Estyn

Rhagoriaeth i bawb - Excellence for all

Arolygiaeth Ei Mawrhydi dros Addysg
a Hyfforddiant yng Nghymru

Her Majesty's Inspectorate
for Education and Training in Wales

Science education for 14-19 learners

May 2008

Iechyd ar Waith
Health at Work

BUDDSODDWR MEWN POBL
INVESTOR IN PEOPLE

The purpose of Estyn is to inspect quality and standards in education and training in Wales. Estyn is responsible for inspecting:

- nursery schools and settings that are maintained by, or receive funding from, local authorities (LAs);
- primary schools;
- secondary schools;
- special schools;
- pupil referral units;
- independent schools;
- further education;
- adult community-based learning;
- youth support services;
- youth and community work training;
- LAs;
- teacher education and training;
- work-based learning;
- careers companies;
- offender learning; and
- the education, guidance and training elements of The Department for Work and Pensions funded training programmes.

Estyn also:

- provides advice on quality and standards in education and training in Wales to the National Assembly for Wales and others; and
- makes public good practice based on inspection evidence.

Every possible care has been taken to ensure that the information in this document is accurate at the time of going to press. Any enquiries or comments regarding this document/publication should be addressed to:

Publication Section
Estyn
Anchor Court
Keen Road
Cardiff
CF24 5JW or by email to publications@estyn.gsi.gov.uk

This and other Estyn publications are available on our website: www.estyn.gov.uk

Contents	Page

Introduction

Purpose

1 This report is published in response to a request from the Welsh Assembly Government in the 2007-2008 remit for Estyn to review science courses for learners in the 14-19 age range. The report focuses on standards and on the course options available for learners to study science and science-related subjects. The report also surveys related issues, including the quality of teaching, the recruitment of science teachers and the quality of leadership in science departments.

2 The report's findings come from an analysis of:

- inspection reports of almost 60 secondary school science departments since September 2004;
- data from examination boards on entry numbers and attainment in science examinations;
- recent Estyn reports on Learning Pathways 14-19[1], collaboration between schools and further-education colleges[2] and Estyn's last four area inspection reports;
- visits to 13 secondary schools and one further-education college during the autumn of 2007 – during the visits, we observed science lessons, listened to the views of learners, and interviewed headteachers, principals and heads of science departments; and
- findings from recent educational research reviews and reports.

Background

3 Since 1988, every pupil who attends a maintained school in Wales has studied science throughout their years of compulsory schooling. This core status recognises the importance of science in the school curriculum and its pivotal role in the development of the scientific knowledge and skills necessary to supply the science and technology needs of Wales.

4 Science policy and funding are not devolved functions of the Welsh Assembly Government. Nevertheless, in 2006, the Welsh Assembly Government published a science policy[3] outlining its strategic vision for science in Wales. The policy states that not enough people study science, technology, engineering and mathematics (STEM) beyond compulsory education to ensure that we have future generations of people to supply our science and technology needs. Improvements in science education are recognised as being central to addressing these shortages.

---

[1] Choice and flexibility for 14-19 learners (Estyn 2008)

[2] Collaboration between schools with sixth forms and further-education colleges to deliver flexible high quality provision that expands choice and achieves value for money (Estyn 2006)

[3] A Science Policy for Wales 2006: The Welsh Assembly Government's Strategic Vision for Sciences, Engineering and Technology

5 Physics and chemistry are areas of science where, compared with secondary subjects overall, there tend to be difficulties in recruiting to posts in schools. The Science Policy for Wales includes a commitment to increasing the proportion of places on initial teacher education and training (ITET) courses to meet the current shortage of specialist teachers in these subjects.

6 In 2006, the Department for Education and Skills (DfES) and the Department of Trade and Industry (DTI) in England published the STEM Report[4]. The report sets out a co-ordinated approach to increasing the flow of individuals with STEM qualifications to secure, sustain and support the United Kingdom's science base. The STEM Mapping Review revealed over 470 STEM initiatives run by DfES, DTI and external agencies in England. These included science-enrichment activities for learners and professional development activities for teachers. Education policy and funding are devolved functions and similar large-scale STEM activities have not been implemented in Wales.

