. We note, also, that concern about the external tests for AoN has been voiced by representatives of those involved in delivering the the work-based route. In particular, it has been argued that the tests are too academic. The Inquiry notes that the Skills White Paper measures represent a response to these and other concerns about the key skills external tests. The measures offer support for key skills teaching and learning, more accessible assessment and more equitable funding. The Inquiry notes that the QCA and its regulatory partners have taken these views into account in their recent review. As a result of the review, the key skills assessment arrangements will remain unchanged in England, with a continuing use of both test and portfolio evidence. In Wales, assessment from September 2004 will be based on a portfolio only model. In Northern Ireland, an operational pilot of a portfolio model with a task-based external element will be implemented from September 2004. A further important factor in the appeal and value of key skills qualifications has been, and will continue to be, the attitude of universities. The current position is that some 33 per cent of the total of 45,974 courses on offer in HE for entry in 2003 accepted the key skills tariff points.

4.30 Another concern communicated to the Inquiry is that the AoN qualifications lead to a serious distortion of the way in which qualifications are deemed to be equivalent to each other. AoN can be taken at levels 1-4 in schools, Sixth Form Colleges and in Colleges of Further Education. Level 3 AoN is only a small subset of the of the mathematics provision at the level 2 end of GCSE Mathematics. Similarly, level 2 AoN is only a very small subset of the entirety of mathematics at the level 1 end of GCSE Mathematics. However, the impression has been given that level 2 AoN can be thought of as equivalent to a GCSE 'pass' in Mathematics and that a level 3 AoN can be thought of as mathematical attainment beyond GCSE. Respondents to the Inquiry are

clear that GCSE Mathematics and level 2 AoN are not fully equivalent in mathematical content and should not be thought of as equivalent on this basis. From the perspective of having an unambiguous understanding of mathematics qualifications, we therefore accept that there is a problem in both GCSE and level 2 AoN being defined as level 2 qualifications. In the same way, level 2 AoN is not nearly as mathematically demanding as a level 2 FSMQ. The fact that AoN demands are not appropriate at their stated level of the NQF is seen by a number of respondents as potentially bringing the framework into disrepute. They note that the level 3 AoN qualification contains no mathematics above the equivalent of grade B GCSE, and only one item at that level; they also note that the mathematics of the AoN level 3 qualification corresponds to the bottom end of level 2. This leads to considerable confusion amongst users, who, not unnaturally, assume that all mathematical qualifications at level 3 include mathematical material at the same level. Respondents also views with concern the Universities and Colleges Admissions Services (UCAS) tariff of 20 points for level 3 AoN. This is the same tariff as for grade A performance on a level 3 FSMQ, which does represent genuine mathematics achievement at this level. Decisions on the current allocation of qualifications to levels within the NQF are the statutory responsibility of the regulatory authorities. This prompts the following recommendation.

Recommendation 4.6

The Inquiry recommends that QCA and its regulatory partners undertake a comparative review and make appropriate re-designations as necessary, to ensure that claimed equivalences of levels of mathematics qualifications are well founded.

4.31 In our increasingly technological and information-rich society, mathematical skills are becoming more and more important. Rather than decreasing the need for mathematics, as evidenced in the *Mathematical Skills in the Workplace* report, the rise of information technology has increased the range of mathematics needed to perform competently in the workplace. The majority of respondents are clear that AoN does not deliver the full range of mathematical skills and knowledge that this report shows to be essential in the work-place across many important sectors of the modern economy. The Inquiry accepts this, but, in fairness to the developers, also recognises that AoN was not designed to achieve these ends. However, the fact remains that evidence to the Inquiry from focus groups organised by QCA on behalf of the Inquiry makes clear that AoN is disliked by many students and by many provider institutions and that there is a widespread perception – which the Inquiry reports rather than endorses – that being in possession of an AoN qualification rarely results in candidates having transferable mathematics skills of any worth. Some respondents to the Inquiry have been much more positive about the extent to which FSMQs have the potential to impart worthwhile, transferable mathematical skills. In view of the limited take up thus far of FSMQs, we can again only report, rather than endorse, this perception.

4.32 The Inquiry has also been told that present funding regimes for colleges create greater incentive to provide AoN at the expense of FSMQs. If this really reflects national LSC funding rules rather than local management decisions, this would seem to the Inquiry to be a somewhat perverse incentive. Piecemeal development has led to patchy provision at levels 1 and 2 and we are persuaded that it is unhelpful to consider numeracy and AoN to be distinct from mathematics itself. There is a need for a more coherent and comprehensive approach. Currently, in FE colleges both the provision of AoN and the widespread use of GCSE resits stand in the way of such an approach. Gaps and overlaps in mathematics provision and qualifications at levels 1-3 were reviewed by the QCA in 2002 and the findings made available to the Inquiry. The Inquiry believes that it would now be timely to ask the QCA and its regulatory partners to extend this work into a general review of problems with the delivery, content and assessment of AoN and the availability to students of FSMQs and AS Use of Mathematics, with a view to feeding into work on the design of future 14-19 mathematics pathways. This would also provide an opportunity to explore and promote greater use of ICT in the delivery of future developments of these courses.

Recommendation 4.7

The Inquiry recommends that the QCA and its regulatory partners undertake an immediate review of current problems of delivery, content, assessment and availability of courses at levels 1– 3 provided by FSMQs, AS Use of Mathematics, AoN and Adult Numeracy. The aim of the review should be to identify scope for improvements in and potential rationalisation of this provision, including opportunities for more systematic integration of ICT in teaching and learning, as part of the longer-term design of a new 14–19 pathway structure for mathematics (see, also, Recommendation 4.11).

Concerns relating to GCE Mathematics

4.33 Although GCE has historically been regarded in some quarters as a gold standard, there have been a number of serious concerns for some time. The Dearing Reforms tried to give more rigour to A-level mathematics and tried to demand prerequisite achievement at the upper end of GCSE Mathematics. However, respondents to the Inquiry have overwhelmingly reported that some of the Dearing recommendations, especially those of a more generic nature reflected in the Curriculum 2000 AS plus A2 model, have had very negative consequences for mathematics. The Inquiry is convinced that the serious problems for Mathematics in 2001 and the subsequent two years arose because the curriculum model imposed for all subjects worked to the detriment of mathematics. The numbers of students studying A-level Mathematics decreased within one year by 20 per cent as a direct result of the implementation of Curriculum 2000 and has stayed at this level the year after.

4.34 In the view of the Inquiry, the seriousness of this cannot be underestimated. The numbers continuing with GCE mathematics post-16 provide the supply chains for mathematicians, statisticians, scientists and engineers in higher

education, research and employment. This supply chain is key to the strategy for tackling the problems identified in *SET for Success,* as well as providing an increased supply of future qualified mathematics teachers. It is vital that ways be found to restore the numbers not only to the levels of two years ago, but to increase them significantly. Far too few achieve level 3 qualifications in mathematics in England and Wales.

4.35 Respondents have also wished to challenge the current arrangement whereby GCE mathematics attracts the same UCAS tariff as any other GCE at either AS or A-level. This is seen as unhelpful on two counts. First, there is clear evidence that mathematics does not present a level playing field in terms of attaining grades and a clear perception that mathematics is hard. It is argued that an incentive is needed to counteract this. Secondly, mathematics is unique in providing the key underpinning of so many other disciplines. It is argued that this needs to be formally recognised in order to encourage greater involvement with mathematics post-16. In particular, it is noted that the AEA in Mathematics currently attracts no UCAS points at all thus providing no incentive to enter for the qualification other than for love of the subject itself. We understand that UCAS are currently reviewing this issue.

Recommendation 4.8

The Inquiry recommends that the effects of the introduction of the revised specifications for GCE be closely monitored by the QCA and its regulatory partners as a matter of high priority and that funding be made available to support this. If there is no significant restoration of the numbers entering AS and A2 mathematics within the next two or three years, the Inquiry believes the implications for the supply of post–16 qualified mathematics students in England, Wales and Northern Ireland to be so serious that consideration should be given by the DfES and the relevant devolved authorities to offering incentives for students to follow these courses. One possible form of incentive could take the form of financial incentives to HEIs to include AS or A-level mathematics as a prerequisite for certain degree courses. Another possibility might be to offer financial incentives directly to students following such course in HEIs, possibly through fee waivers or targeted bursaries.

4.36 In addition to these considerable concerns about the organisation of the curriculum and the serious effects of the Curriculum 2000 changes, there are also serious concerns about the frequency of assessment of material in GCE AS and A-level Mathematics. This is felt by many respondents to hinder the development of the learning and understanding of mathematics at this level. It is the consensus view that far too much time is devoted to examinations and preparing for examinations – "teaching to the test" – and that this is at the expense of the understanding of the subject itself. Many identify the problem as the splitting of the subject matter of A-level mathematics into six separately examined modules. This is seen as having the effect of splintering the unity and connectedness of the mathematics to be learned at this level. It is felt that this fragmented presentation makes it virtually impossible to set genuinely thought-provoking examination questions that assess the full range of mathematical skills. It is also felt that the style of short examination papers

results in a race against the clock that adversely affects weaker candidates. We are aware that the criteria for GCE mathematics have just been reviewed and changed, and we appreciate that there is a natural desire for some stability in the system. However, we have received such strong representations on this issue that we nevertheless make the following recommendation.

Recommendation 4.9

The Inquiry recommends that the QCA and its regulatory partners conduct an immediate review of the frequency and style of current GCE assessment, with a view to reducing the time spent on external examinations and preparation for examinations.

4.37 In terms of student choices and the general perception of the subject, AS and A-level Mathematics are the mainstream qualifications available at this level, but do not attract enough students to study some level 3 mathematics in post-compulsory education. Many respondents have commented that the distribution of grades for A-level mathematics presented in Chapter 3 suggests that the more able students entered for A-level mathematics are insufficiently challenged and the least able are frequently overstretched. In the majority of subjects, the distribution of A-level grades is roughly bell-shaped with relatively few candidates at the extreme grades A or E. However, historically in A-level mathematics, grade A is the modal grade and the distribution of grades is virtually a straight line down to the lower grades. In terms of students' and teachers' perception of the subject, many respondents believe that, for other than the mathematically clearly very able students, there is a tendency for schools to see choosing mathematics A-level as higher risk in terms of outcome than many other disciplines. To add to this perception, it is clear that many weak students do not complete the course in GCE Mathematics and many of those who do complete are not classified on their examination performance. At the other end of the scale, A-level Mathematics is felt not to discriminate sufficiently amongst those awarded the highest grades in the subject. University mathematics departments have made clear to the Inquiry that they are often unsure of the real value of a grade A pass at A-level.

4.38 Following the revision of the GCE criteria for Mathematics in response to the Curriculum 2000 debacle, many respondents are in no doubt that A-level Mathematics has been made easier for the very best candidates. In terms of the potentially most able mathematics students, the Inquiry believes that far too few able candidates are entered for AS or A-level Further Mathematics because their schools or colleges do not have sufficient resources to provide these courses. The same appears to be the case for the AEA in Mathematics, although the original intention of AEAs was that they would not require additional teaching. There are many students who would benefit from studying Further Mathematics or the AEA in Mathematics, but who are currently denied the opportunity. Candidates who have studied Further Mathematics or the AEA in Mathematics are likely to be much more confident with the inner workings of the subject. University departments in all subjects identified as vulnerable in the Roberts *SET for Success* report would benefit

greatly if more candidates were qualified at this level. Further Mathematics and the Advanced Extension Award in Mathematics (redesigned if necessary) are the courses that could and should provide the extra stimulation for the top fifteen per cent or so of the A-level mathematics cohort of students and the Inquiry is deeply concerned that the current system is not able to make adequate provision for this important cohort.

Recommendation 4.10

The Inquiry recommends that there should be an immediate review by the DfES, LSC and the relevant devolved authorities of measures that could be taken to support and encourage current GCE course provision for the most able mathematics students. In particular, we believe there is a need to ensure that there are no funding disincentives in schools and colleges for providing access to Further Mathematics and the Advanced Extension Award in Mathematics We also believe that consideration should be given employing the same incentives as suggested in Recommendation 4.8.

4.39 The higher education sector and the learned and professional societies have made clear to the Inquiry their serious concerns about the interface and transition between A-level mathematics and university courses heavily dependent on mathematics, such as degree courses in mathematics and statistics, or in physics, electronics, engineering and economics. In the short-term, the Inquiry believes that Higher Education has little option but to accommodate to the students emerging from the current GCE process. Many are, of course, already doing this through, for example, the provision of first year enhancement courses. Longer term, we would hope that there would be significant changes resulting from Recommendations 4.5 and 4.10 and the future re-design of 14-19 pathways. More generally, we would hope that there would be significant positive consequences of the greater interaction of HE with schools and colleges proposed in Chapters 5 and 6.

Concerns with Adult Numeracy

4.40 There is some concern that employers are not yet fully recognising the new Adult Numeracy qualifications. It has also been impressed on the Inquiry that adults want to learn mathematics for a variety of reasons, often not concerned with gaining qualifications. Respondents to the Inquiry have expressed some concern that, at present, test questions tend to reflect traditional "school mathematics", in the sense of testing mathematical procedures posed as contextualised problems with multiple choice answers. It is felt that these tests do not necessarily fit well with the idea of individual adult learner plans and properly exploit adult learners' contexts. It is also felt that the present tests at levels 1 and 2 disadvantage ESOL learners and those with dyslexia or dyscalculia, or low levels of literacy. Many respondents feel that:

- numeracy capabilities have generally been undervalued, under-developed and under-resourced;
- support and learning programmes have been few in number and poor in quality;

- materials and qualifications have been child rather than adult centred;
- teachers have been inadequately trained and in many cases specialist numeracy teachers have been replaced by literacy teachers, often working beyond their own levels of mathematical competence;
- performance and alignment with GSCE Mathematics and National Curriculum levels is highlighting inadequacies in the appropriateness of these programmes to prepare young people for adult life in general and the workplace in particular.

4.41 Respondents to the Inquiry are clear that the adult numeracy strategy is a challenging and demanding one for teachers and learners alike. Progress could easily be undermined by:

- uncertainties surrounding the teaching and assessment of mathematics in general and in particular the future of GCSE Mathematics and key skills;
- the limited pool of competent and confident teachers of mathematics and numeracy;
- the lack of employer engagement in raising the skill base of new employees.

In Chapter 6, we suggest that the national infrastructure for the support of the teaching of mathematics include specific support for teachers of adult numeracy.

Possible Future Pathway Models for Mathematics 14-19

4.42 In conjunction with the Advisory Committee on Mathematics Education (ACME), the Inquiry ran a series of workshops attended by a wide range of stakeholders concerned with possible future mathematics 14-19 pathways. These workshops considered the ways in which mathematics is embedded in educational pathways in other countries and tried to stimulate initial constructive thinking about an appropriate future structure for 14-19 mathematics pathways in England.

4.43 As a result of these and other extensive consultations, the Inquiry believes that the following principles should guide the construction of a future pathways approach to mathematics provision 14-19 in the UK:

- all learners should be provided with a positive experience of learning mathematics and should be encouraged to realise their full potential;
- it should be recognised that not all learners learn in the same manner, or at the same speed, or respond positively to the same styles of assessment;

- all pathways should include progression up the qualifications ladder, with each pathway having clearly defined destinations into training, employment, further or higher education;
- there should be flexibility within the overall structure and maximal opportunity to make transitions among the pathways; it will be important to avoid regression to old style O-level versus CSE, or any other now defunct rigid qualifications divide;
- new approaches to pedagogy and, in particular, the use of ICT should be adopted to ensure that all students acquire an appreciation of the power and applicability of mathematics;
- the uses and applications of mathematics, including working with ICT, should be made central to the mathematics curriculum wherever appropriate, but without compromising appropriate levels of abstraction and generalisation.

4.44 In addition to requiring adherence to these principles, respondents to the Inquiry are clear that in developing pathways it will be essential to be clear about the positioning in the pathways of the following key mathematical developments:

- working with the rules of number in a range of contexts, including use of measures;
- developing multiplicative and proportional reasoning;
- developing the geometry of shape and space and geometrical reasoning;
- developing and using algebra in a range of contexts, including 2– and 3–dimensional geometry, the use of variables in formulae and in co-ordinate geometry;
- developing the calculus of functions and the concept of rate of change, and related applications;
- developing ideas of proof and logic;
- developing the mathematics of uncertainty.

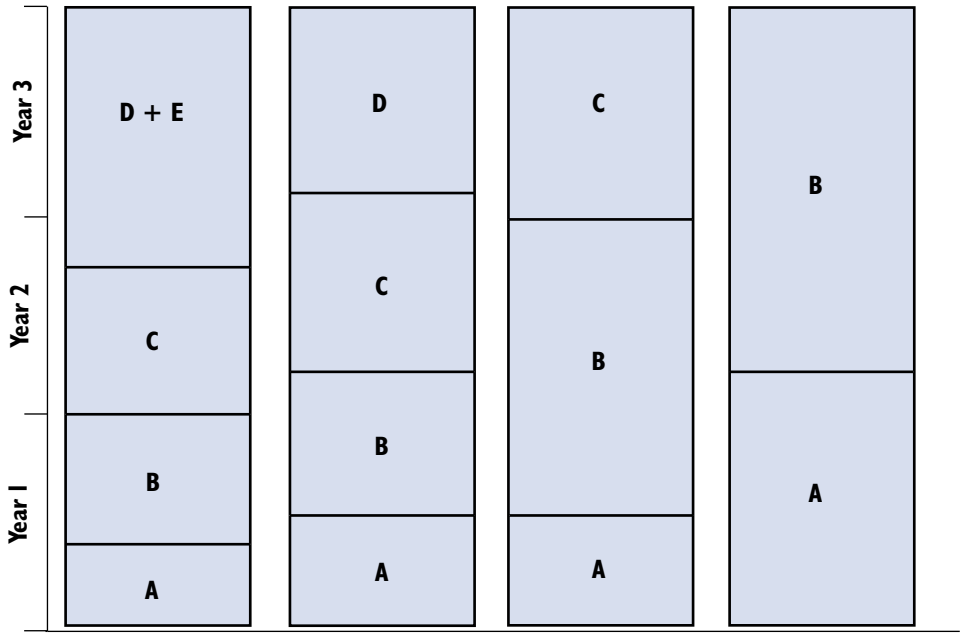
4.45 Subsequent discussion will use 'pathway' to describe progression in mathematics, with the understanding that the mathematics is merely a component, along with other specialist and optional components, of the larger curriculum pathways envisaged by the 14–19 Working Group. Each pathway should be clear in what it offers as a core of mathematics and how it is applied, and it should also be an adequate preparation for the next stage of progression. Much work will be needed to develop the Tomlinson proposals into a coherent curriculum and assessment regime. The Inquiry has had neither the time nor the resource to attempt to begin to do this for the mathematics component of such a curriculum and assessment regime.

