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Her Majesty's Inspectorate for Education and Training in Wales

Good practice in mathematics at key stage 4

October 2013

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Introduction

This report is published in response to a request for advice from the Welsh Government in the Minister's annual remit to Estyn for 2012-2013. The report examines standards in mathematics at key stage 4. Transition from key stage 4 to post-16 is outside the scope of the report. The report includes case studies of best practice.

The report is intended for the Welsh Government, headteachers/principals and staff in schools and local authorities. It may also be of interest to teacher trainers. While the report summarises the outcomes of key stage 3 and key stage 4 assessments nationally, the section that is a summary of standards of achievement does not present a national picture since the sample of schools visited as part of the survey is of schools where mathematics results are strong. The full range of evidence for the report is noted in Appendix 1.

The remit is set in the context of the Welsh Government's priorities for improving standards of literacy and numeracy, reducing the impact of poverty on educational attainment, and for developing a highly skilled workforce with skills in science, technology, engineering and mathematics (STEM). In addition, the remit work will provide evidence for the Welsh Government following recommendations from the Enterprise and Learning Committee's report on 'science, technology, engineering and mathematics January 2011'[1]:

Recommendation 5
We recommend that the Welsh Government should continue to ensure that implementation of its transformation agenda puts the needs of the learner at the centre so that young people have access to the range and quality of opportunities that will take them along their chosen career or learning pathway.

Recommendation 10
We recommend that the Welsh Assembly Government should publish a continuous professional development plan for teachers in Wales, including those in Welsh-medium education, aimed at improving in-service training and updating for STEM teachers and heads of department, not only to enhance their subject knowledge but also their understanding of how to teach specific subject topics up to GCSE level at the very least.

Background

Many employers express concern at the lack of mathematical competence of those leaving the education system and entering the workplace. A recent survey[2] by the Confederation of British Industry noted a shortage of high-skilled employees, particularly in mathematics and science. The survey also suggests that about 44% of employers have invested in remedial training in numeracy skills for school and college leavers.

[1] The National Assembly for Wales Enterprise and Learning Committee; the science, technology, engineering and mathematics (STEM) agenda – published January 2011
[2] Building for Growth: business priorities for education and skills, Education and skills survey 2011

Research by higher education providers highlights concerns about the mathematical skills of undergraduates. In the report, Enhancing Graduate Employability: The importance of basic skills[3], it was noted that many students achieving at least grade C at GCSE were unable to demonstrate appropriate numeracy skills to support their studies.

Wales took part in the Programme for International Student Assessment (PISA) in 2006 and 2009. PISA tests examine how well pupils apply their knowledge and skills to real-life situations and applications. The PISA results in 2009 indicated that performance in mathematics in Wales was lower than in the 2006 tests. Wales was the weakest performing country in the UK in mathematics with a mean score significantly lower than that in England, Northern Ireland and Scotland. Wales had fewer high achievers in mathematics. The difference between the performance of the lowest-scoring pupils and the highest-scoring pupils was less in Wales than the average for other countries.

To emphasise the importance of raising standards in mathematics and numeracy, the Welsh Government has included mathematical outcomes in the school banding system. As well as measuring performance at the level 2 threshold, including English or Welsh first language and mathematics, grades at C and above in mathematics also contribute to the banding model. This reinforces the Welsh Government's aim to increase the proportion of pupils achieving higher grades in mathematics.

GCSE mathematics has undergone several changes to the way it is structured and assessed over recent years. The course has moved from a three tier model to a two tier model. For the higher tier, grades A* to D are available and for the lower tier, grades C to G. There has been a change to the way the course is assessed, with a greater emphasis placed on pupils' ability to apply their knowledge and understanding to solve problems. This has placed a greater responsibility on teachers to develop pupils' problem-solving and independent-learning skills.

The recent review[4] of qualifications in Wales by Welsh Government has recommended the following.

- *The Welsh Government should introduce, for teaching from 2015, two new mathematics GCSEs, one covering numeracy and the other covering aspects of mathematics techniques. The numeracy GCSE should build explicitly on the levels of numeracy that are expected to be developed by the end of key stage 3 in response to the Literacy and Numeracy Framework.*

- *The Welsh Government and learning providers should require and support learners who have not achieved A*-C grade GCSEs in English language or Welsh first language and mathematics (or, from 2017, numeracy) by the age of 16, to work towards achievement of these as part of any full-time programme of study at 16 to 19.*

[3] Reflections, June 2009, Queen's University, Belfast
[4] Review of Qualifications for 14-19 year olds in Wales, November 2012

Main findings

1 The percentage of pupils achieving a grade C or above in GCSE mathematics has increased by eight percentage points since 2007. However, mathematics remains the lowest performing core subject at key stage 4 in Wales. Progress from key stage 3 to end of key stage 4 is weaker in mathematics than in the other core subjects, despite the fact that attainment at level 6 and above and at level 7 and above is stronger in mathematics at key stage 3.

2 Attainment in mathematics at grade C and above in Wales is the lowest in the UK. Last year there was an 11 percentage point gap between England and Wales in this respect. The proportion of pupils attaining higher grades and levels at key stage 3 and 4 in Wales is lower than those attained by pupils in both England and Northern Ireland.

3 The schools visited for this survey have strong results in mathematics. Standards are good or better in many of the lessons observed. In about a quarter of lessons, standards are excellent. In these lessons, pupils demonstrate fluent number and algebraic skills and make links between different areas of mathematics. They apply their skills well to solve real-life open-ended problems and demonstrate very good thinking skills and articulate their thoughts clearly. They provide good explanations and justifications when questioned.

4 Standards are adequate or lower in only a few of the lessons observed in this survey. In these lessons, many pupils struggle to recall key number and algebraic skills quickly and accurately. This hinders their learning in new areas of mathematics. In a very few lessons, pupils work at extremely low levels due to the lesson content. These lessons contain a lot of previously taught work from earlier key stages.

5 In most schools visited pupils' attitudes to learning are very good. In many lessons, pupils are well motivated, participate willingly and apply themselves conscientiously to learning activities.

6 Teaching is good or better in many of the lessons observed. Most teachers display secure subject knowledge and have good teaching expertise. In lessons judged good or better, teachers have high expectations and set challenging tasks. Lessons are well planned and move at pace through a range of well-constructed activities, which skilfully cater for the ability range. In these lessons, pupils have many opportunities to revisit, develop and apply key mathematical skills in a variety of situations. Furthermore, beneficial activities identify common mistakes and misconceptions. This assists pupils in their learning.

7 In a few lessons observed, there are important areas for improvement in teaching. In these lessons, work is not sufficiently challenging and planning does not build sufficiently on pupils' previous experiences. These lessons contain a significant proportion of previously taught work, for example able Year 11 pupils working on topics such symmetry, properties of simple shapes and basic volume, which are appropriate for much younger pupils.

8 The majority of schools use assessment well to inform pupils' learning and to monitor their progress. In these schools, assessment procedures are regular and robust, with information being recorded frequently and shared with teachers, pupils and parents or guardians. In a few schools, there are important shortcomings in assessment. Pupils in these schools are not sufficiently aware of how well they are doing and what they need to do to improve.

9 Pupils who gain level 5 in teacher assessment in mathematics at the end of key stage 3 are not prepared well enough in number and algebraic skills to gain a grade C at GCSE.

10 An increasing number of schools are entering pupils early for GCSE mathematics examinations. Most of these pupils enter the foundation tier. Pupils capable of achieving above a C grade are disadvantaged by this practice. Lesson observations, book scrutiny and analysis of early entry figures show that a minority schools focus more on maximising school performance than on delivering the sustained quality of mathematical education that pupils deserve.