7 In Wales, the Webb report[5] has recently stated (paragraph 3.44) that "the STEM disciplines are important for three reasons:

- they lie at the heart of technologically-driven change;
- many learners are deterred by the perceived difficulty of these subjects; and
- specialist teaching skills are in short supply".

8 The report notes employers' concern about the decline of STEM subjects in schools, further education and higher education and the serious implication of this for the future health of the economy. The report recommends that the Welsh Assembly Government's Department for Children, Education, Lifelong Learning and Skills should, "in the context of WAG's Science Policy for Wales develop and fund a national strategy for improving participation and performance in STEM" (R41).

9 The Organisation for Economic Cooperation and Development[6] (OECD) finds that the United Kingdom is producing increasing numbers of science graduates. However, this growth is primarily due to increases in the numbers studying information technology and the biological sciences, with the overall increase masking downward trends in the numbers studying the physical and chemical sciences.

10 When this report was being prepared, the National Federation for Educational Research (NFER) published 'Achievement of 15-year-olds in Wales: PISA 2006 National Report.' The Programme for International Student Assessment (PISA) is a survey of the educational achievement of 15-year-olds organised by OECD. The survey found that student achievement in science in Wales was not significantly different from the average for OECD countries. However, Wales had a wide spread of attainment compared with many other countries. While there were some learners at the highest level of achievement, there was a substantial 'tail' of low-scoring students.

[4] The Science, Technology, Engineering and Mathematics (STEM) Programme Report: 2006, DfES and DTI
[5] Promise and Performance: The Report of the Independent Review of the Mission and Purpose of Further Education in Wales in the context of The Learning Country: Vision into Action: 2007
[6] Education at a Glance – OECD Indicators: 2007

11 Other key findings of the PISA survey include the following:

- student achievement in science in Wales was slightly above the mean for all OECD countries;
- countries from the European Union that significantly outperformed Wales include Finland, Estonia, The Netherlands and Slovenia; and
- within the United Kingdom, the average performance in all four countries was generally similar, but the score of students in Wales was significantly lower than that in England.

Main findings

Standards in science

12 Standards in inspection are lower in science than in almost all other subjects in secondary schools in Wales, especially at key stage 4, but also in the sixth form and at key stage 3. This contrasts with primary schools where pupils achieve among their best standards in science.

13 GCSE attainment in science is broadly comparable to mathematics but significantly lower than English. The proportion of pupils gaining a good GCSE pass (grades A* to C) is increasing in science, but at a slower rate than in mathematics or English. Girls outperform boys in almost all subjects, although the gap is small in science. A-level performance in the sciences is broadly in line with that in other subjects. However, the number of entries in A-level science subjects has decreased over recent years, although the total number of entries for all A-level subjects in Wales has increased over the same period. There is a strong gender bias in A-level subject choice, with more girls choosing biology and more boys physics. There is a downward trend in the number of physics and chemistry graduates produced in the United Kingdom.

Science teaching and teacher recruitment

14 The quality of teaching in science is generally worse than in other subjects in secondary schools. For example, the amount of outstanding teaching in science is well below the average for all subjects and compares poorly with that in mathematics and English at key stage 4 and in the sixth form.

15 There is a shortage in Wales of physics and, to a lesser degree, chemistry specialist teachers who have relevant qualifications. Almost half the headteachers surveyed have had to re-advertise for physics teachers or have recruited in their place science teachers who are not fully qualified to teach A-level physics. The current numbers of trainee teachers following physics and chemistry courses are low and so these shortages are likely to continue.

16 Because of these shortages, physics specialist teachers tend to be allocated to A-level and higher-tier GCSE classes. Key stage 3 science classes are predominantly taught by biologists. This does not always help to provide a sound knowledge base for, or motivate, learners, who could potentially progress to study physical sciences at a higher level. Few science teachers who are not physics specialists have received in-service training to improve their physics subject knowledge and pedagogic skill.