4.46 The approach we have adopted is therefore the following. We outline, on the basis of suggestions made during the consultation process, schematic versions of some of the different models and approaches put to us for consideration. These indicate, in broad-brush terms, possible future pathways that are guided by the principles summarised above and designed to remedy the perceived defects of the current structure detailed in this chapter. Each of these models and approaches has its supporters among one or other significant grouping of the mathematics community.

4.47 It would be inappropriate for the Inquiry to express a clear preference for one model or approach rather than another, although we are inclined to believe that Figure 4.2 below will provide something close to the desired pathway structure for mathematics. We believe that intensive curriculum development, trialling, feedback and modification will be essential to ensure that the new structure is workable and better than the system it is designed to replace. The construction of pathways depends on both curriculum and assessment considerations and future political imperatives.

4.48 A system based primarily on equity might seek to opt for a single pathway, at least to age 16 and possibly to age 19. In such a model, all students study precisely the same mathematics curriculum, but progress at different rates. Students are then credited for the mastery of the stage they have reached by the chosen age at which the pathway ends. Sweden has adopted essentially this approach. In the Swedish model (see Figure 4.1, which we present schematically, without discussion of the programme content) the mathematics curriculum can be thought of as blocks A,B,C,D,E fitting end to end and forming a continuum up to the standard required for entry to study mathematics at university (D, or D+E). Students learn at different rates, and are certified as successfully completing one or more of the fixed number of partitioned subsets A,B,C and D that make up the continuum. Only relatively few students master the whole curriculum. The majority leave secondary education having achieved a number of 'stepping stone' credits along the mathematical pathway. We note that support for this approach runs counter to the support the Inquiry has received for the extension rather than acceleration approach discussed earlier (see paragraph 4.21 and Recommendation 4.5).

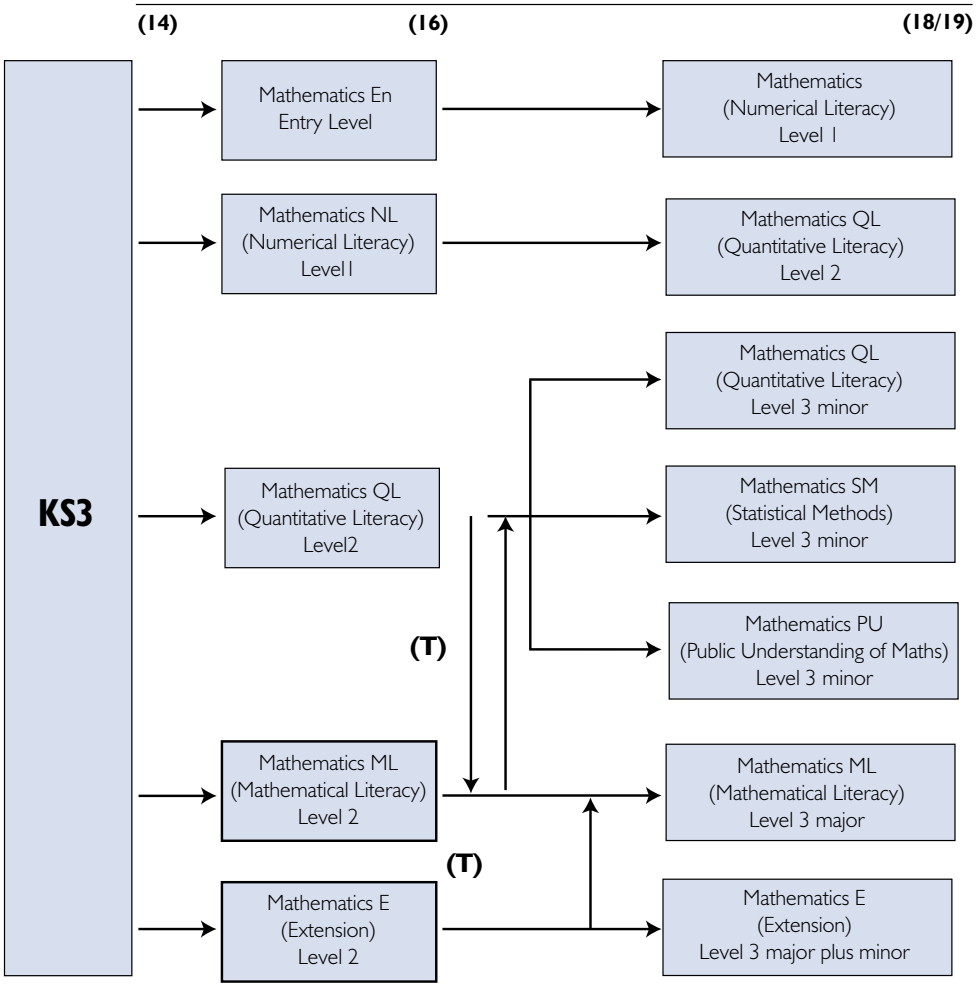
Figure 4.I: The Swedish approach to pathways



4.49 In contrast to the above schematic, Figure 4.2 presents a more detailed possible model of 14–19 pathways. This starts from the assumption that the present Key Stage 3 Programme of Study should form the common basis for all students, prior to the age of 14. It then maps out a number of possible routes through 14–19, five potential pathways from age 14, increasing to seven from age 16. Each pathway varies in content, difficulty and abstraction and is designed to enable students to follow the one best suited to their needs. The model emphasises relative speeds of progression and the nature of the levels of the mathematics components on different pathways. The model allows for movement between the pathways.

4.50 In Key Stages 4 and post–16, all courses shown in the figure have the title "Mathematics" followed by a code. The names associated with the codes are descriptive only. The model emphasises relative speeds of progression and the nature of the levels of the mathematics components along the different pathways. Mathematics in levels 1 and 2 of this qualifications framework would be drawn from the Key Stage 4 PoS, but with not all students expected to make equal progress. The way the intended curriculum is delivered and assessed might differ from pathway to pathway, with more emphasis on applications in some parts and more emphasis on abstract reasoning in others. In this model, students learn to tackle problems appropriate to their current level of mathematical understanding and motivation. The pathways are designed so that individual students would be able to maintain interest in the subject and to make steady and continuous progress as they move to age 18 or 19. Each student should be on a pathway that is accessible and provides meaningful challenges to the student at each stage.

Figure 4.2: A possible 14-19 pathways model



4.51 At level 3, students would elect to do mathematics as a minor or as a major subject, and perhaps some additional mathematics beyond that. Mathematical techniques, applications and mathematical reasoning would be developed through a continuum which allows some variation in the applications encountered and the way mathematics is used to model real problems. The aim would be for an increasing number of students to progress to both levels 2 and 3 by age 19. A small percentage of students might only progress to level 1.

4.52 The degree of mathematical content, difficulty and abstraction increases as one moves down the figure and along each pathway from left to right. All courses from level 1 upwards would develop calculation in a variety of contexts, and, as appropriate, would introduce aspects of algebra, geometry and application of mathematics in a varying mix for different student groups. Entry level would focus mainly on numbers and measures and simple applications. The Extension courses would be for those who absorb mathematics easily and seek a greater understanding of the subject. Students on these courses would study mathematics at greater depth and at greater levels of abstraction, but based on the same curriculum content at a given level. Extension courses would concentrate more on reasoning, proof, chains

of logical reasoning, multi-step problem solving and a range of harder and sometimes open-ended problems. An example of an extension curriculum at level 2 is set out in *Making Better Use of Mathematical Talent*, published by the Mathematical Association, 2003.

4.53 Mathematics E at level 3 would be the nearest equivalent to the current GCE Further Mathematics and the AEA in Mathematics, although it would be a new hybrid with its own distinctive features. There was a very strong positive response to the Inquiry in favour of providing mathematics courses at this level. Mathematical Literacy at levels 2 and 3 would be the nearest equivalent to the higher tier end of GCSE Mathematics (KS4 Higher) and A-level Mathematics, respectively. These would concentrate on the study of a wide range of mathematical ideas, techniques and application, but not developing rigour or harder problem solving to the same extent as on the extension pathway. At level 2, both Mathematics ML and Mathematics E would be worth a double award in the qualifications framework (in line with Recommendation 4.2). Quantitative Literacy level 2 would be the nearest equivalent to working at around the current C grade level of GCSE Mathematics (KS4 Foundation), but with a greatly different emphasis. The course would also encompass level 1 as a fall back position.

4.54 Application of mathematics (involving number and algebra, measures and geometry) to analyse substantial real world contexts would be stressed, and appropriate ICT would be used to analyse realistic data and fit models. Students would also learn about multiplicative and proportional reasoning. They would also learn to communicate mathematical ideas to others. QL level 3 would develop this approach further, building on more mathematical content that goes beyond that currently in the Key Stage 4 Programme of Study. All QL courses would develop the philosophy and pedagogy pioneered by Free Standing Mathematics Qualifications and AS Use of Mathematics. It would be important here to make full use of the power of ICT to analyse real data using appropriate mathematical models. This is the sort of course designated as 'Techno-Mathematics' by the authors of the report *Mathematical Skills in the Workplace*.

4.55 Numerical Literacy courses would only go as far as level 1. They would aim to provide familiarity with the most basic ideas in number, measures, algebra and geometry and how these are used in elementary application and in making geometrical models and patterns. They would play the role of a stepping-stone to mathematical understanding that might begin to unlock doors in training or employment, and in further and higher education. At level 3, a mathematics course is proposed for all students progressing to level 3 from level 2. This would follow the pattern of the French Baccalaureate, in which there is mathematics provision on all the designated academic routes (the sciences, the social sciences and the humanities), and also on the vocational and technological routes. The possible course in Public Understanding of Mathematics (possibly to include Science and Technology) could provide a form of continuing exposure to mathematics for those with academic aspirations that do not include technical use of mathematics, but

for whom society would wish – given that many will have influential and opinion forming roles in their future careers – to understand the role of mathematical ideas in human culture, the development of science and technology and as an instrument for social and economic change.

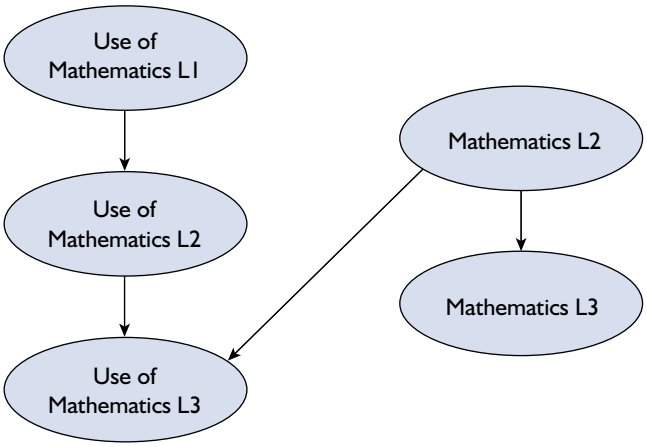
4.56 The level 3 Statistical Methods course would be akin to current AS Statistics and would be an appropriate pre-requisite for those intending to progress to courses in HE which are heavily statistical in nature. Many respondents to the Inquiry have indicated that such a course would fill an existing serious gap in the qualifications framework. The symbol (T) in figure 4.2 denotes that some transition material would have to be mastered to make the indicated transition from one pathway to another. Other transitions might be possible. Students might wish to make a transition after starting on a particular pathway, but then would have to realise that there could be a cost to making such a transition and that extra effort might be required to make the transition successfully.

4.57 We do not believe it would be desirable to indicate rigidly pre-determined destinations for each of the pathways. However, in very broad-brush terms, with considerable cross-over, we would see the following kinds of destinations as corresponding to the pathways as we move down the figure:

- Low skilled employment, part-time FE (Foundation Modern Apprentice);
- Moderate to high skilled employment, part-time FE (Advanced Modern Apprentice);
- High skilled employment; ITT; FE/HE (including for example: technology, engineering, science, business studies, economics);
- High skilled employment; FE/HE (including for example: biological and social sciences, business studies);
- High skilled employment; FE/HE (including for example: arts, humanities, law);
- High skilled employment; HE (including for example: mathematics, physical sciences, electronics, computer science, engineering, medicine, economics);
- High skilled employment; HE (all highly mathematical subjects and research and development in these subjects).

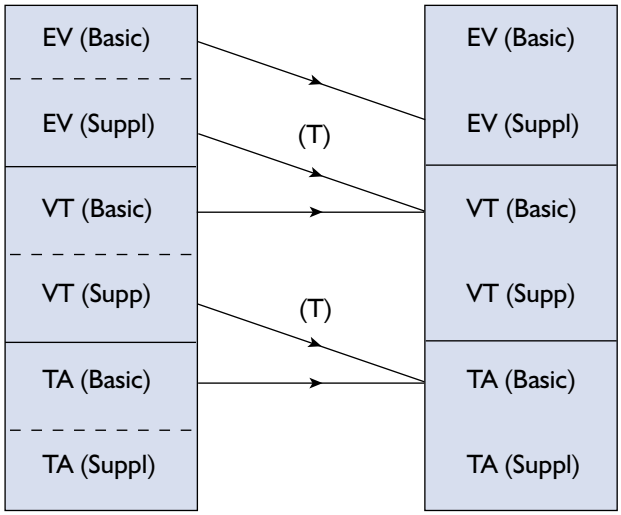
4.58 There are a number of possible variants of the model. One of is shown in highly simplified schematic form in Figure 4.3, based around two fundamental courses *Mathematics* and *Use of Mathematics*. The key idea is that there is scope to develop both a level 1 and a level 2 'Use of Mathematics' course to complement the level 3 AS 'Use of Mathematics' that exists at present. Starting from these, Figure 4.3 then shows the following common pathways: Mathematics L2 to Mathematics L3 (minor, major and beyond) or to Use of Mathematics L3; (Use of Mathematics L1 to) Use of Mathematics L2 to Use of Mathematics L3.

Figure 4.3: A simplified model



4.59 A fourth possibility is to develop two or three distinct pathways from a notionally accepted common curriculum up to age 14. A version of this fourth model is shown below in Figure 4.4. This proposes three distinct programmes from age 14. These are referred to here descriptively as Entry-Vocational (EV), Vocational-Technical (VT) and Technical-Academic (TA). The shared letters indicate the desirability of allowing for subsequent movement; they do not necessarily indicate identical content. All the courses would progress from a common core of mathematics at Key Stage 3, which would act as an effective foundation for all students. However, those students who do not complete the whole of Key Stage 3 by age 14 would not be obliged to continue repeating the same material until it is mastered.

Figure 4.4: An alternative pathways model



4.60 None of the models or approaches presented here has any current validity or preferred status for the Inquiry. They are simply intended to show how actual mathematical pathways could be constructed in line with the principles enunciated earlier and with the aim of overcoming the perceived deficiencies of the current structure. We indicated earlier that a great deal of work will be needed to develop such ideas into a coherent curriculum and assessment regime that will provide appropriate mathematics pathways within the general structure that emerges from the work of the 14–19 Working Group. We understand that the final 14–19 Working Group proposals will be available in Autumn 2004. The Inquiry therefore does not believe it would make sense to try to select a preferred set of mathematics pathways and to work out every detail of the curriculum and assessment for such pathways ahead of understanding the Government's response to the 14–19 Working Group proposals.

4.61 However, whatever emerges as a new 14–19 structure, the Inquiry is clear that we shall need to develop some or all of the elements and components of the models discussed above and to begin to address the major deficiencies identified in the current framework. We believe, therefore, that it is vital to begin work immediately on detailed further curriculum and assessment development based around these pathways models. The aim should be to carry out a cycle of trialling, feedback and modification of two or three variants of these models in time to inform a future decision on the preferred way forward for mathematics in the context of the overall 14–19 structure. We would suggest that this work should be completed by the end of 2007.

4.62 We also firmly believe that in this process of development it will be vitally important to involve as wide a range of the mathematics community as possible. We have been struck in the course of this Inquiry by the energy and commitment of the mathematics community in responding to issues raised. In particular, the outline models we have presented have emerged from significant groupings of the community. All this informs the following major recommendation.

Recommendation 4.11

The Inquiry recommends that funding be provided to the QCA and its regulatory partners to commission, through an open bidding process, up to three curriculum and assessment development studies of variants of these pathway models and approaches, including trialling, feedback and modification and an assessment of the workload implications. These studies should take on board developments arising from Recommendations 4.4, 4.5 and 4.7. The aim of this exercise will be to inform the selection of a preferred pathway model to form part of the reformed 14–19 structure in England and possible parallel developments in Wales and Northern Ireland. Given the importance of ensuring the widest possible involvement and commitment of the mathematics community to the outcome, the Inquiry recommends that the regulatory authorities work in partnership with ACME and mathematics community representatives from Wales and Northern Ireland, and that the DfES and relevant devolved authorities provide appropriate funding to support this.

5 SUPPORT FOR THE TEACHING AND LEARNING OF MATHEMATICS

Continuing Professional Development (CPD) for teachers of mathematics

5.1 The Government has recognized in setting up this Inquiry that there is an urgent need to improve the mathematical skills of the general population. There are concerns about both numbers and quality and, in particular:

- the relatively low numbers of school pupils continuing mathematics post-16 through to the age of 19 and beyond;
- a declining trend in the number of students obtaining degrees in Higher Education courses in disciplines with substantial mathematical content; and
- the under-supply of appropriately qualified teachers of mathematics, which is exacerbated by the high demand in other sectors of the economy for the skills of mathematically qualified graduates.

5.2 In previous chapters of this report, we have examined ways in which the future supply of appropriately qualified mathematics teachers entering the profession might be increased and ways in which the numbers of pupils continuing with mathematics post-16 might be increased.

5.3 We now turn to the issue of support for staff currently teaching mathematics in schools and colleges. We consider possible forms of support to update and enhance subject knowledge and pedagogy and to sustain enthusiasm and commitment. Respondents to the Inquiry have noted with concern that, in contrast to many other professions, there is not a strong tradition of Continuing Professional Development (CPD) among teachers in England, Northern Ireland and Wales.

5.4 The situation is somewhat different in Scotland, where local authorities have a stronger tradition of delivering CPD for teachers and CPD responsibilities and entitlements have been incorporated into a formal agreement, *A Teaching Profession for the 21st Century*, which followed the report of the McCrone Inquiry (January 2001) into professional conditions of service for teachers in Scotland.

5.5 The agreement in Scotland included the following:

- teachers shall have an ongoing commitment to maintain their professional expertise through an agreed programme of CPD;

- an additional contractual 35 hours of CPD per annum will be introduced as a maximum for all teachers, which shall consist of an appropriate balance of personal professional development, attendance at nationally accredited courses, small scale school based activities or other CPD activity; this balance will be based on an assessment of individual need taking account of school, local and national priorities and shall be carried out at an appropriate time and place;
- every teacher will have an annual CPD plan agreed with her/his immediate manager and every teacher will be required to maintain an individual CPD record;
- it was recognized that a framework for professional development will take some time to deliver and therefore teachers would work towards but not be expected to meet the full commitment until August 2003;
- the aims of the agreement are to enhance opportunities available to all teachers and minimize teachers undertaking work that is a not directly related to their key role in teaching and learning; it was also agreed that CPD should be a condition of service, and every teacher should have a commitment to it;
- local authorities will undertake to review their provision within the arrangements for the development of a national register of approved CPD providers, and consideration should be given to the role of a national agency such as Learn Direct Scotland in this regard: not all CPD will necessarily be accredited, but there should be maximum opportunity for accreditation.