11 In the majority of schools visited, leadership of mathematics departments is good at middle and senior levels, and in a few cases it is excellent. In the schools where the leadership of mathematics is strong, middle and senior leaders play key roles in setting high expectations for staff and pupils. These schools have well-developed self-evaluation processes that teachers understand well.

12 In the majority of schools, leaders ensure that teachers have opportunities to share best practice and learn from each other. Peer observation promotes good practice and professional dialogue between teachers. Middle leaders ensure that well-planned schemes of work exhibit strong continuity and progression, building and consolidating on previously-learnt skills, while extending learning into new areas.

13 In a few schools, there are important areas for improvement in leadership. Self-evaluation activities lack a sufficient focus on the standards of pupils' work in lessons and books. In addition, a few middle leaders do not take on the responsibility of ensuring high standards across their departments, and a few senior leaders do not challenge middle leaders effectively to make improvements.

14 In only a few schools do mathematics departments have strong links with their regional consortium advisers. Teachers in these schools benefit from appropriate professional development, external reviews and regular network opportunities. However, this degree of support is not consistent across the regional consortia. Furthermore, very few schools have made successful links with other schools to improve the quality of mathematics teaching. Overall, there is too little support for the professional development of teachers of mathematics whether it be from other schools, local authorities or regional consortia.

Recommendations

15 To improve standards of mathematics at key stage 4:

mathematics departments should:

R1 make sure that pupils develop secure number, algebraic and problem-solving skills at key stage 3;

R2 improve the quality of teaching and learning in mathematics lessons by making sure that:

- lessons are well structured, engaging and challenging, and link to other topics and subjects; and
- number and algebraic skills are developed and applied in new contexts;

R3 use assessment to inform pupils about how they are doing and what they need to do to improve;

R4 minimise early entry for GCSE in mathematics and ensure that pupils follow courses of study that allow them to achieve the highest grades;

R5 base self-evaluation and improvement planning on evidence from observing pupils' standards in mathematics lessons and scrutiny of their work; and

R6 share best practice within and between schools and use it to support teachers' professional development.

Local authorities and regional consortia should:

R7 provide support, advice and professional development opportunities for mathematics teachers, including facilitating professional networks to share best practice.

The Welsh Government should:

R8 support schools and regional consortia in raising standards in mathematics for all pupils; and

R9 review National Curriculum level descriptors at key stage 3 with the view to raising levels of expectation at level 5 in number and algebraic skills.

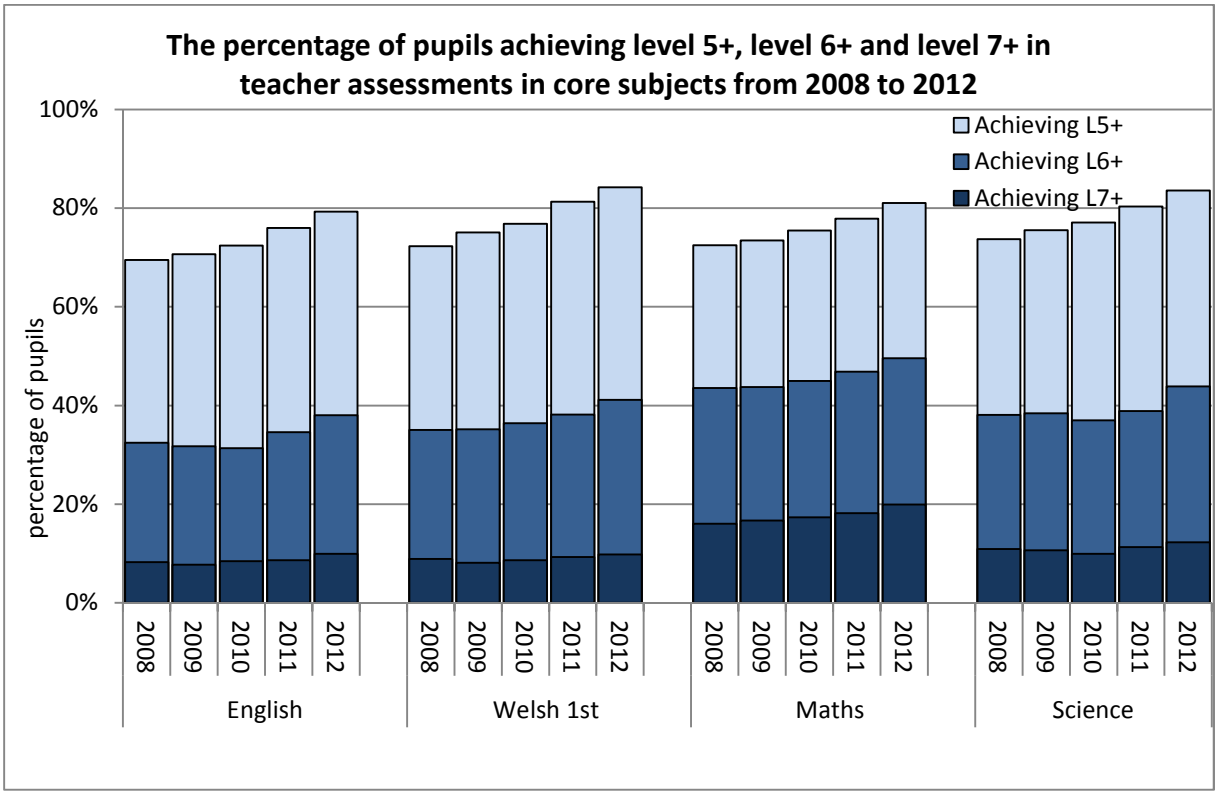
1 Standards

Teacher assessment at key stage 3

16 Pupils' progress against the levels of the National Curriculum in mathematics was measured by standardised assessment tests until 2005, when they were removed. Since 2005, there has been an increase of about 10 percentage points in the number of pupils attaining the expected level (level 5) or above in National Curriculum teacher assessments in mathematics. This improvement is generally in line with that reported in the other core subjects.

17 Attainment at level 5 and above in mathematics is marginally higher than in English, but is below that in Welsh first language and science. However, at level 6 and above, attainment in mathematics is consistently stronger than that in the other core subjects. Over the last three years, it has been at least five percentage points higher than that in the other core subjects. Attainment at level 7 and above is approximately twice that in the other core subjects.

The percentage of pupils achieving level 5+, level 6+ and level 7+ in teacher assessments in core subjects from 2008 to 2012



Source: School Statistics, Welsh Government

18 During the period from 2008 and 2012, the gender gap at level 5, level 6 and level 7 and above increased because girls' attainment at the higher levels improved at a faster rate than that of boys.