Courses and pathways in science

17 The new GCSE science and additional science courses introduced in September 2006 cater better for learners from a wider range of abilities than the previous GCSE science double award course. These new courses promote the development of key skills, environmental awareness and scientific literacy more effectively. The new

GCSE applied science course is one of the fastest growing GCSE courses in Wales. The course motivates learners well and many of the schools visited reported an increase in attendance. Although the GCSE applied science course is intended for all abilities, the portfolio-based assessment and the way the course relates science issues to everyday life are particularly well suited to average to lower-ability science learners.

18 Nearly all schools with sixth forms offer biology, chemistry and physics at A-level. A-level science class sizes, particularly in physics, are often very small and are expensive to run. Only a few schools offer A-level applied science courses, so the chance to study applied science beyond GCSE is often not available in schools.

19 A few further-education colleges offer a good range of courses at level 3 that provide options for learners to study applied science or related subjects beyond GCSE. These include A-level applied science and the national diploma in applied science. However, there is very little provision in further-education colleges of science-related subjects at levels 1 or 2.

20 Many small secondary schools find it difficult to offer more than one pathway in science on their own at key stage 4 or in the sixth form. Schools that offer only one main option to study science do not meet the needs of all pupils. Overall in science-related subjects, there is too little collaboration between schools and colleges to ensure that a good range of pathways is available for 14-19 learners of all abilities and interests.

21 Many schools encourage learners to continue their studies into the school’s sixth form and do not provide clear, unbiased information about the science options available in other providers.

Leadership and management in science

22 The leadership and management of science departments are less effective than in any other secondary subject. Inspections since September 2004 have judged the leadership and management of science departments to be good or better in fewer than half of schools. Heads of science sometimes find it difficult to provide a strong lead for improving standards because they lack the relevant subject and pedagogic knowledge across all the subjects in their department.

23 In-service training does not meet the particular needs of heads of science. Training courses for heads of science have become less frequent, and are mostly concerned with administrative tasks. They do not focus on developing general and subject-specific leadership skills that will encourage innovative teaching methods and curriculum planning.

Recommendations

24 In order to improve standards in science for 14-19 learners, the recommendations listed below should be implemented.

Secondary schools should:

R1 provide science teachers who are not physical science specialists with in-service training to improve their subject and pedagogic knowledge;

R2 provide heads of science with in-service training to develop their general and subject-specific leadership skills; and

R3 increase collaboration with other partners to ensure that, together, they offer a full range of science options to meet the needs of all 14-19 learners and make more effective use of specialist teachers.

14-19 networks should:

R4 encourage greater collaboration between providers to offer a wide range of pathways in science for 14-19 learners, including applied and vocational pathways; and

R5 make sure that Learning Pathways 14-19 co-ordinators and learning coaches understand fully the possible pathways in science and provide full and unbiased advice to learners.

The Welsh Assembly Government should:

R6 develop a science education strategy for Wales that will provide a significant impetus to improving standards and the quality of teaching and leadership in science and in the physical sciences particularly;

R7 support the development of training opportunities for heads of science and for science teachers who are not physical science specialists; and