5.6 In view of these recent developments in Scotland, most of what follows in this chapter – with some exceptions, which we shall clearly flag – should be taken to refer to the situation in England, Northern Ireland and Wales.

5.7 The clear message to the Inquiry from many sources is that there is a need for a radical change in culture regarding CPD in the teaching profession in England, Northern Ireland and Wales. Ideally, it is felt that every teacher should have a personal professional development plan, to which both teacher and school commit in writing, placing obligation for ongoing CPD on them both, as in Scotland. Indeed, the McCrone agreement is seen by many to be a minimal model to which the rest of the UK should aspire.

5.8 The Inquiry believes that CPD is important for all teachers in all subjects. We therefore welcome all recent moves in the UK toward a strategy for more systematic CPD provision. In particular, we welcome the General Teaching Council's (GTC) introduction of the Teachers' Professional Learning Framework (TPLF) in England, which offers a map of professional development experiences. Teachers will use the TPLF to plan their individual development needs. Headteachers, CPD co-coordinators, Local Education Authority (LEA) advisers and others will use the TPLF to develop CPD policy strategy and

facilitate networks of professional learning. The General Teaching Council for Wales (GTCW) is considering a similar initiative for teachers in Wales, as is the recently established General Teaching Council for Northern Ireland (GTC(NI)).

5.9 In Wales, some funding for CPD is provided directly through the GTCW. General funding for CPD is included as an element within the "Grants for Education, Support and Training" (GEST) programme, which is funded 60% directly by the Assembly and 40% by the Welsh LEAs from funds included in the overall revenue settlement. It is intended that CPD be explicitly linked to the newly introduced performance management arrangements in Wales, which will identify individual teacher's development needs. Schools will set their own priorities within the scope of the scheme. Currently, there is no requirement for subject specific CPD and no money is ring-fenced for individual subjects. The Inquiry understands that funds could be used for subject specific CPD, but that the Welsh Assembly Government would not wish to be centrally prescriptive about priorities.

5.10 In Northern Ireland, statutory responsibility for CPD for teachers lies with the Education and Library Boards (ELBs). Each ELB has a Curriculum Advisory and Support Service (CASS), with teams of officers, including those for mathematics, who provide support to schools in both subject specific and more thematic whole-school areas. The CCEA also has a role in relation to the provision of support materials for teachers in Northern Ireland. There is now in place in Northern Ireland a fully integrated programme of initial teacher education, induction and early professional development, as well as the Professional Qualification for Headship programme. Further developments are under consideration by the GTC(NI).

5.11 We have already noted the different situation regarding CPD entitlement and provision in Scotland.

The need for subject-specific CPD

5.12 The Inquiry welcomes increasing evidence of greater emphasis on and commitment to CPD for teachers throughout the UK. However, we note that most of these developments are not specifically aimed at systematic and sustained subject specific CPD.

5.13 A teacher's overall competence involves three separate elements: subject matter knowledge and confidence, general pedagogical skills and subject specific pedagogical skills Overwhelmingly, concerns expressed to the Inquiry about the current overall state of mathematics teaching in schools and colleges in England have focused on subject matter knowledge and subject specific pedagogy. The Inquiry shares these concerns.

5.14 Separate from recent developments in support of generic CPD for teachers, the Inquiry therefore believes that a large-scale programme of subject specific CPD for teachers of mathematics in England, Northern Ireland and Wales is an urgent priority in its own right. This message has been strongly reinforced in relation to teachers of mathematics in England by the December 2002 report, *Continuing Professional Development for Teachers of Mathematics*, from the Advisory Committee on Mathematics Education (ACME PR/01), which we shall discuss in more detail later in this chapter.

5.15 We have not received the same unequivocal message in relation to the situation in Northern Ireland and Wales. However, responses to the Inquiry from Northern Ireland indicate clear needs for both subject matter and pedagogy CPD. In particular, teachers in Northern Ireland expressed the view that more mathematics subject specific CPD would be desirable. We have also been informed of the view of the ACCAC that issues relating to teachers of mathematics are seen in Wales as the key to raising standards in mathematics. We believe therefore that much of the following general discussion of the situation in England will be found to be relevant to Northern Ireland and Wales.

5.16 The ACME report concluded that the most effective way to provide support and raise the quality of mathematical provision in schools in England would be to expand CPD substantially for teachers of mathematics throughout the system.

5.17 Pre-14, a start on this has already been made in England through the National Numeracy Strategy in primary schools, and the mathematics strand of the Key Stage 3 Strategy for 11-14 year olds in secondary schools. Although formally outside the remit of this Post-14 Inquiry, we shall consider the work of these strategies later in more detail in paragraphs 6.4-15.

5.18 In Northern Ireland, the Northern Ireland Numeracy Strategy (NINS) has raised the profile of CPD for teachers of mathematics. The NINS is focusing on three inter-related strands of support, provided by CASS, for primary and post-primary teachers of mathematics: leadership and management, learning and teaching and the use of ICT. It has provided targeted funding for teachers of mathematics (including all primary school teachers), facilitated closer working among the five ELBs and sought to provide a consistent message on the development and support of mathematics across the different phases of compulsory schooling. All teachers of mathematics are entitled to two days of professional development, typically supported by in-school development work. Other elements of the strategy include support for numeracy co-ordinators and heads of mathematics departments.

5.19 Respondents to the Inquiry overwhelmingly endorse the general analysis set out in the ACME report and support the report's conclusions regarding the fundamental need for a substantial increase in the provision of appropriate CPD for teachers of mathematics. The Inquiry also strongly supports the broad thrust of the recommendations set out in the ACME report. Chapter 2 of this

Post-14 Mathematics Inquiry report has discussed the urgent need to address the problem of recruitment of sufficient numbers of suitably qualified mathematics teachers. The ACME report makes clear that there is also an urgent need to provide infrastructure to support the retention and enhancement of existing teachers of mathematics in schools and colleges.

5.20 The ACME report recommendations provide the underpinning of the Inquiry's own recommendations later in this chapter for the establishment of a national support infrastructure for teachers of mathematics. We therefore summarize the key elements of the ACME report in some detail in the following section.

The ACME report

5.21 The ACME report is clear that programmes of CPD in mathematics should recognize the need for the broadening and deepening of mathematical knowledge, as well as of subject specific pedagogy. The report is also clear that such CPD programmes are needed both for teachers of mathematics with strong mathematics qualifications and for those with less strong qualifications, the latter including teachers who have been recruited from other subjects to teach some mathematics.

5.22 To improve retention in the profession, there is a need to revive and sustain the enthusiasm of existing qualified teachers of mathematics, as well as a need to support and develop them throughout their teaching careers. In addition, it is felt by many that a programme of CPD aimed at qualified mathematics teachers might encourage currently inactive mathematics teachers to return to the profession. Overall, in addition to retaining and attracting greater numbers of mathematics teachers, the belief is that a successful CPD programme would lead to a more motivated and enthusiastic teaching force in mathematics, with improved subject matter and subject related pedagogical expertise. The report is clear that there is a need for CPD for teachers of mathematics at all stages of their careers, whatever their knowledge and experience.

5.23 The report recognises and the Inquiry accepts that it is not possible for ITT to provide future teachers of mathematics with all they should know about the subject they will teach, how pupils learn it or how to teach it effectively. There is therefore a need for mathematics specific CPD, which is available from the beginning of their careers for all Newly Qualified Teachers (NQTs) of mathematics.

5.24 The technical nature of mathematics and the subtle interconnections of different elements of the curriculum can pose problems for teachers whose understanding of the subject is partial and limited. There is therefore a particular requirement for CPD for those teachers who teach mathematics, but who are not well-qualified or experienced in terms of mathematics background. This could relate to both newly qualified mathematics teachers and to experienced teachers who were not specifically trained as mathematics teachers.

5.25 It is seen as equally important for the health of the profession that experienced and well-qualified mathematics teachers are given the opportunity to refresh their skills and to renew their enthusiasm for the subject. Teachers of mathematics need not only to deliver curricula, but also to adapt their teaching methods and style to the changing needs of pupils. They also have to engage with new materials and advances in technology, and to learn from advances in research on pupil learning and on teaching practice in mathematics.

5.26 School and college mathematics does not remain static. Content, applications and assessment evolve. In addition, changes in technology impact both on the subject matter and on possible modes of teaching and learning. The last 30 years have seen major curriculum changes as a result of advances in technology and pedagogy, as well as an evolving perception of what is important in the subject. This evolution and change is particularly marked in the discipline of mathematics. In recent years, this has resulted in the introduction of significantly more data handling, statistics, and investigational work. There is therefore also an ongoing need for CPD for more experienced mathematics teachers. Indeed, many respondents to the Inquiry have emphasized that a mathematics teacher's education needs to be seen as a career-long process.

5.27 However, until now, apart from the work of the Numeracy and Key Stage 3 Strategies in England and the NINS in Northern Ireland, there has been very little properly resourced support for teachers of mathematics to meet this need. This is consistent with a culture in which teachers in England and Northern Ireland have not seen professional development in their subject as a right or an obligation and, until recently, the employing authorities have not seen lifelong CPD as a priority.

5.28 The Inquiry believes that teachers of mathematics in schools and colleges in England, Northern Ireland and Wales should have an expectation and a responsibility to engage in CPD throughout their working careers, together with an entitlement to time and resources, including funding, alongside a system of accountability and rewards. Current provision for teachers of mathematics in secondary schools and Sixth Form Colleges is clearly inadequate.

5.29 Respondents to the Inquiry have suggested that provision for teachers of mathematics in FE Colleges has been even worse. We are encouraged therefore by the joint work currently being undertaken by the DfES and the LSC aimed at improving classroom practice and promoting active learning in mathematics in FE. An important central element of this work is to enable FE teachers to develop and reflect on their practice with specialist support.

5.30 The inquiry is convinced of the need for a radical culture change in relation to subject specific CPD for all teachers of mathematics. It has been suggested to us that such a culture change is required for all teachers throughout the educational system. However, this takes us well beyond the remit of this Inquiry. Given the terms of reference of the Inquiry, the recommendation that follows therefore refers only to teachers of mathematics. We note, however, that a similar message is conveyed in Recommendation 2.6 of the *SET for Success* report.

Recommendation 5.1

The Inquiry recommends to the DfES and the LSC, and the devolved authority in Northern Ireland, that formal responsibility for and entitlement to fully funded CPD be introduced as soon as possible into the professional conditions of service for teachers of mathematics in schools and colleges in England, Wales and Northern Ireland. In the light of what we perceive to be far greater problems with the teaching of mathematics in England and Wales as compared with Scotland, the Inquiry further recommends that the number of contractual hours of CPD in such formal entitlement in England and Wales be significantly greater than the provision made in the agreement *A Teaching Profession for the 21st Century in Scotland*.

5.31 The ACME report envisages that it may be necessary to encourage teachers of mathematics to engage in CPD, and to reward in some way those who do so – for example by salary increments on completion of accredited components of CPD. The report also suggests that building up a CPD portfolio should become an important part of career progression, and the key to higher salaries and promotion. The Inquiry fully endorses this conclusion.

5.32 In relation to the problem of mathematics teacher supply, many respondents have noted that the obvious economic market solution is to provide higher salaries and more attractive career paths for teachers in shortage subjects. The Inquiry is sympathetic to this argument, but some respondents are concerned about the threats that this might pose to collegial working within schools and colleges. We remain convinced that the issue of differential salaries will ultimately have to be faced. However, we see no sign of this happening in the immediate future and would therefore not wish to pursue this at the expense of achieving similar practical ends more quickly by other means in the context of teachers of mathematics. We therefore make the following recommendation, which echoes Recommendation 2.5 of *SET for Success* (a recommendation made in relation to science teachers in general).

Recommendation 5.2

The Inquiry recommends to the DfES and the LSC that additional remuneration be linked to mathematics teachers' successful completion of accredited CPD activities and opportunities, thereby rewarding those teachers of mathematics who make particular efforts to improve further their subject knowledge and teaching effectiveness.

CPD content and delivery

5.33 The ACME report and many respondents have provided the Inquiry with a wealth of detailed analysis of issues relating to the content and delivery of CPD. We summarize in what follows many of the key issues raised.

5.34 A point emphasized to us over and over again is that it is essential for teachers of mathematics to have sufficient subject knowledge to challenge and develop the full range of the pupils they teach. Broadening and deepening mathematical knowledge and understanding are essential. Teachers should also be encouraged to have greater awareness of different representations and links within mathematics, as well as awareness of links to other subjects where mathematics plays a role.

5.35 For teachers of mathematics, an important part of broadening their knowledge of subject specific pedagogy is appreciating how pupils learn mathematics, the role of questioning and response, and the potential obstacles to learning that students are likely to face. Teachers also need to become increasingly aware of key ideas and new approaches to promoting mathematical reasoning in ways appropriate to a diverse range of students with differing abilities and motivations.

5.36 Teachers should also have the opportunity to reflect upon different approaches to delivering the mathematics curriculum. This should include how it is structured in terms of progression within each separate topic, the links between topics, and the way topics are introduced and revisited in different contexts. Many have emphasized the need for a shift of emphasis towards the processes of "doing mathematics" and away from "learning outcomes". Experts also cite the importance and value of formative assessment as an aid to future learning and understanding.

5.37 Professional development needs to be differentiated according to the diverse needs of teachers of mathematics. Individual teachers have different combinations of pedagogical skills, mathematical knowledge and experience of teaching. For this reason, subject specific CPD provision should be sufficiently flexible to respond to the individual needs of teachers and enable teachers to identify how these needs can best be met. A range of provision must therefore be available at different stages of teachers' careers and at different points in their mathematical development.

5.38 The ACME report and respondents to the Inquiry have identified distinct categories of teachers of mathematics with potentially differing CPD needs, while recognizing that within each of these categories there will, of course, be considerable variations in individual teachers' backgrounds, goals and needs:

- primary school mathematics co-coordinators;
- primary schoolteachers generally;
- secondary school heads of mathematics or aspiring heads of mathematics;

- secondary school specialist mathematics teachers;
- secondary school non-specialist mathematics teachers, defined as those teaching mathematics whose main subject specialism is not mathematics or a closely aligned discipline; and
- FE lecturers in mathematics and numeracy skills;
- FE heads of mathematics or curriculum coordinators, or those aspiring to these roles;
- those involved in teaching adult numeracy.

5.39 In addition, there are other specialized groups of teachers with an involvement in mathematics teaching, including those working with pupils with special educational needs and in adult learning.

5.40 The Inquiry would also wish to draw attention to the need for mathematics CPD for teachers of other subjects – for example, geography, biology and physics – and for those involved in teaching vocational subjects in FE colleges. The Inquiry believes that this is crucially important and will become increasingly important as the 14-19 curriculum and qualifications structure moves towards greater integration of subjects. It will also be an important prerequisite for genuinely integrating the teaching and learning of mathematical skills with vocational subjects – for example, in modern apprenticeships.

5.41 The ACME report reviews the types of training and professional development that have been available previously. The types of professional development currently on offer range from day courses, usually relating to national strategic initiatives, right through to extended programmes leading to higher degrees. Examples are given below in the panel *Types of professional development now on offer*. Current financial support can range from full-cost, mainly for the day courses, to little or nothing for the extended programmes.

5.42 The clear view of respondents to the Inquiry is that there is now an urgent need to take stock and interconnect these developments, to plug gaps in provision, and to seek to identify what is effective for different groups in order to plan sustained portfolios of subject related CPD that will meet the diverse needs of teachers of mathematics. The ACME report envisages the following kinds of provision, some or all of which might include courses leading to accreditation:

- courses for NQTs;
- courses for those in the first year of holding a co-coordinating/ leading post;
- courses for each group in their second or third year of teaching or holding a co-coordinating/leading post;
- a more diverse range of focused courses for teachers with more than 5 years' experience in their current role.

Types of professional development now on offer to teachers of mathematics

1. Award-bearing courses run by Higher Education Institutions. These may lead to diplomas, MAs or PhDs and may also involve professional associations. The focus varies, but is likely to include mathematics, statistics, teaching and learning and associated research. They are often funded by the individual participating teachers and might be undertaken by either part- or full-time study. The numbers of teachers involved are small.

2. In-school development. Each school should have a policy on CPD and a person responsible for coordinating and managing mathematics education. There is likely to be a plan for development in mathematics, which includes use of external courses and in-school shared development. This may be supported by the materials provided by the National Numeracy and KS3 Strategies.

3. Courses run by the National Numeracy Strategy at primary level. Consultants in each LEA run both nationally prescribed and locally developed courses. A key course is the five-day course, which includes both subject content and pedagogy. Within each LEA, certain courses are for 'intensive' schools (selected by the LEA as being those who would most benefit from support) while some are for all schools. There are also short courses run for coordinators.

4. Courses run by the KS3 Strategy (11-14). Consultants in each LEA run both nationally prescribed and locally developed courses. These have included courses for heads of department and KS3 coordinators, which include developing skills in leading departments. A four day course has been run for less experienced teachers of KS3 mathematics, which includes both subject content and pedagogy. Recent courses include teaching of ratio and proportion and geometrical reasoning, as well as approaches to lower attaining pupils. These all provide materials for departmental meetings to support discussion of content and pedagogy. Within each LEA, certain courses are for 'intensive' schools while some are for all schools.

5. In-school development for numeracy. LEA consultants work in 'intensive' schools to help embed ideas from the courses and to develop skills in teaching and planning. They may work with individual teachers, pairs of teachers or provide training sessions for all teachers of mathematics. This work generally embraces subject content and pedagogy, and action planning.

6. Demonstration lessons by Leading Mathematics Teachers (LMTs). In primary schools, LMTs are identified within each LEA who will demonstrate lessons in their own schools to teachers from other schools. A similar scheme has been introduced in mathematics departments in secondary schools for KS3. Advanced Skills Teachers in both phases will demonstrate lessons and work with teachers in the 'learning' teachers' classrooms.

7. Courses run by examination boards. These are mainly sources of information dissemination at KS4 and 16-19 levels. Examination boards usually run courses focused on changes to specifications or assessment methods. There is a small percentage uptake of these courses, but they influence an opinion-forming sector of the mathematics teaching profession.

8. Conferences/working seminars run by professional subject associations and LEAs. These are usually at weekends or in school holidays. There are also regular local meetings of professional subject associations as well as annual conferences.

9. Other organisations (including private sector). These run courses for mathematics teachers on topics such as managing the curriculum, assessment, teaching more able or less able pupils, managing behaviour, etc.

10. Government initiatives. These are often cross-subject developments arising as part of Government initiatives such as the Gifted and Talented strand of the Excellence in Cities initiative and the transition work of Education Action Zones. There has also been significant investment in ICT training for secondary mathematics teachers through the new opportunities fund.