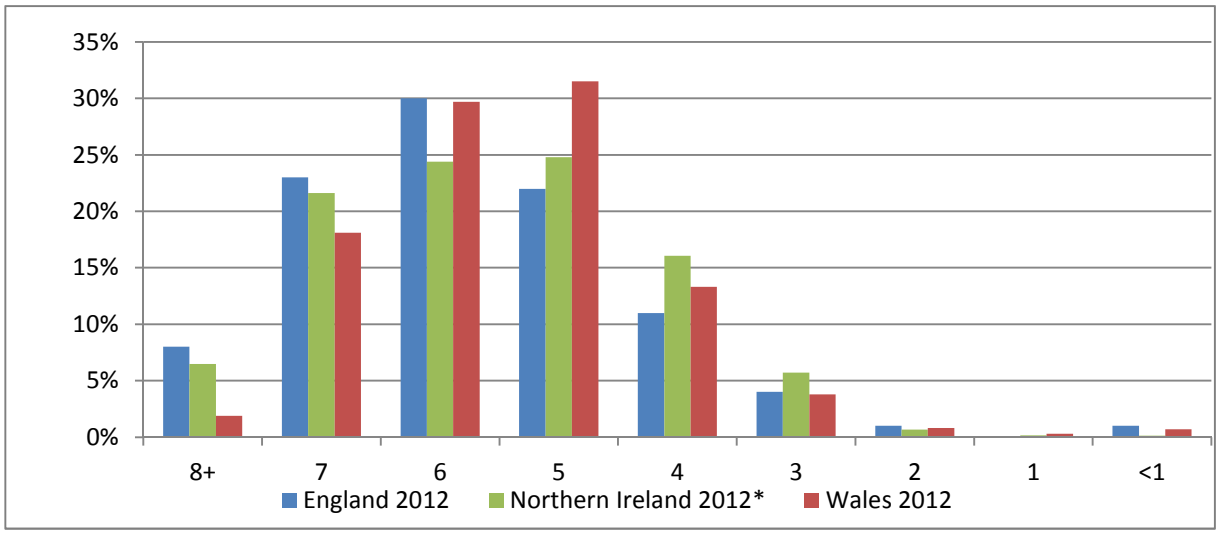
Table 1: Change in gender performance from 2008 to 2012 at key stage 3

	2008	2012	Change
Level 5+ boys	71%	79%	+8%
Level 6+ boys	43%	47%	+4%
Level 7+ boys	16%	19%	+3%
Level 5+ girls	74%	84%	+10%
Level 6+ girls	44%	52%	+8%
Level 7+ girls	16%	21%	+5%

Source: School Statistics, Welsh Government

19 In Wales, although the proportion of pupils who achieve level 7 and above in mathematics is significantly above that in the other core subjects, this does not compare well with performance in England and Northern Ireland. In 2012, 20% of pupils achieved level 7 and above in Wales compared to 31% of pupils in England and 28% of pupils in Northern Ireland.

The percentage of pupils achieving different levels in England, Wales and Northern Ireland in mathematics, based on teacher assessment, at the end of key stage 3



Notes:
<1 includes pupils who were working below level 1, or who were disapplied under sections 113- 116 of the 2002 Education Act or where teachers were unable to provide an assessment.

*Data for NI is provisional as four schools did not submit their results due to industrial action.

Source: School Statistics, Welsh Government, DfES, England, DENI, Northern Ireland

GCSE results at key stage 4

20 The percentage of pupils achieving a grade C or above in GCSE mathematics has increased by eight percentage points since 2007. However, mathematics remains the lowest performing core subject at key stage 4 in Wales.

21 Attainment in science has improved significantly since 2007 and last year it was over 10 percentage points higher than in mathematics.

22 At key stage 4, the percentage of pupils gaining a grade C or above in GCSE English is four percentage points above that in mathematics despite the fact that mathematics outperforms English at key stage 3.

23 The gap between the percentage of girls and boys achieving a grade C or above in GCSE mathematics has decreased over the last six years. This is in contrast to the other core subjects, where the gap has increased, particularly in science. It is also in contrast to performance in mathematics at key stage 3.

24 Progress from key stage 3 to the end of key stage 4 is weaker in mathematics than in the other core subjects. The proportion of pupils who achieve level 5 or above at key stage 3 compared to the proportion of pupils who achieve a grade C or above two years later is lower in mathematics than in the other core subjects. This is despite attainment at level 6 and level 7 being stronger in mathematics at key stage 3.

Table 2: The proportion of pupils who achieved level 5 and above at key stage 3 in 2010 compared to the proportion of pupils who achieved a grade C or above at GCSE in 2012

	2010	**2012**	
	Key stage 3 level 5+	Key stage 4 C+[5]	Difference
English	72%	62%	-10%
Welsh first language[6]	77%	74%	-3%
Mathematics	75%	58%	-17%
Science	77%	71%	-7%

Source: School Statistics, Welsh Government

25 Despite a higher proportion of pupils achieving level 6 or above in mathematics at key stage 3 compared to the other core subjects, two years later, fewer pupils have gone on to achieve A*, A or B grades at key stage 4.

[5] Figures calculated on a whole Wales cohort basis with the exception of Welsh first language
[6] Figures calculated on Welsh first language cohort basis

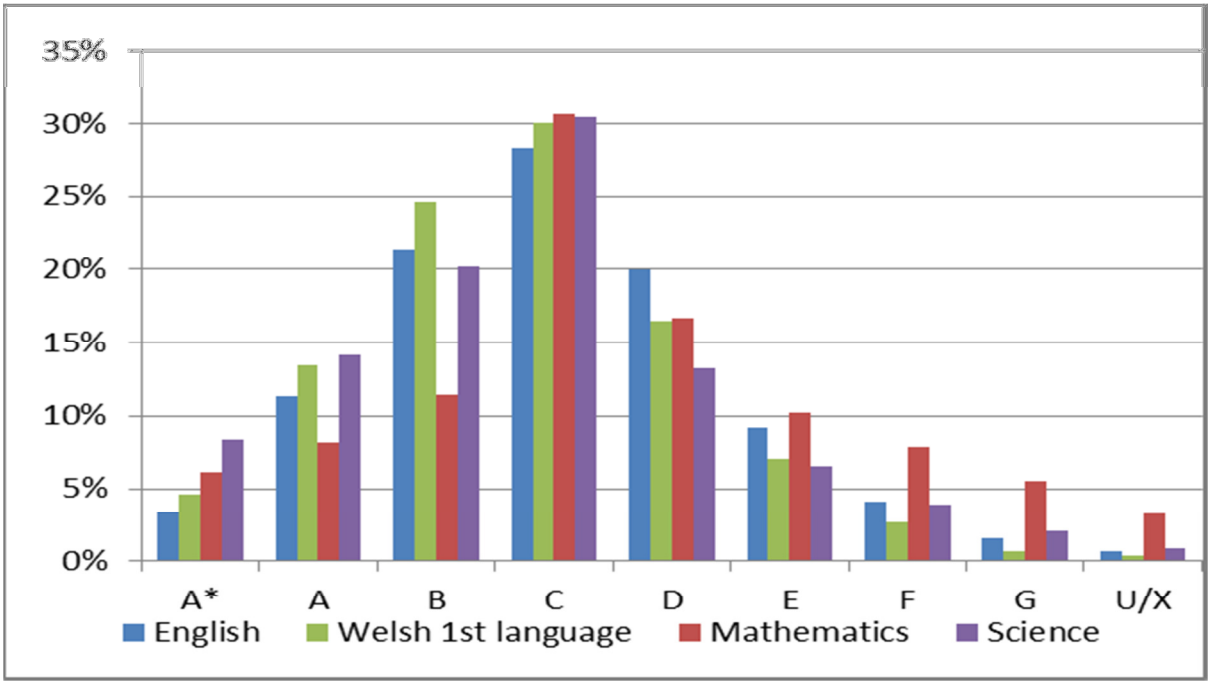
Table 3: The proportion of pupils who achieved level 6 and above at key stage 3 in 2010 compared to the proportion of pupils who achieved a grade B or above at GCSE in 2012

	2010	2012	
	Key stage 3 level 6+	Key stage 4 B+[7]	Difference
English	31%	36%	5%
Welsh first language	36%	45%	9%
Mathematics	45%	26%	-19%
Science	37%	43%	6%

Source: School Statistics, Welsh Government

26 In 2012, a lower proportion of pupils achieved A and B grades in mathematics compared to the other core subjects. In contrast to the other core subjects, a higher proportion of pupils achieved E, F and G grades in mathematics.

The percentage of pupils achieving different grades by core subject based on entries at the end of key stage 4



Notes:
U/X includes pupils who did not achieve enough marks to be awarded a grade, or who were absent from some sections of the examination.