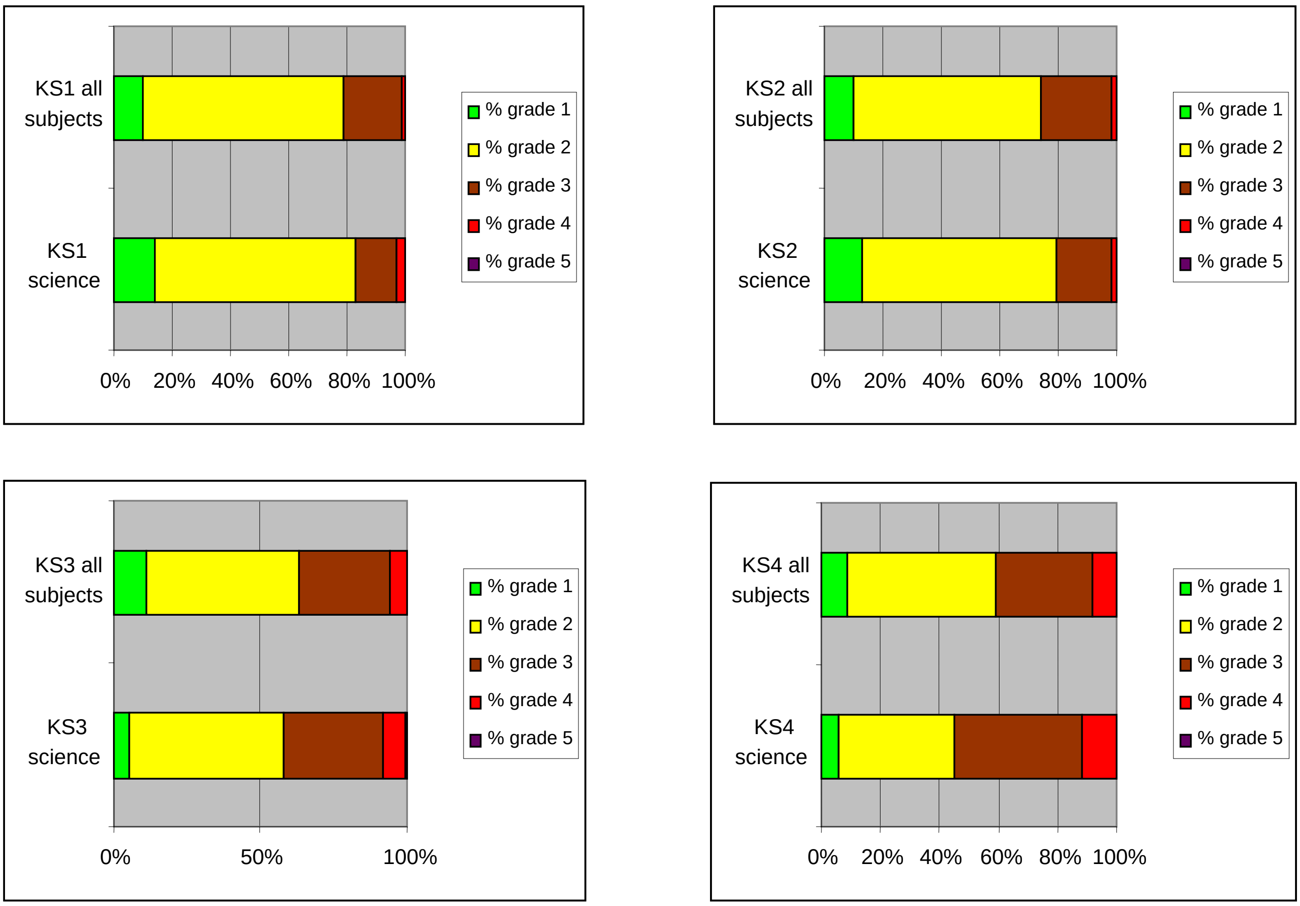
R8 review the incentives that exist to encourage the recruitment and retention of qualified physical science teachers.

Standards in science

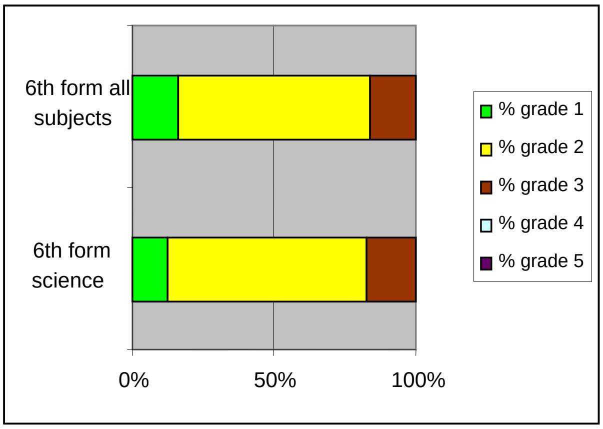
25 Estyn has previously reported concerns about the standards that secondary school pupils achieve in science in Wales. The last six Chief Inspector's Annual Reports have reported low standards in secondary science compared to other subjects, especially in key stage 4, but also in the sixth form and in key stage 3. This contrasts with primary schools, where pupils achieve among their best standards in science.