5.43 Additionally, there is a need for provision concentrating on particular areas of mathematics, such as statistics and data handling, applications and modelling, diagnostic and formative assessment, working with gifted pupils or those with special needs, new initiatives in curricula or in resources, as well as the integration of ICT. We understand that the KS3 Strategy is currently intending to focus on increased use of ICT in mathematics and the teaching of algebra, following on devfelopment work initiated by the QCA.

5.44 Respondents to the Inquiry echo the conclusion of the ACME report that short courses are most effective when time is subsequently made available for teachers in schools and colleges to reflect on what has been learnt, to seek the best ways of implementing ideas and methods in the classroom and to reflect on these practices in an informed way. The report is also clear that teachers need opportunities to reflect on curricular materials and methods in order to encourage the development of professional practice rather than just the reinforcement of current methods. For this to be achieved, teachers need support from experts or mentors with a perspective either of mathematics or of the teaching and learning of mathematics, which is wider than delivery of immediate curriculum goals.

Key elements of a CPD programme

5.45 The ACME report therefore envisages two elements in a CPD programme:

- part should be personalized, to address individual teachers' needs and support them in developing their own versions of the understanding of mathematics and mathematics teaching.
- part should be generalized, so that teachers can place their theories and actions within a wider perspective, but also see how they might influence their own practice in the classroom, school or college.

5.46 We have noted that the ACME report stresses the need for professional development programmes that engage teachers in reflective practice in their own school and college classrooms, so that their knowledge and practice continue to grow and evolve. The ACME report envisages that this process can be encouraged in three ways.

5.47 First, teachers have a great deal to learn from observing colleagues and skilled practitioners in their own and in other schools and colleges. A system of peer mentoring would be beneficial, provided there is appropriate time and support. Peer mentoring should be both supportive and developmental, enabling lesson observation and discussion of teaching practice to become more commonplace in schools and colleges and more acceptable to teachers. To further stimulate discussion and reflection on practice, teachers should also be strongly encouraged to join a national professional subject association. Such organizations might be encouraged to develop career structure grades for mathematics teachers as part of their membership structure.

5.48 Secondly, professional development requires resources. The ACME report emphasises that the critical resource is time. Teachers need frequent and regular opportunities to try out ideas and approaches with their pupils and to discuss their experiences with specialists in mathematics and specialists in teaching and learning mathematics, as well as with other mathematics teachers. However, there is currently very little non-contact time in schools and colleges. The ACME report is clear that key individuals in leadership roles must be given time to spend working alongside teachers to develop good practice, as well as managing their departments effectively. The report therefore suggests that there must be timetabled time for teachers to meet regularly to discuss the teaching of mathematics.

5.49 Thirdly, the report notes that within schools and colleges there is a shortage of money for professional development generally and that, in practice, short-term issues tend to take priority. Outside the earmarked funding for the NN and KS3 strategies, in England funding for CPD for teachers of mathematics currently has to compete within schools with other requests. The ACME report concludes that current levels of resource are woefully inadequate to even begin to address current concerns relating to mathematics CPD needs.

5.50 The ACME report is therefore clear that the mathematics teaching profession will not develop a culture of CPD unless sustained and improved funding is made available. The Inquiry wholeheartedly endorses this conclusion.

5.51 The report also makes the important observation that when teachers participate in communities of practice that support their CPD, the effects of CPD can be sustained more easily. Some of this will occur naturally in school and college communities, but often is more effectively developed in wider communities based in LEAs, or around Education and Mathematics departments in Higher Education Institutions (HEIs), or around professional subject association groups. Respondents to the Inquiry have overwhelmingly supported this view. They have also pointed out that creating synergies across

all these parts of the mathematics community would have the added advantage of engaging more of the community in facing up to the challenge of providing support for teachers of mathematics, including the provision of quality CPD.

5.52 Many have noted, however, that there is a currently a shortage of individuals with appropriate experience and expertise to offer training, support and guidance to teachers of mathematics. This concern has also been echoed by respondents commenting on the situation in Scotland, where there are no longer local authority Advisers in Mathematics to coordinate the work of school departments. One possibility put forward in the report, building on structures already in place in some areas, is to set up a cadre of "expert teachers". However, respondents have emphasized the importance of ensuring that individuals identified as "expert teachers" have the appropriate academic background to provide support for subject-specific CPD, particularly for teachers of 14-19 year olds. It is envisaged that "expert teachers" would remain classroom based, but would also form part of a network of local resource centres for teachers of mathematics. (See Recommendation 6.14.) The Inquiry notes with concern that since the transfer of responsibility for FE to the LSC, teachers of mathematics in FE currently do not have access to the equivalent of LEA advisers.

5.53 The ACME report sees a key aim of these local centres to be that of bringing together mathematics teachers, mathematics educators and research mathematicians. The aim would be to encourage the development in each locality of a community of mathematics teachers from primary, secondary, Sixth Form and FE Colleges, and HE, providing local infrastructure to support provision of resources and information for teachers of mathematics in schools and colleges. The Inquiry believes this to be an important and long overdue development.

5.54 In terms of current provision, the ACME report identifies fragmentation, lack of coherence and gaps in CPD provision for teachers of mathematics. Elements of CPD do already exist, provided by university education departments, subject associations, curriculum development bodies and training companies. Recently, the QCA has also initiated such provision through its six regional groups developing materials for algebra and geometry for the KS3-4 curriculum. However, the report notes that there is currently no overall supporting infrastructure to provide strategic direction and coordination.

The need for national and local support infrastructure

5.55 ACME studied models of CPD in operation through such support infrastructure in France through the IREMs *(Instituts de Recherche sur l'Enseignement de Mathematiques,* literally translated as *Research Institutes for Mathematics Teaching)*, and in Israel through the Weizmann Institute. The conclusion of the ACME report is that there is a pressing need for such national and local infrastructure in the UK to provide strategic leadership and coordination of mathematics CPD. The Inquiry wholeheartedly agrees with this conclusion.

5.56 The report's recommendation is that a centre of excellence for mathematics teaching be established to define strategic objectives for CPD and oversee their local implementation. On 13 March, 2003, at a conference jointly hosted by ACME and the DfES to examine best international practice in CPD, the Secretary of State for Education and Skills announced that he was in broad agreement with ACME's proposals to develop CPD for teachers of mathematics. The Secretary of State also took the opportunity to extend the remit of the Post-14 Mathematics Inquiry, requesting that the Inquiry examine possible options for the organization and funding of what he referred to as a 'National Centre for Excellence in Mathematics Teaching' (NCEMT) and recommend to him, as part of its report, a preferred option.

5.57 The Secretary of State indicated that such a Centre should:

- cover all ages from pre-school, through universities and adult learning;
- provide teachers with curriculum support, opportunities to explore different teaching approaches, exciting classroom materials and access to good quality training and development;
- link with Specialist Schools and through them, with their local partner schools, and universities to create strong subject specialist networks;
- work to support the Numeracy Strategy in primary schools and the mathematics strand of the Key Stage 3 Strategy in secondary schools.

5.58 The Inquiry endorses the need for a national support infrastructure for mathematics teaching in the strongest possible terms and welcomes the support and encouragement of the Secretary of State in taking this forward.

Recommendation 5.3

The Inquiry recommends that there be long-term investment in a national infrastructure to oversee the provision of subject specific CPD and other forms of support for teachers of mathematics, tailored to the needs of teachers of mathematics, both specialist and non-specialist, including leaders in mathematics teaching. A detailed discussion of possible options for such infrastructure support will follow in paragraphs 6.56-78, together with the Inquiry's recommended option.

5.59 In view of the Secretary of State's clear indication that support should be provided for teachers of mathematics across the entire age spectrum, the following sections of the report no longer focus primarily on post-14 mathematics education.

The effective delivery of CPD

5.60 There has been considerable debate about the most effective forms in which to deliver CPD for teachers of mathematics. Respondents to the Inquiry have drawn our attention to some of most widely quoted research evidence currently available on the effectiveness of typical forms of CPD provision and strategies. The Inquiry notes, in particular, the following general criticisms of in-service education set out in Fullan, 2001[1]:

- one-shot workshops are a widely used format, but are often ineffective;
- in-service programmes are rarely directed to the individual needs and concerns of participants;
- follow-up support for ideas and practices introduced during in-service programmes is rarely provided;
- follow-up evaluation occurs infrequently;
- most programmes involve teachers from a number of different schools and colleges, but the potential different impact of positive and negative factors in the individual teacher's local environment is typically not factored in to the programme;
- there is an inadequate conceptual basis underlying the planning and implementation of in-service programmes in order to ensure their effectiveness.

5.61 Cascade training, in particular, is widely identified as a weak link in CPD programmes. In particular, the *Evaluation Report of the Key Stage 3 Pilot and Strategy* (DfES, 2003) identifies some dissatisfaction with this form of training, although the training in general was well received. The report notes that:

> *"Not everyone was positive about the training: over a fifth (21%) of the teacher survey respondents did not find the training by local education authority consultants effective, and more than a quarter (27%) felt that it had not prepared them well for teaching... There was some evidence of dissatisfaction with two aspects of the training: perceived rigidity of some of the presentations and reliance on cascade training".*

The criticisms of the cascade approach primarily concerned lack of time and the opportunity to cascade training adequately in schools. There is also a view that the effectiveness of the cascade process diminishes as one moves down the cascade chain.

5.62 Joyce, 1991[2], makes an important distinction between two key elements of staff development activities – the workshop and the workplace. The workshop (the traditional CPD course) is where understanding is developed, demonstrations are provided of the teaching strategy under consideration and practice takes place in a non-threatening environment. However, if the skills

[1] Fullan, M. (2001). *The meaning of Educational Change*, New York, Teachers College Press

[2] Joyce, B. (1991), Co-operative Learning and Staff Development. Teaching the Method with the Method, *Co-operative Learning* 12(2)

acquired in the workshop are to be transferred to the workplace – that is, the classroom and the school – on-the-job support is required. Respondents have argued that in the context of CPD for teachers of mathematics, there should be a shift away from reliance on the cascade model towards school-based team initiatives in which members of a mathematics department work together in the school context, with an expert mathematics teacher acting as the leader or facilitator. The latter role is a key one and we return to the important issue of ensuring an adequate supply of such individuals in Recommendation 6.13.

5.63 This implies a "diffusion" rather than "delivery" model of CPD and is regarded by many respondents as a far more effective way of implementing real change in classroom practice. Such an approach to CPD, placing emphasis on autonomy and professionalism, is described by some respondents as seeking to "involve teachers in change" rather than seeking to "change teachers". However, as we have noted earlier such an approach requires dedicated time and input from appropriately skilled and reflective people within the school. Resources are clearly needed to support such a model.

5.64 The Inquiry accepts that this implies changes to the workplace and the way in which staff development is organised in schools. In particular, it means that opportunity must be provided for immediate and sustained practice, collaboration and peer review and support. Above all, there is the need to provide time for informed reflection with expert colleagues. One of the strongest messages from the evaluation of the Key Stage 3 Strategy (DfES, 2003) is the importance of time if meaningful change is to occur. Creating time for the CPD provided under the Strategy was a problematic issue for virtually all schools. Almost all of the evaluation survey respondents reported that it had been difficult to find time to develop practice, 65 per cent of school strategy managers identifying the key challenge as that of providing sufficient time for CPD related activities. These difficulties have proved particularly acute in schools facing overall mathematics teacher recruitment and retention problems.

5.65 The Inquiry accepts that these changes will be difficult to achieve in the workplace without, in most cases, quite radical alterations to the way in which schools are organised. There is a real need for more creative solutions to the problems of time and timing that beset on-the-job training. This further emphasizes the need to formalize CPD rights and requirements in contractual form (Recommendation 5.1).

Key requirements and tasks of a support infrastructure

5.66 The ACME report recognises the need to create both a national centre and local centres to support and deliver CPD for mathematics teachers. Respondents to the Inquiry have overwhelmingly echoed the need for both national and local support infrastructure. In general, respondents would wish the role of the national centre to be that of:

- identifying and co-coordinating national strategy for the support of the teaching and learning of mathematics;
- interfacing with Government and its agencies, employer groups, learned societies and professional bodies to ensure effective delivery of that strategy;
- working to influence Government, employer and public perception of the importance and high priority of the study of mathematics both to the individual and society.

5.67 More specifically, respondents would wish the role of the centre to include some or all of the following:

- provision of advice, resources and information in support of all aspects of the teaching of mathematics, including the use of ICT and distance learning materials;
- coordination of the development, dissemination, delivery and accreditation of mathematics CPD;
- provision of guidance on emerging research and development in relation to mathematics teaching and learning.

5.68 We shall consider in detail in Chapter 6 possible options for the remit of a national network involving local centres. Meanwhile, we note that most respondents to the Inquiry on this issue have argued strongly for the establishment of a network of regional centres, in addition to the establishment of a national centre. In addition, the overwhelming view of respondents is that the support infrastructure should not be based on a single institution or agency, however selected, but should be a consortia-based network with central strategic direction. In particular, those with knowledge and experience of the work of the pre-14 strategies have argued strongly that a network of regional centres is essential. Without such a local network, respondents are agreed that the majority of teachers will feel too remote from a national centre to become involved in developments.

5.69 In general, respondents see the role of regional centres to be that of coordinating local support delivery and providing both regional focus and regional awareness – eg by interfacing with the Regional Development Agencies (RDAs), employers, education authorities, institutions and training providers. The Inquiry also believes that links between local education providers and RDAs will become increasingly important and that this further strengthens the case for regional as well as national support infrastructure.

5.70 More specifically, respondents would wish the role of regional centres to include some or all of the following:

- provision of a forum for links and joint working among local education providers and employers;
- development of formal working relationships with LEAs and regional directors of the national strategies;

- support for local networks of teachers, linking schools, colleges and higher education;
- support for and coordination of local delivery of CPD and other support for the teaching and learning of mathematics.

5.71 We shall return later to a consideration of options regarding the role of regional centres as part of national support infrastructure. However, we note that whatever form of structure is adopted the following key mathematics subject specific needs have been identified over and over again in responses to the Inquiry:

- to raise informed awareness of the wider applications of mathematics – in science and technology, in society, in everyday life, in the workplace and in other subjects;
- to extend the base of research-based evidence on teaching and learning strategies;
- to encourage and facilitate interaction throughout the wider mathematics community on an ongoing basis;
- to ensure that teachers at all levels are actively engaged in networking;
- to expose teachers to material on modern developments in mathematics, the scope of its application and the wide range of employment possibilities;
- to ensure confidence and security in teachers' mathematical and pedagogical knowledge and to encourage the use of a wide range of teaching styles;
- to ensure that teachers are fully informed about the role and potential of ICT to enhance the teaching and learning of mathematics and have access to state-of-the-art hardware and software;
- to provide scholarships and secondments for teachers to extend their knowledge and understanding of issues in mathematics education;
- to provide time for teachers to explore and reflect on mathematics for its own sake;
- to link with the National College of School Leadership (NCSL) to provide quality training and advice for experienced, new or aspiring heads of mathematics departments;
- to provide local management and peer support, through responsive teams at school and local level, for teacher-centred self-diagnosis of development needs;
- to integrate CPD with curriculum development and enhancement activity;

- to integrate CPD with classroom/school-based research and development work at national, regional/local/schools levels;
- to develop an entitlement for each school and each individual teacher of an allocation of resources for CPD, including time;
- to ensure that CPD is an ongoing experience throughout the course of each teacher's career;
- to offer accreditation for CPD courses in a way that will allow teachers to collect credits in flexible ways;
- To develop kite-marked accreditation systems for CPD.

5.72 In terms of a longer term research and development agenda for the new infrastructure, respondents have identified the following key areas:

- the development of new 14-19 pathways;
- the development of more critical pedagogies, based on developing mathematical comprehension, communication and argumentation;
- the development of new approaches to assessment, including diagnostic and formative assessment;
- the development of new approaches to mathematics teaching and the curricula to take account of developments in technology and in usage;
- the development of mathematics teaching for and with other subjects and as part of vocational programmes, such as modern appenticeships.

5.73 Continuing professional development in mathematics is currently provided by the NN and KS3 strategies, by higher education, by LEAs, by schools and colleges for their own staff and by private providers, particularly in vocational areas. There are some instances of schools providing professional development for staff in other schools – for example, Beacon schools, schools with Advanced Skills Teachers and Leading Mathematics Teachers. However, at present, there is no national registry of all the continuing professional development opportunities available. Respondents see a need for an infrastructure that would set up a database to keep track of and quality access all externally provided CPD in mathematics. Following on from this, work could be commissioned in close collaboration with the best providers to enhance, develop and promote CPD in mathematics. Many respondents would like to see this lead on to kite-marking of provision.

5.74 As we have indicated, respondents to the Inquiry have overwhelmingly endorsed the important conclusion of the ACME report that there is a need for both a national centre and local centres. The national centre is seen as essential to provide strategic direction and coordination of expertise in all aspects of the support of the teaching and learning of mathematics, as well as to provide a focus for close working with national stakeholders. Respondents have also argued that regional centres are essential to provide

accessible delivery of CPD, coordinate local support networks for teachers of mathematics and provide a focus for close working with RDAs, LEAs and other existing local networks and stakeholders. The Inquiry wholeheartedly endorses this conclusion.

5.75 We have considered the option of only creating a new central structure to oversee all post-14 CPD, with direct delivery through some form of local consultant network, essentially following the model of the existing strategies. This would have the attraction of avoiding creating a formal network of regional centres. However, we believe there to be two major problems with this approach.

5.76 First, the breadth and range of subject matter and subject specific pedagogy across the post-14 agenda is considerably greater and more diverse than that covered by the primary and KS3 strategies. We do not believe it would be possible to achieve coverage of the entire post-14 agenda – including GCSE, AS- and A-level, Further Mathematics, and the whole spectrum of vocational and key and basic skills mathematics courses and qualifications through a manageable network of local consultants. Furthermore, even if sufficient and appropriate expertise could be identified, given the scale of the post-14 mathematics agenda, following the model of the existing strategies is likely to have the undesirable effect of removing a very large number of some of the best qualified teachers from day-to-day post-14 mathematics teaching in the school and college setting.

5.77 Secondly, we have been entirely convinced by the argument that we need to build and sustain local networks of support, bringing together schools, colleges, HE and other stakeholders, including the RDAs and local employers. The absence of an integrated network of all relevant stakeholders is a serious current weakness. As many respondents have impressed on us, this is not just a prerequisite for culture change in relation to CPD and sustainable on-going support and mentoring of teachers of mathematics. It is also a prerequisite for addressing the current lack of involvement of HE and employers with local mathematics teachers and for raising the profile and awareness of mathematics. We are currently failing to harness the full range of available expertise and resource and to share and disseminate knowledge and best practice. Greater involvement of these important stakeholders would provide considerable added value, both in terms of additional expertise and resources and also in raised awareness on all sides – and, in particular, among careers advisers – of the all-pervasive importance and applicability of mathematics. The Inquiry is led to conclude that a network of regional centres is essential.