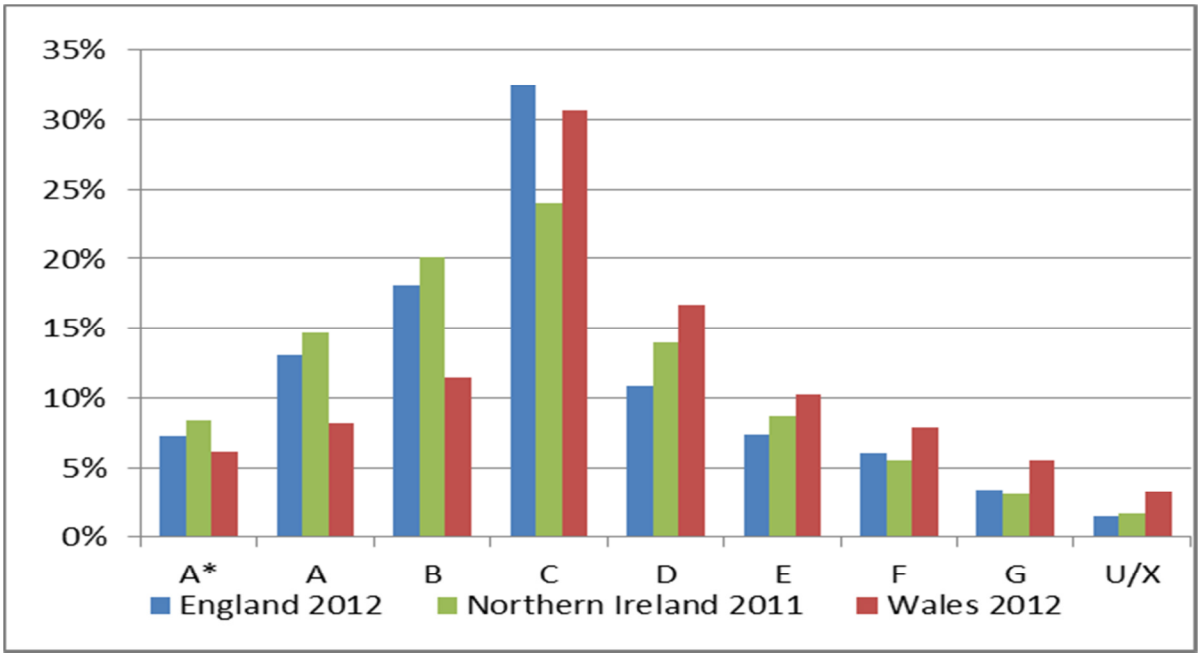
Source: School Statistics, Welsh Government

27 In 2012, the percentage of pupils in Wales attaining a grade C or above in mathematics was over 10 percentage points lower than that in England[8]. The difference between Wales and England in this measure has increased noticeably since 2009.

[7] Grade B+ figures are calculated on an entry basis for each subject.
[8] Northern Ireland figures for 2012 were not available.

28 The proportion of pupils in Wales attaining grades higher than grade C, particularly grades A and B, is markedly lower than the proportion of pupils who achieve these grades in England and Northern Ireland. Furthermore, a greater proportion of pupils in Wales achieve grades D, E, F and G compared to the proportion of pupils achieving these grades in England and Northern Ireland.

The percentage of pupils achieving grades by country, based on entries, 2012[9]



Notes:
U/X includes pupils who did not achieve enough marks to be awarded a grade, or who were absent from some sections of the examination.

Source: School Statistics, Welsh Government, DfES, England, DENI, Northern Ireland

2 Standards of achievement

29 The schools selected to be part of this survey were chosen because they had strong key stage 4 outcomes in mathematics when compared to similar schools. As a result, the percentage of lessons where standards are judged to be good or better does not represent the situation in all schools across Wales.

30 Standards were good or better in many of the lessons observed for this survey. In about a quarter of lessons, standards were excellent.

Common strengths

31 In the many lessons where standards in mathematics are good or excellent, pupils:

- are fluent in number, both in mental and written calculations;

[9] Northern Ireland figures are for 2011; 2012 figures were not available.

- use mathematical diagrams, graphs and notation effectively to communicate findings and ideas to others;
- understand key mathematical concepts from previous lessons and how they underpin current work;
- recall key mathematical facts quickly and accurately and apply them in their work;
- see connections between mathematical topics;
- can reason and explain their work logically using appropriate mathematical language;
- use calculators proficiently where appropriate;
- make sensible estimates;
- interpret statistical information correctly;
- choose suitable mathematical techniques to solve problems;
- use mathematics systematically to explore unfamiliar contexts;
- justify and prove results using valid mathematical reasoning; and
- display evidence of steady progress across the full range of mathematics in the relevant programme of study.

32 In the lessons observed where standards are excellent, pupils work with confidence at high levels. A very few demonstrate skills beyond GCSE that prepare them well for A-level mathematics. In these lessons, pupils make links between different areas of mathematics and apply their skills to solve real-life open-ended problems.

33 In a few lessons, pupils solve multi-step problems that include high-level inverse operations, such as finding the surface area of a hemisphere given its volume. In other instances, pupils make highly effective use of square root, trigonometric functions and calculator brackets keys to perform complex calculations and check the reasonableness of their answers against the context of the question.

Ysgol Bryngwyn School, Carmarthenshire

11-16 mixed comprehensive school, 900 pupils on roll, 19% FSM, 42% SEN
Year 11, higher tier class, problem-solving with volume

Nearly all pupils demonstrate a thorough recall of mathematical formulae. Pupils use mathematical diagrams to communicate their findings on area and volume exceptionally well. Diagrams and workings are communicated effectively, which enables pupils to follow each other's methods. Pupils use calculators effectively and can justify and prove their results using mathematical reasoning. They explain and justify their work using appropriate mathematical language. Pupils apply their mathematical skills effectively to solve real-life problems, and can calculate the number of 600 cubic metre trucks required to fill hot air balloons that measure 40 metres tall and 20 metres wide.

34 The standard of pupils' work was good or better in the majority of books reviewed.

35 In the books where standards were good or better, pupils display a good depth of understanding across a range of suitable and challenging topics. In higher tier classes, pupils demonstrate good mathematical skills such as algebraic and

numerical manipulation, graphical work and statistical analysis. In foundation tier classes, pupils demonstrate sound understanding in areas such as compound measures, Pythagoras' theorem, linear equations and graphs, and volume of prisms.

36 Most pupils' work displays good continuity and progression by building on previous work at key stage 3 and extending into new areas. Pupils can apply their mathematical skills to a wide range of problem-solving activities. For example, pupils show a very good understanding of straight-line graphs and can calculate the gradient of curved graphs to estimate the speed of objects.

37 In many schools, nearly all pupils present their work neatly, with calculations, diagrams and graph work proficiently laid out. This enables pupils to use their books easily for reference and revision purposes. For example, pupils in one activity are required to review previously taught work to select key information to solve problems. Nearly all pupils perform this task well due to the high standard of written work and presentation in their books.

Common weaknesses

38 Standards were adequate or lower in a few of the lessons observed for this survey. In a very few lessons, standards were unsatisfactory.

39 In the lessons where standards are adequate or lower, pupils are unable to recall key mathematical skills to support their learning. In particular, in a few lessons, pupils struggle with negative numbers in new situations. In another example, many pupils struggle to measure reflex angles to work out three figure bearings.

40 In a few lessons, pupils are too dependent on using calculators to solve problems. In one lesson, many pupils are unable to identify simple equivalent indices without using a calculator to find their values. Using calculators, as some do, undermines the aim of the activity, which is to improve pupils' skills with simplifying indices.

41 In lessons where standards are adequate or lower, pupils frequently work at very low levels because the content of the lesson does not stretch them enough. These lessons often contain a significant proportion of previously taught work. For example, able Year 11 pupils work on topics such symmetry, properties of simple shapes and basic volume, which are appropriate for much younger pupils.

42 The standard of pupils' work was adequate or lower in a minority of books reviewed. In these books, pupils' work indicates low levels of challenge with an over-emphasis on doing just enough to attain a grade C at GCSE.

Participation and enjoyment in learning, social and life skills

43 Many pupils develop their personal, social and learning skills particularly well in mathematics. In most of the schools visited for this survey, inspectors identified very good features in pupils' attitudes to learning. In many lessons, pupils are well motivated, participate willingly, and apply themselves conscientiously to learning activities.

44 In most lessons, pupils respond very well to high levels of challenge. Pupils also respond well to feedback and are able to make appropriate corrections to their work when required. Most pupils settle to work well, support each other in their learning and engage well in assessment activities.

45 In a very few lessons, low-level disruption prevents a minority of pupils from making enough progress. This is due to poor lesson planning and the lack of pace and challenge in lessons.

Communication and thinking skills

46 Mathematics contributes to the development of pupils' communication and thinking skills. In the majority of schools, pupils make good progress in developing these skills. This is because pupils work well together in pairs and groups to:

- discuss, predict, reason and form opinions in classroom discussions;
- plan, communicate and evaluate outcomes, particularly in problem-solving and investigative activities; and
- analyse, synthesise and evaluate information from a range of sources.

47 In many schools, pupils work well in pairs and groups, often using mini whiteboards to share ideas and communicate findings.

48 Most pupils listen attentively and respond effectively to teachers and peers, building on others' comments in classroom discussions.

49 Most pupils demonstrate good thinking skills and can solve problems in a variety of new and different situations. These pupils demonstrate good evaluative skills and can provide justifications for their responses.

50 However, in a few schools, pupils do not develop their communication and thinking and skills well enough. In these schools, many responses from pupils in classroom discussions are limited, and pupils find it difficult to justify their ideas and articulate their thoughts clearly.

3 Factors affecting achievement

Teaching

51 Teaching is good or better in many of the lessons observed for this survey. Most teachers display secure subject knowledge and have good teaching expertise. The quality of teaching is generally better in higher-tier classes than in foundation-tier classes. In a few lessons observed, teaching has important areas for improvement.

Ysgol Eirias, Conwy
11-18 mixed comprehensive school, 1,500 pupils on roll, 13% FSM, 11% SEN
Year 11, higher-tier class, problem-solving with measuring

The teacher starts the lesson with an effective starter activity to test pupils' recall and understanding of dimensions and circle formulae. Questions become more sophisticated and include links to other areas, such as rearranging formulae. The main task introduces the 'Big Question' on costing the building of a landscaped garden that consists of arcs, segments and sectors, but key information is missing. This challenges the pupils to think and work together to solve the problems. Clues are available for pupils if they require additional support. A few pupils use the clues. However, many show resilience and persevere with the task independently. This activity generates good discussion as pupils consider different strategies to solve the problem. Near the end of the lesson the teacher provides pupils with a worked solution and asks them to compare their methods with the one provided. The teacher challenges pupils to improve both methods. Nearly all pupils make excellent progress in the lesson. They make links between different topics and mathematical methods and explain their chosen solution with confidence and understanding.

52 In the schools where teaching is good or better, teachers:

- set high expectations of what pupils can achieve;
- skilfully manage question and answer sessions to develop pupils' thoughts and responses by using open-ended questions, building in thinking time, testing understanding etc.;
- stimulate pupils' intrinsic fascination of mathematics by making links to real-life situations;
- develop pupils' recall and fluency with number and algebraic skills;
- use mistakes and misconceptions to improve learning;
- set engaging activities that cater for all abilities, involve pupils in their own learning and give lessons a good pace;
- enable pupils to understand mathematical principles and concepts that underpin their work in mathematics and other subjects;
- encourage pupils to apply their mathematical knowledge, skills and understanding in a wide range of contexts; and
- require pupils to reason and explain orally, using correct mathematical terms.

53 In many lessons, pupils have opportunities to revisit, develop and apply key mathematical skills in a variety of situations. Beneficial activities make strong links with previous learning and extend pupils' learning into new areas.

Porthcawl Comprehensive School, Bridgend
11-18 mixed comprehensive school, 1,440 pupils on roll, 10% FSM, 12% SEN
Year 11, additional mathematics class, trigonometric ratios and surds

The teacher begins the lesson by using activities to test pupils' knowledge and understanding of trigonometric ratios and Pythagoras' theorem. Pupils respond well and assist each other in paired work where necessary. Mini-whiteboards are used effectively to gauge the accuracy of pupils' work and the teacher supports pupils as appropriate. The teacher introduces a challenging real-life problem that pupils are to solve without the aid of a calculator. In pairs, pupils begin to articulate a way forward. The teacher follows the pupils' responses and together they construct a method to break down the problem. The lesson moves into a consolidation phase where pupils learn to represent various trigonometric ratios in fractional and surd form where necessary, before they solve the problem. They display good skill levels with this high-level subject matter. Effective peer-assessment allows pupils to allocate marks and identify areas for correction. Pupils identify and discuss common mistakes and misconceptions. To draw the lesson together, pupils use their newly-learnt skills to solve the original problem without the aid of a calculator.

Treorchy Comprehensive School, RCT
11-18 mixed comprehensive school, 1,600 pupils on roll, 24% FSM, 16% SEN
Year 11, foundation-tier class, ratio and proportion

The teacher provides a useful starter for pupils as they enter the classroom. This settles pupils down quickly, tests their understanding of previous work and prepares them for the lesson content. Good questioning skills and the use of mini-white boards ensures that all pupils are engaged in discussion sessions. Pupils have thinking and discussion time before responding to questions, which improves the quality of their responses. The teacher accepts all responses and together with the class highlights common misconceptions. The preparation phase of the lesson quickly moves into a problem-solving phase and the teacher challenges pupils to solve real-life ratio and proportion problems. Pupils are required to verify their solutions by using a cross-checking technique. Activities are designed well and cater for the needs of all pupils, with more able pupils quickly moving on to solve more complex questions. The teacher provides very good in-class support for all pupils and gives valuable visual representations of dividing by a given ratio to assist many pupils in their understanding. A pupil-focused plenary session enables pupils to assess their progress during the lesson and highlight key aspects of their learning.

54 In the majority of lessons, teachers use effective questioning skills to probe pupils' understanding and to make them think more deeply. This develops and promotes their wider thinking and reasoning skills. Valuable thinking and discussion time enables pupils to provide good responses to problems and activities. Purposeful classroom discussion enables the identification of common misconceptions, which

assists pupils in their learning. Teachers encourage and promote the use of relevant mathematical language.

Radyr High School, Cardiff
11-18 mixed comprehensive school, 1,250 pupils on roll, 7% FSM, 13% SEN
Year 10, higher/foundation tier class, problem-solving with angles

The lesson is planned well by setting a variety of tasks that increase in complexity. Each task provides challenge and links to the aims of the lesson which is to 'use familiar facts in unfamiliar questions'. Pupils are arranged into groups and each member of the group has a clearly defined role. A starter activity is used to recall prior knowledge and pupils are asked to construct triangles to meet set criteria. Pupils are encouraged to think for themselves. The teacher responds to pupils' questions by referring pupils to fact sheets and notes in their exercise books. All pupils discuss their work well in their designated groups.