Recommendation 5.4

The Inquiry recommends that the national support infrastructure for the teaching and learning of mathematics take the form of a national centre providing strategy and coordination, together with regional centres providing local support and networking.

5.78 In responses to the Inquiry, there has been an indication of interest from Northern Ireland and Wales in developing centres that would in part play a similar role to English regional centres, but would also have a strategic role in relation to specific local concerns arising in the Northern Ireland and Wales systems. In the case of Northern Ireland, the NINS Steering Group (which has representatives from key stakeholders in NI) has informed the Inquiry that they "would be strongly in favour of a regional mathematics centre". Scotland will consider at a later stage whether or how future developments of CPD for teachers of mathematics in Scotland might relate to or interact with such an infrastructure in England.

6 NATIONAL AND REGIONAL SUPPORT INFRASTRUCTURE

Existing and potential providers, networks and initiatives

6.1 Whilst supporting strongly the need for a national support infrastructure for the teaching and learning of mathematics, many respondents have been concerned to point out that such a structure should work with, build on and, wherever appropriate, incorporate existing provision, networks and initiatives. In addition, respondents have drawn attention to the need to promote and encourage greater involvement of key stakeholders who have hitherto not played a central role in supporting teachers of mathematics. Much of this echoes the key requirements laid down by the Secretary of State in March, 2003 (see paragraph 5.56).

6.2 In reviewing existing provision and initiatives and in considering possible models for a national support infrastructure, we have had to consider whether and to what extent we should recommend that existing provision and initiatives should be formally incorporated within a national centre or regional centres. On the one hand, we clearly need greater strategic coordination of certain key established activities, but on the other hand we are aware of the need to allow – and indeed encourage – creative, experimental initiatives. We are also aware that the latter often depend on the energies of committed individuals or groups who typically value their independence, often underwritten initially by charity funding. In what follows, in considering options for the remit of the national and regional centres we shall therefore adopt two different kinds of recommendation, corresponding to two different kinds of role for the national and regional centres in relation to existing or emerging provision and initiatives.

6.3 The first kind of recommendation will identify certain areas as definitely needing to come directly under the auspices of the national or regional centres as a prerequisite for overall coherent strategy and coordination of support for teachers of mathematics. The second will identify areas where, in our view, the centre should have a more indirect role, not seeking any immediate direct control but having the role of a provider of development funding and a monitor and evaluator of the outcomes of initiatives. The aim here should be to identify activities that might eventually be sustained and rolled out across the wider school and college sector under the auspices of the centre.

The role of the Numeracy and Key Stage 3 Strategies

6.4 We consider first the Secretary of State's requirement that the new infrastructure work to support the National Numeracy Strategy in primary schools and the mathematics strand of the Key Stage 3 Strategy in secondary schools.

6.5 For primary teachers in England, professional development opportunities in mathematics have been provided by the National Numeracy Strategy. This has addressed key areas of the mathematics curriculum and teaching practices and has produced a wealth of materials and guidance for numeracy consultants and teachers. These are widely acknowledged to have strengthened subject knowledge, curriculum provision, planning and teaching. The Strategy supports some 400 numeracy consultants and much of the support and training the Strategy provided to schools is delivered through consultants working in LEAs. The consultants mediate centrally produced training, which is accredited by some HE Institutions by acknowledging the successful completion of this training within their award structures.

6.6 The NNS consultants in each LEA run both nationally provided and locally developed courses. The key core component is a five-day course, which includes both subject content and pedagogy. These have provided at least 5 days of out of school training plus a series of personal classroom visits to more than 100,000 primary teachers. In each LEA, there are further courses targeted at selected schools deemed by the LEA to be most likely to benefit from further support. In addition, there are short courses run specifically for head teachers and school mathematics coordinators. Evidence to the Inquiry, suggests that around 20,000 primary head teachers and a similar number of mathematics coordinators have had opportunities out of school to consider the management of mathematics and the professional support they give their teachers.

6.7 For teachers of mathematics to 11-14 year olds in secondary schools in England, professional development opportunities in mathematics have been provided by the mathematics strand of the KS3 Strategy. This, too, has produced a wealth of material and guidance for Key Stage 3 consultants and teachers. The KS3 consultants in each LEA run both nationally prescribed and locally developed courses that have been delivered to around 4000 teachers of mathematics in secondary schools. A key core component is a four-day course for less experienced teachers of mathematics, which includes both subject content and pedagogy. Another key course is that for heads of mathematics departments in secondary schools, which includes developing skills in leading departments. This has been delivered to around 4,000 secondary heads of department. Recent developments include providing courses on how to organize and stimulate discussion on content and pedagogy in the within-school context of departmental meetings. All schools have been offered training and classroom resource materials to support the development of innovative pedagogic strategies to engage pupils in handling

data, ratio and proportion and geometric reasoning. In addition, all schools have received resources and training to improve the teaching of pupils working below expected levels.

6.8 Evidence to the Inquiry suggests that, notwithstanding some reservations, the training provided by the NN and KS3 strategies has generally been well received and has had positive effects on professional development for many teachers of mathematics. The Inquiry has also noted that the KS3 Strategy is currently developing a range of whole-school support initiatives, which are intended to complement subject specific work. The Inquiry is not competent to judge whether such whole-school initiatives will contribute to improvements in mathematics teaching. However, we would be seriously concerned were there to be any move away from at least current levels of resources for mathematics CPD for primary teachers and KS3 teachers of mathematics. Respondents from Northern Ireland have reported that decisions about future work plans, funding and staffing for the NINS have yet to be taken.

6.9 Although these issues are formally outside the remit of the Inquiry, respondents have made clear their obvious concern that ongoing improvements to pre-14 mathematics education are a pre-requisite for future developments and improvements post-14. Also, whilst respondents have acknowledged the very real positive impact of the strategies, there is a clear view that much still remains to be done. For example, respondents have noted that in a survey in 2001 of teachers of mathematics in the Key Stage 3 pilot schools, it was found that nearly 50 percent of KS3 mathematics classes were being taught by non-specialists. The Inquiry also notes that the total of 4000 teachers thus far involved in the KS3 strategy represents an average of less than one mathematics teacher per secondary school. We shall discuss the issue of taking forward the work of the strategies later in this chapter. Meanwhile, we make the following clear recommendation.

Recommendation 6.1

The Inquiry recommends that the work of the National Numeracy Strategy and the mathematics strand of the KS3 Strategy be continued and built upon, and that resources for mathematics are ring-fenced for any future form of successor to these strategies for KS1-3.

6.10 Many with experience of the strategies in England have pointed out to the Inquiry that the network of local consultants in place to support the strategies itself already provides an important existing infrastructure for the future support of primary and KS3 initiatives or their successors. There is a strong consensus that this should be further strengthened and exploited in developing the national infrastructure. Respondents to the Inquiry on behalf of the strategies have themselves also indicated a desire for close working with any new national infrastructure. The Inquiry has therefore considered carefully how best this might be done.

6.11 As indicated in Recommendation 6.1, the Inquiry believes it to be essential that there be ring-fenced funding for the numeracy and mathematics components of the primary and Key Stage 3 strategies. Assuming the continuation of funding, one option would be to continue with the current stand-alone managerial and organizational arrangements for the strategies. These seem to have worked well in delivering the strategies to date. However, a number of respondents have argued that this would be a mistake and a missed opportunity to begin to get a coherent overall strategy for CPD, linking mathematics education across all ages.

6.12 We note first that respondents have stressed the need in any case for the existing strategies themselves to be reviewed and refreshed in the near future and that it would be timely to undertake such a review in the light of the post-14 Inquiry report. In particular, it has been pointed out that within a few years there will almost certainly be significant curriculum changes post-14 and that these will necessarily have a significant impact on KS3 CPD needs. Incorporating the KS3 strategy into the new infrastructure is therefore seen as a prerequisite for developing a coherent approach to providing teachers with mathematics CPD throughout the secondary school.

6.13 More fundamentally, respondents to the Inquiry have overwhelmingly drawn attention to what they perceive to be a current lack of a forum for joined up thinking about school mathematical teaching and learning across the entire age spectrum – from primary schools through to higher education. Although outside the formal remit of this Inquiry, we have been very surprised to learn how little historical local contact and joint working there has been in relation to mathematics teaching and learning at the primary/secondary interface and at the secondary/FE/HE interface. Most of the initiatives we have encountered have only been undertaken in the past couple of years. The Inquiry is convinced that incorporating the existing strategies into the new infrastructure would greatly facilitate coherent thinking in relation to transitions between stages within schools and colleges and from schools and colleges to higher education.

6.14 Also, in relation to CPD provision for teachers in secondary schools, respondents have drawn attention to the fact that within schools there is for the most part no sharp divide between KS3 and post-14 teaching at the individual teacher level. Indeed, some respondents to the Inquiry have indicated that changes to teaching and learning in KS3 promoted by the Strategy have already begun to permeate KS4 and college teaching. Coherent provision of ongoing CPD for the individual teacher therefore clearly requires there to be no unnecessary demarcation in the planning and delivery of "pre- and post-14" CPD.

6.15 The Inquiry believes that, providing care is taken to preserve the good local working relationships that currently exist, there would be considerable advantages in incorporating both the existing strategies into the new national support infrastructure. In the case of the KS3 Strategy, we believe the case to be overwhelming. For there to be coherent planning and delivery of CPD

for mathematics teachers within secondary schools and colleges, we believe it to be essential that the mathematics strand of the KS3 Strategy be incorporated into the national support infrastructure.

Recommendation 6.2

The Inquiry recommends that the existing mathematics strand of the KS3 Strategy be incorporated into the national support infrastructure and that the existing funding for this strategy be brought under the auspices of the infrastructure. The Inquiry also recommends that serious consideration be given to similarly incorporating the National Numeracy Strategy. The Inquiry further recommends that, on incorporation, a review of the content and delivery of the strategies be carried out under the auspices of the new infrastructure.

6.16 With respect to Northern Ireland, the Inquiry notes that were there to be a local component of the national support infrastructure, the relationship with CASS and the NINS (or any successor strategy) would have to be worked out locally in Northern Ireland.

The role of Higher Education in supporting Schools and Colleges

6.17 The acknowledged problem of professional isolation amongst teachers is also seen as a key issue that must be addressed. An important function of the constituent consortia is therefore seen to be that of bringing together into local networks practitioners from different areas of the profession of mathematics. In particular, respondents from both the schools and FE sectors have drawn attention to the need to stimulate greater interaction between HE mathematics and school and college mathematics, in part at least to encourage students at schools and colleges to become the next generation of mathematics teachers, graduate students and academics. We therefore next consider the Secretary of State's requirement (paragraph 5.56) that the new infrastructure link schools, colleges and universities to create strong subject specialist networks.

6.18 Schools of Education in HEIs do, of course, work closely with schools. However, the Inquiry notes with concern that – with some notable exceptions – there is relatively little current, systematic interaction between mathematics departments in HEIs and schools and colleges. There also appears to be little interaction in some instances between mathematics departments and schools of education within individual HEIs.

6.19 This state of affairs should not be allowed to continue. The Inquiry believes that there should be closer working between all HE mathematics departments, schools of education and their local schools and colleges. The Inquiry believes that this would open up a number of opportunities for higher education to provide significant new and sustainable support for local teachers of mathematics by:

- enhancing pupils' and teachers' mathematical attainment, through individual mentoring;
- increasing pupils' and teachers' awareness of the extraordinary range of applications of mathematics and the many career opportunities opened up by the study of mathematics;
- encouraging pupils to consider the possibility of a mathematics teaching career.

6.20 Within their own institutions, staff in university mathematics departments, and in other disciplines with a high mathematical content, are well placed to contribute by:

- encouraging school student participation in mathematics enhancement – eg by providing master classes;
- encouraging undergraduates to consider teaching as a valued and rewarding career, including practical opportunities to obtain some classroom teaching experience – eg through Ambassadors, Student Associate and other mentoring schemes (see Chapter 2);
- where appropriate, supporting ITT in partnership with Schools of Education;
- supporting teachers through mentoring and supervising advanced degrees;
- ensuring that teachers are well-informed about developments in mathematics research and applications.

6.21 In addition to the Ambassadors, Student Associate and other mentoring schemes for those contemplating a teaching career, the Inquiry believes that the general population of HE students in disciplines with a high mathematical content provides a potential pool of skilled teaching assistants to support teachers of mathematics in schools and colleges. The Inquiry would wish therefore to add support to Recommendation 2.8 of the *SET for Success* report.

Recommendation 6.3

The Inquiry recommends that a programme be established to pay selected volunteer undergraduate and postgraduate students in disciplines with high mathematical content to support teachers of mathematics in schools and colleges. Payment should be on a competitive basis with other sources of employment open to such students. The precise nature of the support role should be for schools, colleges and universities to decide locally. (See also Recommendation 6.14, ninth bullet point.) It will be important to ensure that those participating have the appropriate skills and training.

6.22 The Inquiry has also noted the potential for greater involvement of the HE Mathematics, Statistics and Operations Research Network, part of the HE Learning and Teaching Support Network (LTSN). The primary focus of the LTSN is teaching innovation and quality in Higher Education throughout the

UK, and the LTSN is currently in the process of being incorporated into The Higher Education Academy, a new body committed to the enhancement of the quality and status of teaching in HE. University departments involved in both the Mathematics, Statistics and Operations Research and the Engineering LTSNs seek to develop effective approaches to mathematics teaching for mathematics students and students of mathematics in other disciplines, and to share best practice.

6.23 The work of the LTSNs is primarily directed to teaching and learning within higher education. However, the Inquiry has noted with considerable interest that the network also provides significant support materials at the school/university interface. Current outreach activities of the network at the school/university interface include involvement with A-level students through the MEI Further Mathematics Project (see later paragraph 6.44) and involvement with school-based statistics activities through the Royal Statistical Society's Centre for Statistical Education. Through this latter organization, the network has, for example, created Key Stage 2, Key Stage 4 and A-level resources for pupils, produced teacher CPD training material and delivered training through short courses.

6.24 In Scotland, the Network's Assessment Consultant has played a leading role in SCHOLAR, an initiative that provides online educational materials and experiences in the form of a "virtual college" with a strong mathematics component. Materials include simulations, animations, interactive tutorials and online discussion groups. SCHOLAR aims to ease the transition from secondary school to further and higher education and to assist more self-directed learning.

The role of ICT in support of the teaching and learning of mathematics

6.25 The Inquiry has noted with great interest that members of the LTSN Mathematics, Statistics and Operation Research Network also have considerable experience in the electronic delivery of materials aimed at enhancing learning and teaching in mathematics and statistics. This is an area requiring much more detailed consideration in the school and college context. The Inquiry has not been able to identify any clear audit of the current availability and use of ICT delivered learning and teaching resources in support of mathematics teaching.

6.26 However, many respondents to the Inquiry have impressed on us that not all mathematics classrooms in secondary schools and FE colleges in England have even the basic resources for handling a significantly greater expansion of the use of ICT. In particular, we have been informed that many mathematics departments in secondary schools do not have an interactive whiteboard, or sufficient access to rooms with sufficient computers and software for whole class lessons, or an up to date, functioning set of graphical calculators for the whole class.

6.27 The Inquiry believes that there are important tasks here for the new national

infrastructure. First, there is a need to understand the current position with regard to the availability of ICT resources for mathematics teaching. Secondly, there is a need to encourage appropriate use of currently available ICT resources, ranging from better exploitation of videoconferencing facilities, through to newer developments with the web and interactive and hand-held technologies. Thirdly, there is a need to identify high quality software.

6.28 In Northern Ireland, there are significant ICT investments being undertaken under the auspices of the C2K (Classroom 2000) initiative. In relation to Recommendation 6.4, we therefore note that any local component of the national support infrastructure in Northern Ireland would need to liaise closely with existing or future C2K developments.

Recommendation 6.4

The Inquiry recommends that the remit of the new national support infrastructure include responsibility for auditing existing ICT provision for mathematics in schools and colleges, assessing the need and potential for future ICT provision in support of the teaching and learning of mathematics and advising the DfES and the LSC on ICT investment requirements for mathematics in schools and colleges.

6.29 Within the higher education sector in the UK, there is already considerable specialist expertise in the LSTNs in relation to videoconferencing activities and the use of ICT tools for mathematics communication and teaching and learning. The Inquiry believes that ways should be found of extending and sharing this expertise, through greater involvement of the LTSN with schools and colleges. The LTSN Mathematics, Statistics and Operation Research Network have indicated that they would very much welcome this opportunity, provided that appropriate resources were made available.

6.30 More generally, the Inquiry believes it to be vital that universities should be more actively engaged in interacting with and supporting mathematics teachers in schools and colleges. In particular, they should be actively engaged with consortia at national and local levels. The national infrastructure should encourage this and provide pump-priming resources to underpin the development of cooperative working between schools, colleges and HE throughout the system.

Recommendation 6.5

The Inquiry recommends that the national support infrastructure provide appropriate resources to enable the Committee of Heads of Departments of Mathematical Sciences in HEIs in the UK (HoDoMS) to work together with the LTSN Mathematics, Statistics and Operations Research Network to seek ways to promote sustainable closer links between HEI mathematics (and other relevant) departments and mathematics teachers in their local schools and colleges.

The potential role of the Open University (OU)

6.31 Many universities already play a significant role in the provision of CPD, networking and other forms of reach-out to schools and the wider community and we greatly welcome this. However, we have not been able to undertake a survey of all such initiatives and it would therefore be invidious for the Inquiry to single out specific institutions for special mention. However, we feel it appropriate to draw attention to the particular role and track record of the OU as evidence that elements of the structure and roles envisaged for the national support infrastructure can be made to work effectively. The OU has the organizational experience of being both a national education provider and also running its own significant regional and local support infrastructure. The latter works closely with the local delivery of the NN and KS3 strategies and with a wide range of schools networks and other partners.

6.32 One of the Secretary of State's requirements for the new infrastructure is that it should cover all ages from pre-school, through universities and adult learning. The Inquiry notes that the OU has experience of provision of mathematics education across all ages from pre-school, through universities to adult learning, including specialist postgraduate courses for mathematics teachers. It has a national presence in the early learning years area through its Faculty of Education and Language Studies (FELS) and a national presence throughout the schools curriculum via FELS and its Centre for Mathematics Education (CME). In addition, it has a considerable track record of mathematics teaching at a distance for mature undergraduates and adults who study part-time. Over the past 25 years, some 70,000 students have passed through the equivalent of a foundation course in mathematics at the OU and many practising teachers of mathematics have studied for Masters Degrees.

Recommendation 6.6

The Inquiry recommends that in the detailed planning of the national support infrastructure for the teaching and learning of mathematics particular attention should be given to involving the relevant experience and expertise of the Open University.

The role of Specialist Schools

6.33 A recent development in England relating directly to subject matter support and networking in the school system is the government's specialist schools initiative. As part of its general strategy for providing subject matter support in schools, the Government is committed to creating *'a new specialist system where every school has its own specialist ethos and works with others to spread best practice and raise standards'* (Secretary of State for Education and Skills, A New Specialist System, 2003). One of the Secretary of State's requirements for the new infrastructure for the support of teachers of mathematics is that it link with specialist schools and through them, with their local partner schools, and universities to create strong subject specialist networks.