During the main activity, pupils use an instruction sheet, source material and a set of over-lapping shapes to identify missing angles in the diagrams. The task starts with three minutes of study. The pupils demonstrate good thinking skills and spatial awareness to apply several geometrical facts in combination to solve the problems. Pupils discuss the questions maturely and discuss possible strategies and methods in detail. Most pupils ask questions and challenge each other to explain methods. Nearly all pupils explain their reasoning and offer suitable alternative solutions. At the end of the lesson, pupils consider how they developed their understanding during the lesson and identify any difficulties by using a "Dear teacher" note. The teacher collects and reviews the pupils' notes and addresses the important "Dear teacher" issues. Most pupils agree that this technique helps them improve their work – "If we get a question wrong we cannot just leave it, we have to correct it". Nearly all pupils make excellent progress in this lesson.

55 Worthwhile in-class assessment is evident in the majority of lessons. Beneficial techniques, such as the use of mini-whiteboards in question and answer sessions, the close monitoring of pupils' progress as they work and self and peer-marking, ensure that both pupils and teachers and are aware of progress in lessons. Importantly, this means that issues are addressed as they arise. In the majority of lessons, useful plenary sessions reflect well on key aspects and make important links to other areas of learning.

56 The few adequate or unsatisfactory lessons are not planned well. These lessons do not cater appropriately for all pupils and are not challenging. The lessons lack appropriate activities to build on pupils' previous learning. In these lessons, teachers do most of the talking and thinking. In a few instances, teachers introduce too many new concepts at the same time and this leads to many pupils becoming confused.

Llanishen High School, Cardiff
11-18 mixed comprehensive school, 1,600 pupils on roll, 11% FSM, 15% SEN
Year 10, foundation/higher tier class, probability

A well-constructed lesson ensures very good pace and challenge. The teacher employs a variety of activities which include group work, practical work and individual tasks. The pupils have a copy of the lesson plan in front of them and, at various points in the lesson, they have opportunities to choose relevant tasks and, under the direction of the teacher, set the pace and challenge of the lesson.

The teacher uses a starter activity with a useful literacy focus, which requires pupils to write a 'probability story' using appropriate terminology and vocabulary associated with single events. The teacher questions well throughout the lesson, tests prior knowledge and identifies any misconceptions pupils may have associated with the probability of two independent events. The teacher presents a practical activity, which introduces the concept of independent events. The questions in the main written task are carefully constructed and set in the context of the pupils' prior learning. For example, pupils work out the probability of events related to topics previously studied such as using negative numbers (four rules) and expanding two linear brackets. This approach ensures that pupils develop their understanding of new topics, such as probability, in context and supports their on-going development of challenging topics in number and algebra. Pupils engage actively throughout the lesson and most make excellent progress.

57 A few lessons do not ensure that pupils have sufficient opportunities to develop and practise key mathematical skills. As a result, pupils find it difficult to apply their numerical skills in new contexts. This is evident in a number of lessons where pupils needed to demonstrate fluency with the use of negative numbers in algebraic work.

58 In a few schools, the work for pupils following the higher-tier course lacks sufficient depth. For example, the delivery of many higher-level topics consists of one or two worked examples with two or three follow-up questions performed by the pupils. In these schools, teachers do not allow pupils to consolidate their learning or apply their mathematical skills to new situations enough.

59 In a few lessons, there is a narrow focus on examination questions. This limits pupils' ability to explore and appreciate mathematics in its fullest context. Many pupils in these lessons become disengaged.

60 In a few lessons, teachers' poor questioning skills and limited plenary sessions mean that pupils are unaware of key learning points from the lesson. Even in a few good lessons, the effective use of plenary sessions is not always evident. In many cases, teachers perform all the summarising and reasoning skills, and make the links to real-life contexts for pupils.

Duffryn High School, Newport
11-18 mixed comprehensive school, 1,280 on roll, 37% FSM, 31% SEN

The mathematics department instigated a range of strategies to improve the consistency in teachers' planning and ensure that lessons followed an appropriate structure, with good pace and challenge. Team meetings focused on classroom practice, such as sharing and discussing activities that focus on pupils' skills development. Teachers trial strategies and work together to develop a set of shared resources. The department adopts a 'positive observation policy' and teachers observe each other's lessons in pairs. Outcomes from the peer observations are shared in departmental meetings. Further meetings are used to discuss strategies, lesson plans and schemes of work.

As a result of the department's new approach, the quality of teaching across the department has improved and there is a better shared understanding of expectations and pace and challenge in lessons. Pupils are more engaged in their learning. They recognise a common structure to their lessons – starter, main, plenary – and are aware that during each part of the lesson there are opportunities for them to be actively involved. Pupils now have strategies to help them solve open-ended problems such as highlighting the key words and relevant information. Pupils' ability to recall knowledge and apply their skills to solve problems has improved.

Assessment and tracking pupil progress

61 In majority of schools visited, assessment and pupil tracking are used well. This enables teachers to set challenging targets for pupils and groups of pupils, and identify pupils who are underachieving.

62 In the few schools where assessment is at its most effective, pupils understand how well they are doing and they know what they need to do to improve. In these schools, assessment procedures are regular and robust. Information is recorded frequently and shared with teachers, pupils and parents or guardians. The common features of good assessment noted in the schools surveyed are:

- effective in-class monitoring of progress with timely feedback, dealing with issues as they arise;
- up-to-date marking of pupils' work with useful formative comments;
- involvement of pupils in assessment;
- effective plenary sessions to assess learning and progress in lessons;
- timely summative assessments to track progress over time; and
- pupils' and parents' awareness of target and progress grades.

63 In the majority of the schools surveyed, marking is generally up-to-date. In many cases, teachers' comments are informative. They offer useful suggestions to help pupils to improve. However, in a minority of schools, pupils do not consistently follow up comments and suggestions for improvement.

64 In the few schools where pupil tracking is at its most effective, teachers use assessment data successfully to identify groups of learners for specific targeted support, which includes more able pupils. In these schools, mathematics departments provide well-organised catch-up sessions and parents or guardians are kept well informed. In particular, there is a strong focus on extending more able and talented learners in these schools, and the tracking of their progress is systematic from the end of key stage 3 and through key stage 4. In the schools with the most advanced tracking systems, middle leaders work closely together to monitor groups of pupils across subjects by considering language and mathematical skills and other subjects in combination. These schools ensure that nothing is left to chance.

Bishop Gore Comprehensive School, Swansea
11-18 mixed comprehensive school, 1,210 pupils on roll, 25% FSM, 26% SEN

In Bishop Gore, pupils are set an aspirational global grade for their achievement across all subjects. Form tutors review progress of pupils against global grades three times a year and identify subject areas of strength or weakness. Senior leaders hold review meetings with pupils and parents/guardians and discussions focus on the progress made by pupils across subjects. Where appropriate, targets are set for improvement. In mathematics, performance grades are awarded after every assessment. At the end of these assessments, pupils complete self-assessment sheets to identify strengths and areas for improvement and compare progress against global grades.

As a result of these actions, teachers, pupils and parents/guardians have a very good understanding of the grades pupils are working at and underachievement is identified and tackled early. Attainment at grade C and above in mathematics places the school highest in its family by 15 percentage points and consistently in the top quarter when compared to similar schools based on free school meal entitlement. Twenty per cent of pupils gained A*or A grades in GCSE mathematics in 2012.

65 In a few schools surveyed, assessment processes are unsatisfactory. In these schools, senior and middle leaders do not challenge pupil underachievement enough. Many pupils are not aware of how they are doing and they are unsure of how to improve. Many pupils, including the more able, do not achieve as well as they should.

Curriculum

66 For pupils to progress successfully towards a grade C in mathematics at GCSE they are required to demonstrate a secure knowledge and understanding of many grade C and D topics. A high proportion of the topics at these grades are the building blocks of mathematics and underpin important work in other areas of mathematics and, indeed, in other curriculum areas. Such topics include:

- Number
  - order of operations;
  - express one quantity as a fraction of another;

  - calculate fractions of a quantity;
  - equivalent, simplification and ordering of fractions;
  - four rules with mixed and improper fractions;
  - percentage of a quantity;
  - increase/decrease by a percentage;
  - expressing a change as a percentage of the original value;
  - converting between fractions, percentages and decimals;
  - compound interest;
  - ratio and proportion problems;
  - long and short multiplication/division with 2 digit decimals;
  - efficient use of a calculator;
  - rounding to significant figures and decimal places; and
  - upper and lower bounds of rounded numbers; and

- Algebra
  - forming and solving simple linear equations;
  - substitution;
  - finding and using the n^{th} term of a sequence;
  - algebraic simplification including expressions with fractions;
  - expanding and simplifying brackets;
  - simple factorisation;
  - solving linear equations with brackets/fractions;
  - forming equations;
  - changing the subject of a formula;
  - inequalities;
  - trial and improvement;
  - laws of indices;
  - straight line graphs; and
  - manipulate compound measures and Pythagorean formulae.

67 Furthermore, as well as developing a secure knowledge and understanding, in these important areas of mathematics, pupils need to be able to:

- acquire and use problem-solving strategies;
- select and apply mathematical techniques and methods in mathematical, every-day and real-world situations;
- reason mathematically, make deductions and inferences and draw conclusions; and
- interpret and communicate mathematical information in a variety of forms appropriate to the information and context.

Therefore, for pupils to work successfully at grade C and D, pupils need to demonstrate high levels of proficiency in subject-specific skills, as well as in wider problem-solving and reasoning skills.

68 At key stage 3, in the important areas of number and algebra, the National Curriculum for mathematics indicates that pupils working at level 5 should be able to:

- construct and use simple formulae involving one or two operations;
- describe situations mathematically using symbols, words and diagrams and draw

their own conclusions, explaining their reasoning;
- calculate fractional or percentage parts of quantities and measurements; and
- use their understanding of place value to multiply and divide whole numbers and decimals.

It is clear that the range and depth of skills required at grade C and D are a substantial step up for many pupils who achieve the expected level at key stage 3. In particular, there is not enough emphasis on important number and algebraic skills development at level 5. This hinders the progress of many pupils at key stage 4. Therefore, pupils awarded a level 5 teacher assessment at the end of key stage 3 are not prepared well enough for key stage 4 and, consequently, many do not go on to make expected progress in mathematics at GCSE.

69 There are a number of different pathways for pupils to follow at key stage 4 in mathematics. Currently, schools can choose from modular, unitised or linear courses that are structured differently. Departmental schemes of work and assessments are defined by the particular course that pupils follow.

70 In the majority of departments, middle leaders ensure that well-planned schemes of work exhibit strong continuity and progression, building and consolidating on previously learnt skills, while extending learning into new areas. Additionally, these middle leaders ensure that progress is tracked closely through schemes of work by the use of timely assessments. This ensures that teachers know how pupils are progressing, and pupils know how to improve.

71 In a minority of schools visited, pupils' classwork illustrates that departmental schemes of work are not sufficiently challenging. This is the case in foundation and higher tier books. In these schools, a large proportion of the work carried out by pupils is below the level expected for their age and ability.

72 In a minority of schools, pupils' work focuses too heavily on examination questions even at the start of key stage 4. This means that pupils in these schools have a narrow focus on learning how to answer examination questions. These pupils struggle to demonstrate a broad understanding of mathematical concepts and their applications. In a few cases, pupils' work illustrates that they mainly work through past papers, usually counterproductively because they do not receive enough teaching to help them to improve.

Bishop Gore Comprehensive School, Swansea
11-18 mixed comprehensive school, 1,210 pupils on roll, 25% FSM, 26% SEN

The school took action to establish coherent schemes of work across year groups to ensure that teachers work consistently and in a coordinated manner. They set up regular assessments to assess pupil progress through the schemes of work. All grades are recorded and compared with school 'global' grades. Staff improved the quality of teaching and learning through training sessions, formal and informal observation and by setting suitable performance management targets.

The department created a bank of digital and non-digital resources to support the consistent delivery of the schemes of work.

Finally, they introduced a marking of the quality of teaching and learning by observing lessons, reviewing books, listening to learners etc.

As a result, teachers now work as a team and share ideas, resources and best practice. Teachers, pupils and parents/guardians are aware of attainment levels and the progress being made, and staff morale has improved. Pupils attain very high performance at grade C and above in mathematics compared to those in other schools in its family and similar schools.

73 An increasing number of schools are entering pupils early in GCSE mathematics. Last year, about one-in-six pupils entered mathematics early in Year 10. Most of these pupils enter the foundation tier. Pupils capable of achieving above a C grade are disadvantaged by this entry practice.

74 For pupils who follow an early entry path, depending on the outcome of the early entry examinations, there are three main pathways available to them after early entry:

- study at a higher level;
- study at the same level; and
- finish studying mathematics.

Porthcawl Comprehensive School, Bridgend
11-18 mixed comprehensive school, 1,440 pupils on roll, 10% FSM, 12% SEN

Porthcawl Comprehensive decided on a pathway to support study at a higher level.

Staff decided on a strategy to extend more able and talented pupils, increase the number of pupils taking AS and A-level qualifications in mathematics, and increase the number of pupils looking to study STEM subjects at university. They offered more able pupils experience of an accelerated curriculum in Years 9 and 10 by introducing more stretching mathematical topics (levels 9 and 10). They required the more able and talented pupils to take the higher tier paper in November Year 11. Following this, pupils with A* and A grades from the November examination then follow the additional mathematics level 2 qualification in preparation for A level.

As a result, increased numbers of pupils now follow the additional mathematics course and the AS and A-level uptake has increased steadily from around 20-30 pupils to 40-50 pupils. Pupils are better prepared for A-level, results have improved across the grade range and the number of pupils studying further mathematics has increased. Many of these pupils take the STEP[10] examination and go on to study mathematics in top universities.

75 About 20% of the schools in the survey enter pupils early for mathematics. However, not all pupils who take mathematics early have the opportunity to make further progress in the subject. In around 10% of schools, pupils quickly move on to study

[10] The STEP examination is designed to prepare candidates for undergraduate mathematics.

mathematics at a higher level and achieve well. However, in a minority of schools, too many pupils who gain a grade C after being entered early for mathematics finish their studies at that point. These pupils end key stage 4 with a lower grade than they are capable of achieving.

76 The increase in the number of pupils entered early for the foundation tier shows that a minority of schools focus more on school performance measures than on the underlying quality of the mathematical education that pupils receive.

Leadership and improving quality

77 In the majority of schools visited as part of this survey, leadership at middle and senior levels is good, and in a few cases it is excellent. In these schools, leaders:

- communicate a vision for improving standards in mathematics;
- display a commitment to improving the quality of teaching;
- set high expectations for staff and pupils;
- implement strong self-evaluation processes based on robust evidence;
- ensure that self-evaluation outcomes inform improvement planning;
- establish strong lines of accountability between staff; and
- encourage a positive culture of sharing best practice and resources.

78 In the schools where the leadership of mathematics is strong, middle and senior leaders play key roles in setting high expectations for staff and pupils. In these schools leaders clearly communicate their vision of good teaching in mathematics and set high expectations for the standards pupils are to achieve. The focus is not just on achieving examination success at grade C, but on extending pupils to reach their full potential and preparing them well for their next stage of learning. These schools focus on standards observed in lessons and in pupils' books.