6.34 There are currently around 80 Mathematics and Computing specialist schools. Each school applying for specialist status produces a four-year development plan that addresses the needs of the school, its family of schools and its community. The plan is framed around objectives which focus on:

- improving standards of attainment in the specialist subjects and on using the specialism as a lever to achieve whole school improvement;
- enriching pupils' learning experiences and provision in the specialist subjects, through enhanced links with business; supporting curriculum development and provision of appropriate courses;
- encouraging increased take up in the specialist subjects, especially post-16.

6.35 A school's community development plan is based on work with at least five partner schools (primary and secondary) and the wider local community. This will include activities planned across the transition from KS2 to KS3 and from KS4 to post-16 education, for example with Colleges of FE and Sixth Form Colleges in discussion with the local Learning and Skills Council. A key feature of specialist schools is their commitment to developing and sharing best practice through continuing professional development of their own staff and local colleagues. Developments arising from this initiative are being taken forward through a network provided by the Specialist Schools Trust. In support of this network, the Trust runs a programme of conferences, seminars, workshops and individual visits as part of its core function.

6.36 Many specialist schools have written into their plans the creation of an AST post in mathematics to support effective teaching and learning strategies. The Specialist Schools Trust is seeking to coordinate and develop the subject and subject pedagogy leadership potential of ASTs and Leading Teachers, by setting up lead practitioner networks to support subject and regional teams.

6.37 The DfES has provided some funding to enable the Trust to establish a series of regional lead practitioner networks in subject specialisms, including mathematics. In Spring 2003, the Specialist Schools Trust organised and ran 16 regional workshops for teachers of mathematics in the Trust's affiliated schools. Building on the experience of these regional events, the Trust is establishing a CPD programme for teachers via a network of regional and local centres, based around a taskforce of lead practitioners and a network of ASTs in mathematics.

6.38 The Secretary of State referred explicitly to the need for the national support infrastructure for teachers of mathematics to link with networks arising from this initiative. The Inquiry has therefore considered carefully how the Special Schools Trust's emerging CPD programme and networks should relate to the national support infrastructure.

6.39 On the one hand, we are aware that this is a very recent initiative, most of whose activities are at a very preliminary stage of implementation and trialling. We are also mindful of the clear view of respondents that the support infrastructure should be a consortia-based network, rather than based on a single body or around a single initiative. The Inquiry is therefore clear that it would be inappropriate at this stage to assign too central a role to these developments. On the other hand, it would clearly be perverse for the development of the work of the mathematics support strand of the specialist schools to proceed outside the national infrastructure framework. The Inquiry believes that the emerging special schools mathematics networks and the other work of the Specialist Schools Trust have the potential to provide a valuable resource and focus for supporting teachers of mathematics in both secondary schools and colleges.

6.40 We believe therefore that, where appropriate, those involved in the piloting and development of specific aspects of these initiatives – as with other initiatives undertaken by other stakeholders – should be able to bid for support from the national and regional centres (see Recommendation 6.7). However, given the key role the Government intends the specialist schools to play in relation to specific subject matter support, the Inquiry is clear that those aspects of CPD and other developments which are intended to provide an ongoing core element of the support of teachers of mathematics must be brought under the overall strategic direction and coordination of the national and regional centres, and be subject to inputs and guidance from a wide range of stakeholders.

Recommendation 6.7

The Inquiry recommends that overall strategy for and coordination of the networking and other CPD developments relating to the mathematics elements of specialist schools be brought under the auspices of the national support infrastructure for the teaching and learning of mathematics.

The role of voluntary initiatives

6.41 Outside the framework of large-scale developments imposed across the school and college system, the UK has a tradition of independent small-scale voluntary initiatives to support particular aspects of the teaching and learning of mathematics. The Inquiry has not attempted a survey of all such initiatives and is certainly not able to judge their relative contributions and impact. However, in order to indicate how we think their relation with the national and regional centres might typically be handled, we shall briefly describe six such initiatives, selected to illustrate six rather different aims and approaches to improving and enhancing the teaching and learning of mathematics.

6.42 The UK Mathematics Trust (UKMT) is an independent body established, in its own words, "to advance the education of children and young people in mathematics and in particular by organising and running mathematical competitions." It runs annual Mathematics Challenges at junior, intermediate and senior levels and organises the British Mathematical Olympiad, including selective training and mentoring activities. The UKMT is responsible for selecting and training the British team for the International Mathematical Olympiad. Currently, over half a million secondary pupils and most secondary schools in the UK participate in the Trust's range of competitions and related activities.

6.43 The Millennium Mathematics Project (MMP) was set up in 1999 as a joint project between the Faculties of Mathematics and Education at the University of Cambridge, bringing together a number of existing outreach activities, which have since been developed and extended, supported by short-term funding from a number of sponsors. The broad aim of the project is to help people of all ages and abilities share in the excitement of mathematics and understand the enormous range and importance of its applications. This it attempts to do mainly through a programme of enrichment of the standard curriculum. The MMP is active in a number of locations across the UK, both through its web resources and video-conferencing programme and through school visits and face-to-face teacher training and mentoring. The project has worked directly with hundreds of schools all over the UK and its web-based resources are used by thousands more teachers, pupils and parents across the world, with around 25% of users located in the US and significant numbers in Australia, New Zealand, South Africa, Hong Kong and Singapore.

6.44 The Mathematics in Education and Industry (MEI) project 'Enabling Access to Further Mathematics' aims to make it possible for all sixth form students to have access to studying Further Mathematics A-level through distance learning, where this is unavailable to them through more traditional means because of lack of resources in their local school or college. The project is in a pilot phase that began in September, 2000, and is funded by the Gatsby Charitable Trust. Students are allocated to an experienced distance tutor who monitors progress and gives individual tutorial support via a combination of e-mail, fax, telephone, visits and where possible on-line video conferencing, which is being developed to enable students to have distance tutorials with tutors at their lead centre. When not tutoring students, the tutors spend some of their time developing web resources. Module 'study days' take place at lead centres, enabling students to meet each other and the project staff. In one university involved in the project, second year mathematics undergraduates act as mentors to local sixth formers studying for Further Mathematics qualifications through the project.

6.45 MEI is currently embarking on another project, "Upgrading Mathematics Teachers". The target group is the very substantial number of non-specialist mathematics teachers teaching mathematics, who are experienced good teachers, committed to the profession, but with rather limited knowledge of the subject. The project – run jointly by MEI and the University of Warwick

with funding from the Gatsby Charitable Trust – will provide teachers with a structured course at the end of which the expectation is that they will have the mathematical knowledge and confidence to be able to teach mathematics up to AS and A Level.

6.46 On-line web-based mathematics courses have been pioneered by the Thomas Telford School as a response to the shortage of specialist mathematics teachers in many schools and with the particular aim of raising achievement in mathematics at GCSE. The project is currently funded by the HSBC Education Trust. The GCSE course is designed in a way that enables it to be taught by non-specialist mathematics teachers. The course aims to present mathematics at Key Stage 4 level in a way that motivates and stimulates the learner, by including a number of different categories, such as sport, travel and careers, which give students a context to their study of mathematics. To date, 200 schools have used the Thomas Telford on-line programmes.

6.47 The National Education and Business Partnerships Network is the umbrella organisation and national voice for 138 Education Business Partnerships working in the UK. Within this framework, Number Partners have developed a training scheme and operational practice for bringing cohorts of business volunteers, HE students and community volunteers to work in schools supporting selected students having difficulties with mathematics. This currently works through activities such as board games at KS3. The organisers believe the scheme could easily be extended to encompass activities suitable for students at KS4 level and above. At present, the scheme operates in 38 locations nationwide, with 140 schools hosting 1036 volunteers supporting 2244 pupils.

6.48 It is not within the competence of the Inquiry to provide a serious evaluation of the quality or impact of the particular initiatives described above, or of others we have encountered. However, the Inquiry believes – along with many respondents to the Inquiry – that, prima facie, these and other initiatives do have the potential for significantly enhancing the teaching and learning of mathematics in schools and colleges. Some respondents have argued that we suffer from having too many, small scale, uncoordinated, independent initiatives, each competing for limited funding, not systematically evaluated and rarely leading to any sustained embedding of new practice throughout the system. It is argued that it would be better if all these initiatives were now brought together under the auspices of the national and regional centres, in order to provide coordination and, where appropriate, sustainability. We do not support this option. We believe there to be an important role for independent initiatives and believe there to be a danger of stifling creativity and individual energy by insisting on central bureaucratic control of all developments, right from the beginning.

6.49 However, we recognise the point that has been made about embedding and sustainability. We believe, therefore, that we should continue to encourage and welcome independent initiatives but that a way needs to be found to systematically evaluate their impact and subsequently to embed and sustain

successful practice throughout the system. Here, we see a natural role for the national and regional centres. The centres should be given responsibility for keeping a watching brief on such initiatives in order to identify those with potential for larger scale implementation. Subsequently, in response to bids for funding from those initiatives seeking to proceed beyond the pilot stage, the national and regional centres should have the remit to undertake formal evaluation, with a view to supporting the systematic roll out of successful initiatives across the school and college system. Large-scale implementation of successful initiatives will, of course, require the commitment of sustained funding and appropriate ongoing management and accountability. Again, we see this as part of the remit of the national and regional centres.

Recommendation 6.8

The Inquiry recommends that the remit of the national infrastructure include responsibility for encouraging and evaluating independent initiatives in the teaching and learning of mathematics and for funding and managing dissemination of successful initiatives more widely across the school and college system. The Inquiry recommends that the overall resources provided for the national and regional centres include specific funding for this purpose.

6.50 The Inquiry has some specific concerns about an existing initiative relating to subject enhancement. SETNET, the Science Engineering and Technology Mathematics Network, is a high-profile existing initiative involving 86 member organisations representing Government, industry, the engineering professional institutions, education and education charities. SETNET aims to stimulate a flow of well-motivated, high quality students from schools who have an interest in, and an understanding of, engineering related subjects. The report *SET for Success* identified SETNET as the Government's preferred route for presenting a coherent message to teachers and industry about the schemes and initiatives available to enhance and extend the key curriculum subjects of science, technology and mathematics.

6.51 The Inquiry supports SETNET's mission to enrich and support the curriculum in schools. However, we are very concerned about the paucity of provision of enrichment resources relevant to mathematics that are currently available nationally through SETNET and the regional delivery SETPOINTS outlets. There is extremely limited provision in mathematics, particularly at secondary level, and we believe that this gap should be filled as soon as possible. The Inquiry also notes that exactly the same problem exists in relation to the provision of material to inform careers teachers and advisers in schools and colleges about the all-pervasive applicability of mathematics and the career opportunities opened up by the study of mathematics. The Inquiry has received a great deal of worrying comment from respondents about the lack of availability of informed careers advice in schools and colleges about mathematics and the study of mathematics. We believe that this issue should be given high priority.

Recommendation 6.9

The Inquiry recommends that the national infrastructure work with SETNET to improve the provision of mathematics enrichment and careers advice resources provided through SETNET and that appropriate funding be made available either through SETNET or the national infrastructure to support this development.

Support of teachers of adult numeracy

6.52 Among the Secretary of State's requirements for the new infrastructure is that it should support adult learning. In this connection, respondents to the Inquiry have indicated that, in the context of the Government's *Skills for Life* strategy, teachers of adult numeracy in adult education institutes and in the workplace and non-specialist teachers of mathematics and numeracy to adults in further education would particularly welcome support from the new infrastructure.

6.53 The Inquiry believes that, in order to understand how best to provide this support, the new infrastructure will need to collaborate with researchers and practitioners with special experience and expertise in the area of adult education. The Inquiry believes that the key body will be the DfES funded National Research and Development Centre for adult literacy and numeracy (NRDC), which is a consortium of partners led by the University of London Institute of Education. Adult numeracy is a particular focus of the NRDC's work and, in November 2003, it published its first major report, *Adult Numeracy: review of research and related literature.*

Recommendation 6.10

The national infrastructure for the support of the teaching and learning of mathematics should set up formal collaborative links with the NRDC, with a view to exploring how best to support teachers of adult numeracy.

Evaluation and dissemination of research in mathematics education

6.54 There is currently considerable research activity in the field of mathematics education, but there is no national forum charged with systematic evaluation and dissemination of national and international research findings in order to provide an appropriate evidence base for policy and practice. The Inquiry believes that such a forum is required.

6.55 One option would be for this to be a stand-alone entity. However, the Inquiry has noted the views of respondents that it is essential that the development of CPD and other support activities for teachers of mathematics should be appropriately informed by relevant research findings. We therefore see great merit in including in the remit of the new infrastructure responsibility for systematic reviews of research and development findings and materials and

ensuring that these inform mathematics CPD and other support developments. The British Society for Research in the Learning of Mathematics provides one possible partner for the national centre in taking this forward. The Inquiry has also noted the recent significant investment by the Economic and Social Research Council in mathematics projects within its Teaching and Learning Research Programme. The Inquiry believes that the new infrastructure will wish to work closely with these and other partners in developing a research and development evaluation and dissemination capacity.

Recommendation 6.11

The Inquiry recommends that the remit of the national infrastructure for the support of the teaching and learning of mathematics include the responsibility and resource for providing a national forum for the evaluation, synthesis and dissemination of research and development findings in the field of mathematics education in order to provide an evidence base to inform policy and practice.

Remit and responsibilities of the national and regional centres

6.56 The Inquiry has considered the option of only establishing a single national centre, directly working with schools through the LEAs, thus obviating the need for regional centres. We have rejected this option on two broad grounds. First, the breadth and depth of the post-16 curriculum far exceed those of the KS1-3 curricula and we do not believe that a local consultant based CPD delivery model similar to those of the Numeracy and KS3 strategies would be appropriate or feasible, given the very wide-ranging CPD needs post-16. Secondly, we have received overwhelming endorsement from respondents to the Inquiry of the need to build and sustain local communities and networks. These should not just be concerned with CPD delivery, but should also serve to bring together a wide range of stakeholders in support of all aspects of the teaching and learning of mathematics and also wider issues of profile raising, awareness and career advice. This led us to Recommendation 5.4, which we now follow up in more detail.

Recommendation 6.12

The Inquiry recommends that the national infrastructure for the support of the teaching and learning of mathematics consist of:

- a National Centre for Excellence in the Teaching of Mathematics (NCETM) to provide expert advice, resources and information in support of the teaching of mathematics, and to oversee the funding for the development and dissemination of mathematics CPD provision at a strategic level and to coordinate its operation nationally;
- a network of Regional Mathematics Centres (RMCs) to encourage the formation of local communities of teachers of mathematics and relevant stakeholders across all phases and to oversee and coordinate local delivery of CPD.

Recommendation 6.13

The Inquiry recommends that the NCETM should:

- provide a forum to bring together all major groups and agencies involved in mathematics education, including from England the DfES, National Strategies, QCA, Ofsted, LEAs, HEIs, LSC, SSCs, ACME, ITT providers, together with equivalent groups and agencies from those territories which choose to be part of the NCETM;
- work with the GTC, TTA and other appropriate groups, including the relevant groups from those territories which choose to be part of the NCETM, to ensure national cohesion in mathematics CPD provision and accreditation;
- incorporate the current CPD work and funding of the NN and KS3 Strategies;
- work closely with the RMCs to provide a centre of expertise for research and development and the commissioning and dissemination of CPD and learning and teaching materials, including distance learning materials and materials to enhance the teaching of mathematics through the use of ICT;
- work closely with the RMCs to ensure an adequate supply of "expert teachers" to provide mentoring and support to local schools and colleges;
- coordinate and monitor CPD delivery provided by the RMCs;
- provide a national forum for the evaluation, synthesis and dissemination of research and development findings in the field of mathematics education;
- provide a database and act as an archive for exemplary teaching and learning and CPD resources and research and development findings;
- support and encourage the further development and dissemination of existing mathematics enhancement and distance-learning initiatives;
- foster international links and collaborative exchanges in relation to research and development in mathematics education.

Recommendation 6.14

The Inquiry recommends that the RMCs should:

- be located one in each of the 9 English regions as defined by RDAs, with possible additional national centres in Wales, Northern Ireland and Scotland;
- have formal close working relationships in England with local LEAs and Numeracy and KS3 Strategy regional directors, and with equivalent bodies and individuals from those territories which choose to establish a RMC;
- provide a forum for school, college, FE and HE local links and joint working;
- provide a forum for links and joint working among education providers and teachers, and employers, including RDAs, local LSCs, SETNET, Education and Business Partnerships and equivalent territorial agencies;
- provide support for local networks within the regional networks, building on existing local networks, including mathematics teacher associations, mathematics specialist schools networks, the LTSN for Mathematics, the regional and local activities of the mathematics professional and learned societies, the OU and other HEIs;
- work with the NCETM to deliver CPD regionally/locally for teachers of mathematics (including those teaching other disciplines or vocational subjects) and those who support mathematics teaching across all age groups;
- work with the NCETM to provide a regional/local CPD research and development and dissemination capability in mathematics education;
- provide a regional/local source of expert advice and information on all aspects of the teaching of mathematics;
- provide infrastructure support for quality assured schemes for bringing HE students into the classroom (see, also, Recommendation 6.3);
- together with the NCETM, develop and promulgate programmes and projects aimed at raising the profile of mathematics with pupils, teachers, careers advisers, parents, employers and the public.

Funding requirements for the NCETM and the RMCs

6.57 The Inquiry has been asked by the Secretary of State to give an indication of the scale of funding required for the national support infrastructure in England. In terms of the proposed NCETM and RMCs, we shall approach this by comparison with related existing activities. Throughout, we assume that if the existing strategies in England are incorporated into the new infrastructure, existing funding will be made available to the NCETM and RMCs. The discussion that follows therefore refers only to additional funding relating to the new (ie not existing strategy) roles of the NCETM and RMCs in England.

6.58 We note, for example, that as part of the National Network of Science Learning Centres, the proposed National Science Learning Centre (funded by the Wellcome Trust) has a ten year funding horizon, with a total capital contribution of £10M over the first three and a recurrent contribution of £15M over the period. The focus is directed primarily towards subject leaders.

6.59 The proposed 9 Regional Science Learning Centres (funded by the DfES) have a five year funding horizon, with a capital total of £11M over the first three years and a recurrent contribution of £15M over the period.

6.60 The National Numeracy Strategy (for primary school teachers) has been funded at the level of around £100M per annum for each of the past four years. Of this, around £21M has supported consultants and associated administration costs; £10M has funded a leadership programme; and most of the rest has funded training and direct school interventions. The current costing for delivery (not including central costs) is £175 per training day per teacher. In addition, there is a central team responsible for writing training materials, briefing the LEA consultants on the materials and overseeing the local delivery.

6.61 The KS3 Strategy (consisting of 5 subject strands and aimed at teachers of 11-14 year olds) has been funded at the level of £220M per annum. Of this, as direct expenditure on mathematics one can identify about £14M for subject specific expert consultants employed by LEAs; about £14M to schools to access training; and out of the £20M spent on the central management of the strategy (including development of teaching and learning materials and monitoring of the delivery) around £3–4M.