79 The majority of schools have well-developed self-evaluation processes that teachers understand well. Senior and middle leaders use a good range of information to inform judgements on the standards pupils attain and on the quality of teaching. This includes evidence from:

- analysis of performance data;
- lesson observations;
- work scrutiny; and
- listening to learners.

80 The results of self-evaluation feed directly into school and departmental improvement plans. As a result, these departments focus on the issues that are most likely to lead to improvements.

Cefn Hengoed Community School, Swansea
11-16 mixed comprehensive school, 660 pupils on roll, 43% FSM, 42% SEN

Senior leaders in Cefn Hengoed took action to improve the process of self-evaluation and improvement planning across the school.

Core subject leaders together with senior leaders and a member of the governing body developed a self-evaluation model for the school. Teachers representing other faculties and departments created a focus group to extend self-evaluation and improvement planning across the school. This group used the findings from self-evaluation model to share best practice across the school and provide whole-school training. Following the training, departments had four weeks to develop self-evaluation processes and the self-evaluation team provided the necessary support as required.

The strategy has brought about improved self-evaluation processes across the school that are informing and shaping departmental and whole school priorities. Furthermore, departments now focus more clearly on evaluating standards in lessons and books. As a result, departmental development plans now focus more sharply on improving pupils' standards of work. Nearly all middle leaders carry out effective analysis of performance data and are able to monitor the progress of groups of learners and compare outcomes with similar providers. Teachers use the analysis to set challenging but realistic expectations for pupils.

A greater proportion of pupils now produce consistently good standards of work in lessons and books. More departments use good quality summative and formative assessment strategies to support pupils in their learning. The school's outcomes in mathematics have been consistently higher than in similar schools for the last three years.

81 Meticulous analysis of data is a common feature of schools with strong leadership in mathematics. In these schools, senior and middle leaders know how well standards compare with those in similar schools and act on any variation in the performance of different groups of learners. When pupils underachieve, middle leaders, with appropriate support from senior colleagues, challenge and support pupils to improve.

82 In the schools with good leadership, senior leaders regularly monitor departmental progress and pupil achievement. This ensures there are clear lines of accountability for middle leaders and teachers and that there is a regular focus on pupil outcomes. Leaders strike a good balance between challenge and support for teachers.

83 Middle leaders in the most effective departments develop a team approach to creating and using resources and they ensure the consistent use of resources across classrooms. This happens by focusing on teaching and learning in team meetings and by carrying out systematic monitoring activities.

84 In a few schools, middle leaders do not take on the responsibility of ensuring high standards across their departments. This means that the quality of teaching experienced by pupils varies too much between classes. In these schools, departmental self-evaluation and improvement planning are underdeveloped.

85 In a few schools, senior leaders do not challenge middle leaders to make improvements.

Continuing professional development

86 In the schools where the quality of teaching is good or better, the professional development of mathematics teachers is a high priority. In these schools, leaders ensure that teachers of mathematics have access to appropriate training. Senior managers ensure that teachers have worthwhile opportunities to learn from each other, for example by observing best practice. In these schools, there are also strong links between departments and effective use of in-service training time to enable teachers to share new ideas and innovative practice. This strong focus on professional development enables teachers to reflect on their own practice, regularly review and update their skills and keep abreast with new practice.

Ysgol Gyfun Gymraeg Bro Myrddin, Carmarthenshire
11-17 mixed comprehensive school, 680 pupils on roll, 3% FSM, 15% SEN

The mathematics department introduced plans to improve the quality of teaching and learning across the department.

Teaching and learning became a priority for departmental meetings and staff received structured training on effective classroom practice. In addition, a supportive programme of peer observation developed a culture of sharing best practice in the department.

As a result, teachers use consistent and common approaches that engage and involve pupils in their learning. These approaches include activating prior knowledge, focussing on the quality of pupil responses, identifying common mistakes and misconceptions, using higher order questioning skills to extend pupils thinking skills, ensuring that pupils know how they are doing and what they need to do to improve, highlighting links to real life situations and challenging pupils to apply their skills to solve problems.

Since the drive to improve the quality of teaching and learning, self-evaluation activities indicate that pupils have a deeper understanding of their work. Pupil outcomes at grade C and above in mathematics compared to those in similar schools are very high. Around half of pupils entered achieved either A* or A grades in GCSE mathematics 2012. Most pupils demonstrate consistently good value added performance, particularly at higher grades. There is a very good uptake for mathematics in the sixth form with around 60% of pupils opting to take A-level mathematics.

87 In a few schools, mathematics departments receive good support from regional consortium advisers. In these schools, the regional consortia provide effective levels of support and challenge for departments from experienced advisers. Teachers in these schools benefit from appropriate professional development, external reviews and regular network opportunities. However, this degree of support is not always

available across Wales. Furthermore, very few schools have made successful links with other schools to improve the quality of mathematics teaching.

88 In a few schools, and this is where pupils' standards are at their weakest, teachers work in isolation and do not benefit from learning with other professionals. This is particularly challenging for newly-appointed middle leaders, newly-qualified teachers and non-specialist teachers.

Evidence base

The findings and recommendations in this report draw on visits to 18 secondary schools. The schools selected for this survey had strong results in mathematics. The sample takes account of geographical location, socio-economic background, size of school and linguistic contexts. In these visits, HMI:

- observed lessons at key stage 4;
- reviewed books and departmental documentation;
- met representative groups of pupils; and
- held discussions with middle and senior leaders.

Additional evidence was drawn from:

- GCSE results at the end of key stage 4, key stage 3 National Curriculum teacher assessments; and
- a review of the National Curriculum for mathematics at key stage 3.

List of schools visited

Aberdare Girls Comprehensive School, RCT
Bishop Gore Comprehensive School, Swansea
Bishop Vaughan Roman Catholic School, Swansea
Bryngwyn School, Carmarthenshire
Castell Alun High School, Flintshire
Cefn Hengoed Community School, Swansea
Cynffig Comprehensive School, Bridgend
Duffryn High School, Newport
Eirias High School, Conwy
Fitzalan High School, Cardiff
Llangatwg Community School, Neath Port Talbot
Llanishen High School, Cardiff
Newbridge School, Caerphilly
Porthcawl Comprehensive School, Bridgend
Radyr Comprehensive School, Cardiff
Treorchy Comprehensive School, RCT
Ysgol Gyfun Gŵyr, Swansea
Ysgol Gyfun Gymraeg Bro Myrddin, Carmarthenshire

Glossary/references

PISA	The programme for international student assessment. PISA is an international study that was launched by the OECD in 1997. It aims to evaluate education systems worldwide every three years by assessing 15-year-olds' competencies in the key subjects of reading, mathematics and science.
STEM networks	A national organisation that promotes the understanding of and participation in science, technology, engineering and mathematics
CBI	Confederation of British Industry
Level 2 qualification	A qualification equivalent to grades A*-C at GCSE
Level 2 threshold, including English or Welsh first language and mathematics	A volume of qualifications at level 2 equivalent to the volume of five GCSEs at grades A*-C including English, or Welsh first language and mathematics
Higher tier	GCSE course in mathematics that awards grades at A*-D
Foundation tier	GCSE course in mathematics that awards grades at C-G

Explanation of words and phrases used to describe our evaluations

The words and phrases used in the left hand column below are those that we use to describe our evaluations. The phrases in the right hand column are the more precise explanations.

nearly all	with very few exceptions
most	90% or more
many	70% or more
a majority	over 60%
half or around a half	close to 50%
a minority	below 40%
Few	below 20%
very few	less than 10%

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