6.62 If currently small-scale pilot projects like the Millenium Mathematics Project, the MEI Further Mathematics project and the Thomas Telford online mathematics course developments are to achieve significant penetration of the school population, they would need significant scaling-up (perhaps by factors of 20). The scaling up of funding would not necessarily be linear, but, for example, we note that the MEI project has been funded at the level of £360K over 3 years by the Gatsby Educational Trust and the cost of producing the on-line GCSE courses by Telford school has been £700K, funded thus far by the HSBC Education Trust.

6.63 The relevant aspects of these comparisons for the envisaged remit of the NCETM are those pertaining to initial set-up (refurbishment and ICT provision), the costs of a central team and overheads and the costs of the production and dissemination of materials for CPD. In what follows, we assume throughout that the funding for actual CPD delivery, teacher release, etc, will be assigned to the budget for the RMCs.

6.64 For the NCETM, in addition to the incorporation of staff from the existing strategies, we envisage the appointment of a (high profile) director, together with an executive core of around 8 senior and 4 support staff (comparable in full time equivalent staff numbers to the Numeracy and KS3 central

directing teams). We further envisage that the scale of operation for new post-14 provision over an initial five-year horizon (with a front loading to the first three years) will be at least as great as that of the KS3 operation. This takes into account the greater complexity and diversity of post-14 qualifications and the developing and disseminating of materials to cover all the needs both for CPD aimed at non-specialists and at specialists. It also recognises the potential need for more emphasis on distance delivery to overcome the recognised problem of releasing mathematics teachers from schools and FE Colleges.

6.65 These comparisons suggest that the start-up funding requirements for the NCETM (refurbishment of offices, archive/library, meeting and seminar rooms, ICT, including broad-band and video-conferencing facilities) over and above requirements arising from the incorporation of the existing strategies are likely to be similar to those of the regional science centres, but with an additional premium in recognition of providing a national library/archive; ie around £2.5M for the first year.

6.66 These comparisons also suggest that the recurrent funding required to achieve initial comprehensive coverage of the development and dissemination needs for CPD and the other elements listed above for the remit of the NCETM over a five year time horizon is likely to be of the order of £4.5M recurrent for each of the first three years. Thereafter, recurrent funding of £2M might suffice to sustain a steady-state operation.

6.67 Clearly, these recurrent funding needs can be reduced by extending the time horizon over which it is aimed to achieve complete coverage of initial CPD needs and/or by scaling down the remit of the NCETM. However, the Inquiry believes that this would be unwise. There is considerable urgency in tackling the teaching skills deficit and we are mindful that the Secretary of State has indicated that the centre should serve the needs of teachers of mathematics across the whole spectrum.

Recommendation 6.15

The Inquiry recommends that, in addition to the transfer of funding from the existing strategies, the funding provision for the first five years of the NCETM should be of the order of £7M in year 1, £4.5M in years 2, 3 and £2M in years 4, 5, giving a total of £20M over 5 years.

6.68 For the RMCs, in addition to the staff funded by the existing NN and KS3 strategies, we envisage that each of the nine English RMCs would have a core full time equivalent staff of the order of 2.5 senior and 4 support staff. This suggests something of the order of £400K start-up funding (refurbishment of offices, meeting and seminar rooms, ICT, including broad-band and video-conferencing facilities), and 300K annual direct running costs for each RMC.

6.69 The major expenditure in the RMCs will be on CPD delivery. There are currently around 25,000 teachers of mathematics in secondary schools. We have found it impossible to quantify properly the number of teachers of mathematics in FE because mathematics pervades so many aspects of the post-16 curriculum. However, respondents have felt that 10–15,000 teachers of mathematics in FE Colleges is probably a reasonable estimate. In addition, there is some need for mathematics CPD for those teaching mathematics in other disciplines and in vocational courses.

6.70 Suppose, therefore, for the purpose of a baseline calculation, we were to take 25,000 as the (conservative) target population for new CPD provision (assuming that a fraction in secondary schools will continue to receive CPD under the KS3 strategy funding and that CPD funding currently related to the current Key Skills agenda will be available for many in FE – although we understand that currently this funding is not accessed by the majority of mathematics teachers in FE). Suppose further that we were to aim – inadequately in the view of many respondents to the Inquiry – to provide everyone in the cohort with the equivalent of an average of 6 days CPD per annum (not necessarily provided in out-of-school "6 day course" form and probably varying from 0 to 12 days in actual individual CPD need).

6.71 Using the guideline figure of £175 per teacher per day provided by the Numeracy Strategy, this suggests, based on a 6 day per annum assumption, an annual recurrent cost for training of £26.25M (pro rata, just under £3 M per RMC). There will also be an element of RMC recurrent cost for support of other activities within the remit of the RMCs. This is likely to be of the order of £100K per RMC.

Recommendation 6.16

The Inquiry recommends that, in addition to the transfer of funding from the existing strategies, the funding provision for the first five years of the RMCs should be at least of the order of £27M in year 1 and £26.6M in years 2, 3, 4, 5, giving a total of some £133.4M over 5 years.

The governance of the NCETM and the RMCs

6.72 The Inquiry has sought opinions on appropriate governance arrangements for the NCETM and the RMCs. We have received the clear message that the composition of the governing body should reflect the wide range of stakeholders identified during the Inquiry, but should also have a majority of members drawn from bodies representing the mathematics and mathematics teaching communities.

6.73 The Inquiry has identified the following government department and agency key stakeholders in England (these would need to be augmented by equivalent bodies for any territories that choose to be part of the NCETM and choose to establish a RMC):

- the DfES will clearly play a key role in funding the new infrastructure and will necessarily have a role in overseeing the set up process and subsequent governance of the national and regional centres;
- the LSC plays a key role in overseeing mathematics teaching in Sixth Form and FE colleges;
- the QCA currently has the remit to write, develop and keep under review the national curriculum; its role in assessment, curriculum and qualifications development also make its work of key interest to mathematics teachers; QCA has established stakeholder networks and contacts and has pioneered joint working between schools, colleges and HE in developing materials in algebra and geometry;
- Ofsted is charged with inspection and evaluation of the quality of delivery of teaching in schools and colleges and of ITT provision;
- the GTC has specific responsibility for providing advice to the Secretary of State for Education and Skills on the training, career development and performance measurement of teachers;
- the TTA is responsible for the recruitment and retention of teachers, funds ITT and uses inspection outcomes to determine which ITT courses are allowed to continue;
- LEAs, through mathematics specialists, play key roles in relation to local networks and delivery;
- the NN and KS3 strategies play key roles and we have already made clear (Recommendation 6.2) the Inquiry's view that the existing strategies should be incorporated into the new infrastructure;
- relevant departments of HEIs must also become key stakeholders.

6.74 In addition, there are a number of subject associations in mathematics, whose members include many of the most active and innovative members of the teaching and advisory profession in mathematics. These associations are also key stakeholders. The two main associations for school and college teachers are the Mathematics Association (MA) and the Association of Teachers of Mathematics (ATM). The MA individual membership consists almost entirely of secondary school or college teachers of mathematics. The ATM has a larger primary membership, but there are still many more secondary members in ATM than primary teachers. There are also three other associations with teacher/adviser members: the National Association of Mathematics Advisers (NAMA), whose members typically work at LEA level as inspectors, advisers or as consultants for the NN or KS3 strategies; the National Association for Numeracy and Mathematics in Colleges (NANAMIC) and the Association of Mathematics Education Teachers (AMET); these associations also have some members in HEIs.

6.75 There are also key stakeholders among the professional and learned societies representing the various sub-areas of the discipline of mathematics: the London Mathematical Society (LMS), the Institute of Mathematics and its Applications (IMA) and the Royal Statistical Society (RSS). These bodies operate on a UK-wide basis and the IMA has strong links with representatives of engineering interests in HE and national professional bodies. The Presidents of the four learned and professional bodies together form the Council for Mathematical Sciences, which serves as a policy discussion forum for issues of common concern. In addition, Scotland has the Edinburgh Mathematical Society and the Scottish Mathematics Council. Also, the Education Committee of the Royal Society (RS) has within its UK-wide remit an interest in mathematics education.

6.76 These associations are brought together under the umbrella of the Joint Mathematics Council of the UK (JMC). The Advisory Committee for Mathematics Education (ACME) is a more recently formed body empowered by the constituent bodies of the JMC to speak with authority on behalf of the mathematics community on matters pertaining to mathematics education. Respondents to the Inquiry have argued strongly that ACME should be closely involved in the governance of the national support infrastructure. The Inquiry supports this view and we shall return to this in the context of our detailed recommendation concerning the national infrastructure and its governance (Recommendation 6.17).

6.77 Employers are clearly key stakeholders in the new infrastructure. Recently, it has been decided that the new sector skills council for science, engineering and manufacturing technologies, SEMTA, is to lead on mathematics on behalf of the sector skills councils. SEMTA is currently in the process of establishing a new Mathematics Forum, which will include representatives of relevant awarding bodies, regulatory authorities and government. The role of the Forum will be to provide a means through which employers can help shape future developments of all aspects of the mathematics curriculum, assessment, standards, qualifications and quality assurance. In addition to the national role to be played by SEMTA and the Mathematics Forum in representing employers, at a local level the interests of employers will increasingly be reflected in the work of the RDAs.

Recommendation 6.17

The Inquiry recommends that, following an appropriate process of consultation, as the first step towards the establishment of the centres for England the DfES appoint and provide a secretariat for a council, to be responsible for overall policy and priorities for the NCETM and RMCs within the remit identified in the Inquiry's Recommendations 6.13 and 6.14. The Inquiry further recommends that the DfES channel funding for the NCETM and the RMCs through the council, which should be accountable to the DfES for its use. The council should represent the wide range of stakeholders we have identified and the Inquiry recommends that over half of the membership should be appointed on the advice of ACME.

The location and management of the NCETM and the RMCs

6.78 The Inquiry has considered carefully the options for selecting the locations and managements of the centres. As we have indicated on several occasions, respondents to the Inquiry overwhelmingly favour consortia-based models for the management of the NCETM and the RMCs. The Inquiry fully supports this view and believes that the selection of locations and managements of the centres should be made on the basis of an open bidding process

Recommendation 6.18

The Inquiry recommends that the locations and managements of the NCETM and the RMCs in England be selected by a process which invites consortia bids to deliver the agendas set out in Recommendations 6.13 and 6.14 and to provide appropriate management and administrative infrastructure for the running of the centres. Consortia will need to incorporate an appropriate range of national and local stakeholders. This bidding process should be overseen by the DfES, advised by the appointed governing council for the NCETM and the RMCs.

APPENDIX 1: LIST OF RECOMMENDATIONS BY CHAPTER

Chapter 1: The importance of mathematics

Recommendation 1.1

The Inquiry recommends that in England a high-level post be created in the DfES with dedicated subject-specific responsibility for mathematics. The Inquiry further recommends that in England a joint forum be created between the DfES and the LSC through which high-level officers in the DfES and LSC with subject-specific responsibilities for mathematics are charged with overseeing coherent strategy for 14-19 mathematics education.

Recommendation 1.2

The Inquiry recommends that, in order to enable ACME to play an important extended role, including taking forward a number of the Inquiry's recommendations, substantial Government funding be made available to ACME. We recommend that this be channelled, as is existing funding, through the Royal Society, in order to enable ACME to retain its standing as an independent voice acting on behalf of the mathematics education community.

Recommendation 1.3

The Inquiry recommends that the UK mathematics learned and professional societies form an Advisory Committee on Mathematics Research and Industry (ACMRI), which would be empowered to speak on behalf of the community to Government and others on strategic level issues concerning the role of mathematics in the economy and society, complementing ACME's role in relation to mathematics education. The Inquiry suggests that it would be valuable to also have a joint Advisory Committee for Mathematics (ACM), formed from representatives of ACME and ACMRI, to speak on behalf of the community on general strategic issues concerning mathematics.

Chapter 2: The supply of teachers of mathematics

Recommendation 2.1

The Inquiry recommends that the DfES undertake a review of school level resource management of qualified mathematics teachers in England. This review should include an assessment of whether current career paths and rewards provide appropriate incentives for qualified mathematics teachers to continue teaching mathematics. The LSC might wish to consider a similar exercise regarding the deployment of qualified mathematics teachers in colleges.

Recommendation 2.2

The Inquiry recommends that the DfES and the LSC work together and with the TTA to review the frequency and scope of data collection relating to mathematics teacher and teacher trainer numbers and qualifications. They should seek to agree a data collection strategy that will provide the evidence base for a coherent policy approach to the supply of appropriately qualified teachers for the teaching of mathematics across all secondary schools, sixth form and further education colleges, and of appropriately qualified ITT mathematics trainers. In particular, the Inquiry recommends that:

(i) a revised form of SSCSS, requiring a mandatory response, should be designed and undertaken as soon as possible to cover not only secondary schools, including those in the independent sector, but also sixth form and further education colleges and providers of mathematics ITT;

(ii) categories of response be redefined, along similar lines to the Cockcroft categorisation, to provide a clearer indication of teacher qualifications;

(iii) the breakdown of qualifications should be available separately for the those teaching key skills, KS3, KS4 and post–16;

(iv) in view of the current critical position in regard to provision of teachers of mathematics and the need for close monitoring of policy initiatives to improve recruitment and retention, at least the first three new surveys should be undertaken every two years.

Recommendation 2.3

The Inquiry recommends that at the earliest possible opportunity forecasts of future teacher training number requirements for mathematics teachers be re-examined in the light of:

- the estimate we have suggested of a current shortfall of at least 3,400 qualified mathematics teachers in secondary schools;
- the age profile findings from the 2002 SSCSS;
- and taking into account the current position and future needs of independent schools, Sixth form and FE Colleges, in addition to secondary schools.

Recommendation 2.4

The Inquiry recommends that the DfES give high priority to encouraging and funding a significant increase in the number of mathematics graduates admitted to the Fast Track Scheme and, in particular, a significant increase in the number of mathematics ASTs.

Recommendation 2.5

The Inquiry recommends that the current TTA enhancement programmes for graduates be evaluated carefully and that additional resources be made available to support and reinforce successful programmes in mathematics. The Inquiry further recommends that the TTA should consider introducing enhancement programmes that offer non-graduate career changers opportunities, including bursaries, to complete graduate mathematics course and secure QTS. The Inquiry recommends that, subject to appropriate quality assurance, the DfES give high priority to providing any extra resources required by the TTA in expanding mathematics enhancement programmes.

Recommendation 2.6

The Inquiry recommends that consideration be given to the introduction of new mathematics teacher certification schemes, aimed at increasing the overall supply of teachers appropriately qualified to teach at least some part of the curriculum.

Recommendation 2.7

The Inquiry recommends that a significant number of places in the Student Associate Scheme be earmarked for undergraduates on degree courses in mathematics or courses involving a substantial component of mathematics. We encourage the TTA to work closely with the Committee of the Heads of Departments of Mathematical Sciences (HoDMS) and others in higher education to continue to raise the level of awareness of the scheme among relevant undergraduates.

Recommendation 2.8

The Inquiry recommends that more must be done to address the issue of pay and other incentives to teachers of mathematics and other shortage subjects (see, also, Recommendation 5.2).

Chapter 4: Action on current and future mathematics pathways

Recommendation 4.1

The Inquiry recommends that, subject to the present pilot being fully and successfully evaluated, immediate consideration be given by the QCA and its regulatory partners to moving as soon as is practicable to a two-tier system of overlapping papers for GCSE Mathematics in England, Wales and Northern Ireland. The Inquiry recommends that the regulatory authorities try to recruit more schools and colleges to take part in pre-implementation piloting after summer 2004.

Recommendation 4.2

The Inquiry recommends that, at the earliest possible opportunity, consideration should be given by the QCA and its regulatory partners to re-designating GCSE Mathematics, appropriately modified if necessary, to merit a double award at level 2. This re-designation should be considered in tandem with the possible move to a two-tier system (see Recommendation 4.1).

Recommendation 4.3

The Inquiry recommends that there should be an immediate review by the QCA and its regulatory partners of the quantity of coursework in GCSE mathematics and, in particular, the data handling component, with a view to reducing the amount of time spent on this specific element of the course. (See, also, Recommendation 4.4)

Recommendation 4.4

The Inquiry recommends that there should be an immediate review by the QCA and its regulatory partners of the future role and positioning of Statistics and Data Handling within the overall 14–19 curriculum. This should be informed by: (i) a recognition of the need to restore more time to the mathematics curriculum for the reinforcement of core skills, such as fluency in algebra and reasoning about geometrical properties and (ii) a recognition of the key importance of Statistics and Data Handling as a topic in its own right and the desirability of its integration with other subject areas (see, also, Recommendation 4.11).

Recommendation 4.5

The Inquiry recommends that the QCA and its regulatory partners should be funded to develop an extension curriculum and assessment framework for more able pupils at Key Stages 3 and 4. This extension curriculum should be firmly rooted in the material of the current Programmes of Study, but pupils should be presented with greater challenges. These should involve harder problem solving in non-standard situations, a greater understanding of mathematical inter-connectedness, a greater facility in mathematical reasoning (including proof) and an ability to engage in multi-step reasoning and more open-ended problem solving (see, also, Recommendation 4.11).

Recommendation 4.6

The Inquiry recommends that QCA and its regulatory partners undertake a comparative review and make appropriate re-designations as necessary, to ensure that claimed equivalences of levels of mathematics qualifications are well founded.

Recommendation 4.7

The Inquiry recommends that the QCA and its regulatory partners undertake an immediate review of current problems of delivery, content, assessment and availability of courses at levels 1 – 3 provided by FSMQs, AS Use of Mathematics, AoN and Adult Numeracy. The aim of the review should be to identify scope for improvements in and potential rationalisation of this provision, including opportunities for more systematic integration of ICT in teaching and learning, as part of the longer-term design of a new 14–19 pathway structure for mathematics (see, also, Recommendation 4.11).

Recommendation 4.8

The Inquiry recommends that the effects of the introduction of the revised specifications for GCE be closely monitored by the QCA and its regulatory partners as a matter of high priority and that funding be made available to support this. If there is no significant restoration of the numbers entering AS and A2 mathematics within the next two or three years, the Inquiry believes the implications for the supply of post–16 qualified mathematics students in England, Wales and Northern Ireland to be so serious that consideration should be given by the DfES and the relevant devolved authorities to offering incentives for students to follow these courses. One possible form of incentive could take the form of financial incentives to HEIs to include AS or A-level mathematics as a prerequisite for certain degree courses. Another possibility might be to offer financial incentives directly to students following such course in HEIs, possibly through fee waivers or targeted bursaries.

Recommendation 4.9

The Inquiry recommends that the QCA and its regulatory partners conduct an immediate review of the frequency and style of current GCE assessment, with a view to reducing the time spent on external examinations and preparation for examinations.

Recommendation 4.10

The Inquiry recommends that there should be an immediate review by the DfES, LSC and the relevant devolved authorities of measures that could be taken to support and encourage current GCE course provision for the most able mathematics students. In particular, we believe there is a need to ensure that there are no funding disincentives in schools and colleges for providing access to Further Mathematics and the Advanced Extension Award in Mathematics We also believe that consideration should be given employing the same incentives as suggested in Recommendation 4.8.

Recommendation 4.11

The Inquiry recommends that funding be provided to the QCA and its regulatory partners to commission, through an open bidding process, up to three curriculum and assessment development studies of variants of these pathway models and approaches, including trialling, feedback and modification and an assessment of the workload implications. These studies should take on board developments arising from Recommendations 4.4, 4.5 and 4.7. The aim of this exercise will be to inform the selection of a preferred pathway model to form part of the reformed 14–19 structure in England and possible parallel developments in Wales and Northern Ireland. Given the importance of ensuring the widest possible involvement and commitment of the mathematics community to the outcome, the Inquiry recommends that the regulatory authorities work in partnership with ACME and mathematics community representatives from Wales and Northern Ireland, and that the DfES and relevant devolved authorities provide appropriate funding to support this.

Chapter 5: Support for the teaching and learning of mathematics

Recommendation 5.1

The Inquiry recommends to the DfES and the LSC, and the devolved authority in Northern Ireland, that formal responsibility for and entitlement to fully funded CPD be introduced as soon as possible into the professional conditions of service for teachers of mathematics in schools and colleges in England, Wales and Northern Ireland. In the light of what we perceive to be far greater problems with the teaching of mathematics in England and Wales as compared with Scotland, the Inquiry further recommends that the number of contractual hours of CPD in such formal entitlement in England and Wales be significantly greater than the provision made in the agreement *A Teaching Profession for the 21st Century in Scotland*.

Recommendation 5.2

The Inquiry recommends to the DfES and the LSC that additional remuneration be linked to mathematics teachers' successful completion of accredited CPD activities and opportunities, thereby rewarding those teachers of mathematics who make particular efforts to improve further their subject knowledge and teaching effectiveness.

Recommendation 5.3

The Inquiry recommends that there be long-term investment in a national infrastructure to oversee the provision of subject specific CPD and other forms of support for teachers of mathematics, tailored to the needs of teachers of mathematics, both specialist and non-specialist, including leaders in mathematics teaching. A detailed discussion of possible options for such infrastructure support will follow in paragraphs 6.56-78, together with the Inquiry's recommended option.

Recommendation 5.4

The Inquiry recommends that the national support infrastructure for the teaching and learning of mathematics take the form of a national centre providing strategy and coordination, together with regional centres providing local support and networking.

Chapter 6: National and regional support infrastructure

Recommendation 6.1

The Inquiry recommends that the work of the National Numeracy Strategy and the mathematics strand of the KS3 Strategy be continued and built upon, and that resources for mathematics are ring-fenced for any future form of successor to these strategies for KS1-3.

Recommendation 6.2

The Inquiry recommends that the existing mathematics strand of the KS3 Strategy be incorporated into the national support infrastructure and that the existing funding for this strategy be brought under the auspices of the infrastructure. The Inquiry also recommends that serious consideration be given to similarly incorporating the National Numeracy Strategy. The Inquiry further recommends that, on incorporation, a review of the content and delivery of the strategies be carried out under the auspices of the new infrastructure.

Recommendation 6.3

The Inquiry recommends that a programme be established to pay selected volunteer undergraduate and postgraduate students in disciplines with high mathematical content to support teachers of mathematics in schools and colleges. Payment should be on a competitive basis with other sources of employment open to such students. The precise nature of the support role should be for schools, colleges and universities to decide locally. (See also Recommendation 6.14, ninth bullet point.) It will be important to ensure that those participating have the appropriate skills and training.

Recommendation 6.4

The Inquiry recommends that the remit of the new national support infrastructure include responsibility for auditing existing ICT provision for mathematics in schools and colleges, assessing the need and potential for future ICT provision in support of the teaching and learning of mathematics and advising the DfES and the LSC on ICT investment requirements for mathematics in schools and colleges.

Recommendation 6.5

The Inquiry recommends that the national support infrastructure provide appropriate resources to enable the Committee of Heads of Departments of Mathematical Sciences in HEIs in the UK (HoDoMS) to work together with the LTSN Mathematics, Statistics and Operations Research Network to seek ways to promote sustainable closer links between HEI mathematics (and other relevant) departments and mathematics teachers in their local schools and colleges.

Recommendation 6.6

The Inquiry recommends that in the detailed planning of the national support infrastructure for the teaching and learning of mathematics particular attention should be given to involving the relevant experience and expertise of the Open University.

Recommendation 6.7

The Inquiry recommends that overall strategy for and coordination of the networking and other CPD developments relating to the mathematics elements of specialist schools be brought under the auspices of the national support infrastructure for the teaching and learning of mathematics.

Recommendation 6.8

The Inquiry recommends that the remit of the national infrastructure include responsibility for encouraging and evaluating independent initiatives in the teaching and learning of mathematics and for funding and managing dissemination of successful initiatives more widely across the school and college system. The Inquiry recommends that the overall resources provided for the national and regional centres include specific funding for this purpose.

Recommendation 6.9

The Inquiry recommends that the national infrastructure work with SETNET to improve the provision of mathematics enrichment and careers advice resources provided through SETNET and that appropriate funding be made available either through SETNET or the national infrastructure to support this development.

Recommendation 6.10

The national infrastructure for the support of the teaching and learning of mathematics should set up formal collaborative links with the NRDC, with a view to exploring how best to support teachers of adult numeracy.

Recommendation 6.11

The Inquiry recommends that the remit of the national infrastructure for the support of the teaching and learning of mathematics include the responsibility and resource for providing a national forum for the evaluation, synthesis and dissemination of research and development findings in the field of mathematics education in order to provide an evidence base to inform policy and practice.

Recommendation 6.12

The Inquiry recommends that the national infrastructure for the support of the teaching and learning of mathematics consist of:

- a National Centre for Excellence in the Teaching of Mathematics (NCETM) to provide expert advice, resources and information in support of the teaching of mathematics, and to oversee the funding for the development and dissemination of mathematics CPD provision at a strategic level and to coordinate its operation nationally;
- a network of Regional Mathematics Centres (RMCs) to encourage the formation of local communities of teachers of mathematics and relevant stakeholders across all phases and to oversee and coordinate local delivery of CPD.

Recommendation 6.13

The Inquiry recommends that the NCETM should:

- provide a forum to bring together all major groups and agencies involved in mathematics education, including from England the DfES, National Strategies, QCA, Ofsted, LEAs, HEIs, LSC, SSCs, ACME, ITT providers, together with equivalent groups and agencies from those territories which choose to be part of the NCETM;
- work with the GTC, TTA and other appropriate groups, including the relevant groups from those territories which choose to be part of the NCETM, to ensure national cohesion in mathematics CPD provision and accreditation;
- incorporate the current CPD work and funding of the NN and KS3 Strategies;
- work closely with the RMCs to provide a centre of expertise for research and development and the commissioning and dissemination of CPD and learning and teaching materials, including distance learning materials and materials to enhance the teaching of mathematics through the use of ICT;
- work closely with the RMCs to ensure an adequate supply of "expert teachers" to provide mentoring and support to local schools and colleges;
- coordinate and monitor CPD delivery provided by the RMCs;
- provide a national forum for the evaluation, synthesis and dissemination of research and development findings in the field of mathematics education;
- provide a database and act as an archive for exemplary teaching and learning and CPD resources and research and development findings;
- support and encourage the further development and dissemination of existing mathematics enhancement and distance-learning initiatives;
- foster international links and collaborative exchanges in relation to research and development in mathematics education.

Recommendation 6.14

The Inquiry recommends that the RMCs should:

- be located one in each of the 9 English regions as defined by RDAs, with possible additional national centres in Wales, Northern Ireland and Scotland;
- have formal close working relationships in England with local LEAs and Numeracy and KS3 Strategy regional directors, and with equivalent bodies and individuals from those territories which choose to establish a RMC;
- provide a forum for school, college, FE and HE local links and joint working;
- provide a forum for links and joint working among education providers and teachers, and employers, including RDAs, local LSCs, SETNET, Education and Business Partnerships and equivalent territorial agencies;
- provide support for local networks within the regional networks, building on existing local networks, including mathematics teacher associations, mathematics specialist schools networks, the LTSN for Mathematics, the regional and local activities of the mathematics professional and learned societies, the OU and other HEIs;
- work with the NCETM to deliver CPD regionally/locally for teachers of mathematics (including those teaching other disciplines or vocational subjects) and those who support mathematics teaching across all age groups;
- work with the NCETM to provide a regional/local CPD research and development and dissemination capability in mathematics education;
- provide a regional/local source of expert advice and information on all aspects of the teaching of mathematics;
- provide infrastructure support for quality assured schemes for bringing HE students into the classroom (see, also, Recommendation 6.3);
- together with the NCETM, develop and promulgate programmes and projects aimed at raising the profile of mathematics with pupils, teachers, careers advisers, parents, employers and the public.

Recommendation 6.15

The Inquiry recommends that, in addition to the transfer of funding from the existing strategies, the funding provision for the first five years of the NCETM should be of the order of £7M in year 1, £4.5M in years 2, 3 and £2M in years 4, 5, giving a total of £20M over 5 years.

Recommendation 6.16

The Inquiry recommends that, in addition to the transfer of funding from the existing strategies, the funding provision for the first five years of the RMCs should be at least of the order of £27M in year 1 and £26.6M in years 2, 3, 4, 5, giving a total of some £133.4M over 5 years.

Recommendation 6.17

The Inquiry recommends that, following an appropriate process of consultation, as the first step towards the establishment of the centres for England the DfES appoint and provide a secretariat for a council, to be responsible for overall policy and priorities for the NCETM and RMCs within the remit identified in the Inquiry's Recommendations 6.13 and 6.14. The Inquiry further recommends that the DfES channel funding for the NCETM and the RMCs through the council, which should be accountable to the DfES for its use. The council should represent the wide range of stakeholders we have identified and the Inquiry recommends that over half of the membership should be appointed on the advice of ACME.

Recommendation 6.18

The Inquiry recommends that the locations and managements of the NCETM and the RMCs in England be selected by a process which invites consortia bids to deliver the agendas set out in Recommendations 6.13 and 6.14 and to provide appropriate management and administrative infrastructure for the running of the centres. Consortia will need to incorporate an appropriate range of national and local stakeholders. This bidding process should be overseen by the DfES, advised by the appointed governing council for the NCETM and the RMCs.

APPENDIX 2: BACKGROUND AND TERMS OF REFERENCE

The Inquiry was announced, by the Chief Secretary of the Treasury, in July 2002, as part of the Government's response *Investing in Innovation* to Sir Gareth Roberts' UK wide review *Set for Success: The supply of people with science, technology, engineering and mathematics skills*.

Professor Adrian Smith FRS, Principal of Queen Mary, University of London, was appointed as Chair of the Post–14 mathematics Inquiry in November 2002.

The terms of reference of the Inquiry are:

> *"To make recommendations on changes to the curriculum, qualifications and pedagogy for those aged 14 and over in schools, colleges and higher education institutions to enable those students to acquire the mathematical knowledge and skills necessary to meet the requirements of employers and of further and higher education."*

The Inquiry has a UK wide remit and has taken evidence from over 300 organisations and 50 individuals in England, Northern Ireland, Scotland and Wales.

Steering Group

The members of the Inquiry's Steering Group were:

- Professor Eileen Baker
- Professor Sir Christopher Llewellyn-Smith FRS
- Sir Michael Lickiss
- Dr Gordon Marshall
- Dr Sir Thomas McKillop
- Professor Sir Gareth Roberts FRS
- Susan Singer
- Sir Peter Williams FRS

APPENDIX 3: GLOSSARY

This list includes abbreviations and acronyms commonly used throughout this report, as well as further information about some of the terms used.

A2	From September 2000, the second stage of GCE A level programme. Cannot be taken as a stand alone qualification, tied to the AS level
ACCAC	Awdurdod Cymwysterau Cwricwlwm ac Asesu Cymru/ Qualifications, Curriculum and Assessment Authority for Wales – is the body responsible in Wales for regulating external qualifications and keeping under review all aspects of the curriculum for compulsory school age pupils in maintained schools
ACME	Advisory Committee on Mathematics Education
AEA	Advanced Extension Award introduced for first examination in 2002 as part of C2K reforms
AoN	Application of Number, the numeracy qualification from the key skills suite, available at levels 1 to 4 in the National Qualifications Framework
AQA	Assessment and Qualifications Alliance, one of three Unitary Awarding Bodies in England
AS Level	Introduced for first teaching from September 2000, GCE Advanced Subsidiary Level, can be taken as a stand alone qualification or as the first stage in an A level course
AST	Advanced Skills Teacher – teachers who are deemed 'excellent' in a range of skills' in which they train colleagues
BA	Bachelor of Arts, first degree
BEd	Bachelor of Education, first degree
BSc	Bachelor of Science, first degree
C2K	Curriculum 2000 – *Qualifying for Success* reforms introduced for first teaching in September 2000
CCEA	Council for the Curriculum, Examinations and Assessment is the body responsible in Northern Ireland for advising Government on what should be taught in schools, monitoring standards of qualifications and examinations and awarding qualifications
CPD	Continuing Professional Development

DfES	Department for Education and Skills
Edexcel	London Qualifications Ltd (formerly Edexcel Foundation) one of three Unitary Awarding Bodies in England
ELB	Education and Library Boards (NI only)
FE	Further Education
FSMQ	Free Standing Mathematics Qualification – suite of Mathematical Qualifications available at levels 1 to 3 in the National Qualifications Framework
GEST	Grants for Education, Support and Training (CPD programme in Wales)
GCE	General Certificate of Education, comprising AS and A2, is a key qualification at level 3 of the NQF and primarily taken post-16
GCSE	General Certificate of Secondary Education a key qualification spanning levels 1 and 2 of the NQF and primarily taken at the end of Key Stage 4
GNVQ	General National Vocational Qualification available at levels 1 and 2 of NQF
GTC	General Teaching Council for England
GTCNI	General Teaching Council for Northern Ireland
GTCS	General Teaching Council for Scotland
GTCW	General Teaching Council for Wales
GTP	Graduate Teacher Programme – this programme is designed to allow schools to employ unqualified teachers who are preparing for QTS assessment, assess them against the standards for the award of QTS, and devise individual training plans for them.
GTTR	Graduate Teacher Training Registry
HE	Higher Education
HEIs	Higher Education Institutions – these encompass colleges of higher education as well as universities.
HoDMS	Heads of Departments of Mathematical Sciences
ICT	Information and Communication Technology
INSET	In-Service Education of Teachers
IT	Information Technology
ITT	Initial Teacher Training

KCL	King's College London (University of London)
JMC	Joint Mathematics Council
Key Stages	Introduced through the Education Reform Act 1988. Learning in maintained and special schools is divided into four periods of learning: key stage 1 covers pupils aged 5 to 7, key stage 2 covers pupils aged 7 to 11, key stage 3 covers pupils aged 11 to 14, key stage 1 covers pupils aged 14 to 16
KS 3 Strategy	Key Stage 3 Strategy introduced in 2000 is a multi strand approach which includes mathematics and is designed to support teachers, trainee teachers and others working to improve mathematics at Key Stage 3.
LEA	Local Education Authority
LSC	Learning and Skills Council
LTSN	Learning and Teaching Support Network
MEI	Mathematics in Education and Industry
MMP	Millennium Mathematics Project based at the Cambridge Centre for Mathematical Sciences
NAMA	National Association of Mathematics Advisers is a professional association with the aim of ensuring that inspection, advice and guidance and support make an effective contribution to mathematics education
NINS	Northern Ireland Numeracy Strategy
NNS	National Numeracy Strategy introduced in September 1999 to support teachers, trainee teachers and others working to improve numeracy in primary schools
NQF	National Qualifications Framework (see Appendix 4)
NQT	Newly Qualified Teacher
OCR	Oxford, Cambridge and RSA Examinations, one of three Unitary Awarding Bodies in England
OECD	Organisation for Economic Co-operation and Development
Ofsted	Office for Standards in Education (formally Office of Her Majesty's Chief Inspector of Schools in England).
OST	Office of Science and Technology
OTTP	Overseas Trained Teacher Programme
OU	The Open University

PGCE	Postgraduate Certificate in Education – a one year postgraduate qualification needed to teach in English state schools
PISA	Programme for International Student Assessment is a collaborative study among 28 member countries of OECD and 4 others to assess the knowledge and skills of 15 year olds in literacy, numeracy and science
POS	Programme of study in individual subjects of the National Curriculum taught during the four key stages
postgraduate	A student on a course which normally requires a first degree as a condition of entry
QCA	Qualifications and Curriculum Authority – is the body responsible in England for regulating external qualifications and keeping under review all aspects of the curriculum for compulsory school age pupils in maintained schools
QTS	Qualified teacher status required by teachers to work in maintained schools and special schools in England and Wales
RTP	Registered Teacher Programme – a DfES programme for people that have completed recognised teacher training overseas, and who have been accepted onto a UK course leading to a first degree (or equivalent qualification). Schools employ RTP trainees, working in partnership with HEIs, since participants must complete a degree at the same time as qualifying as a teacher. This programme requires maths, English and science standards.
SEAs	Science and Engineering Ambassadors programme – this is sponsored by DTI and DfES, and encourages scientists and engineers to help in schools
SET	Science, Engineering and Technology – includes mathematics for the purposes of this report
SETNET	Science Engineering Technology and Mathematics Network that represents Government, industry, the engineering professional associations, education and education charities to ensure that there is a flow of well-motivated, high quality people from schools to specialise in engineering-related subjects
SQA	Scottish Qualifications Authority is the national body in Scotland responsible for the development, accreditation, assessment and certification of qualifications other than degrees

TPLF	Teachers' Professional Learning Framework, produced by the GTC, it outlines the professional development opportunities that teachers should be entitled to
TTA	Teacher Training Agency
UCAS	Universities and Colleges Admissions Service
UCEA	Universities and Colleges Employers Association
undergraduate	Student working towards a first degree, higher education certificate or diploma or equivalent
VCE	Vocational Certificate of Education designed as a vocationally-related alternative to GCE A level at level 3 of NQF

APPENDIX 4: NATIONAL QUALIFICATIONS FRAMEWORK

Level of qualification	General		Vocationally related	Occupational
5	Higher-level qualifications BTEC Higher Nationals			Level 5 NVQ
4				Level 4 NVQ
3 advanced level	A level	Free-standing mathematics units level 3	Vocational A level (Advanced GNVQ)	Level 3 NVQ
2 intermediate level	GCSE grade A*–C	Free-standing mathematics units level 2	Intermediate GNVQ	Level 2 NVQ
1 foundation level	GCSE grade D–G	Free-standing mathematics units level 1	Foundation GNVQ	Level 1 NVQ
Entry level	Entry level certificate			