26 The charts below show that standards in science are high at key stages 1 and 2 relative to other subjects, but are lower than other subjects at key stages 3 and 4. The difference is greatest at key stage 4, where standards judged to be good or better (grades 1 and 2) in science are 14% lower than the average for all subjects. The difference is less in the sixth form, although the percentage judged to have outstanding features is lower in science subjects than the average of other subjects.

Chart 1: Inspection grades for standards in science for the last three years[7]

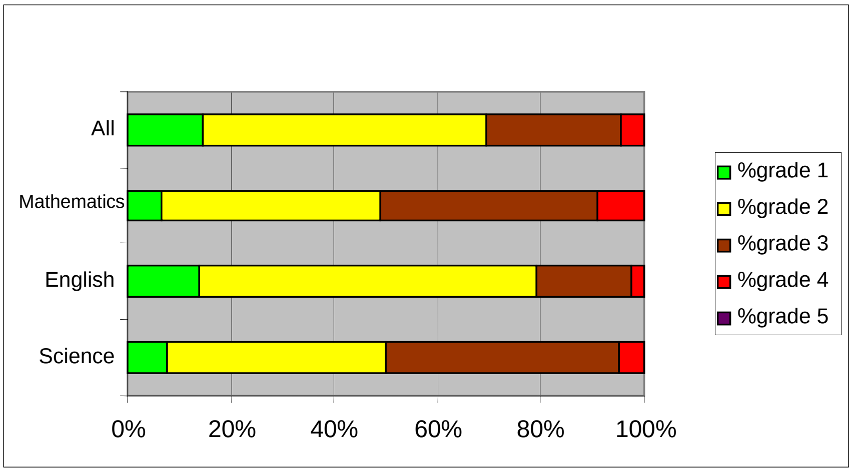


[7] Estyn inspections of maintained secondary schools between September 2004 and July 2007



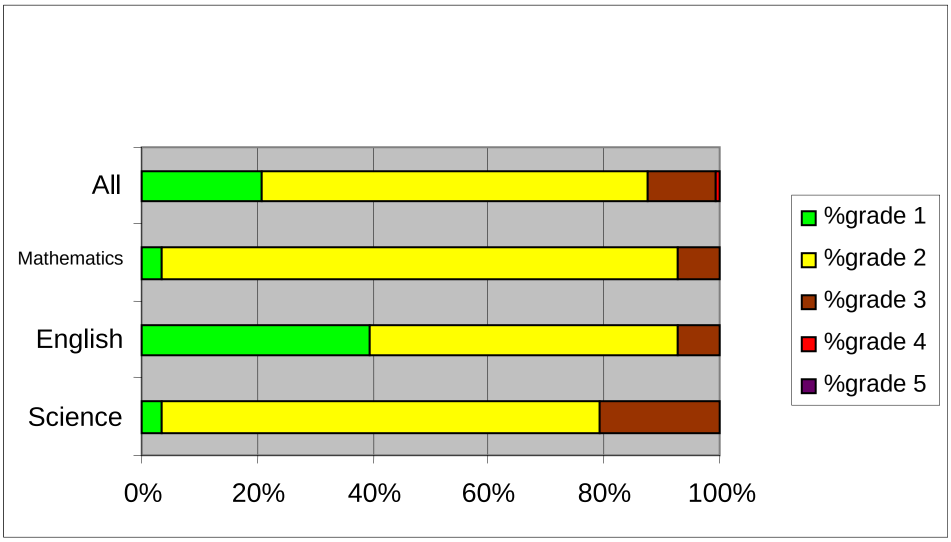
27 The following charts compare standards achieved by pupils at key stage 4 and in the sixth form over the last three years with other core subjects (mathematics and English) and the average for all subjects.

Chart 2: Inspection grades for standards at key stage 4[8]



[8] At key stage 4, Welsh is taught as a first or a second language. Not all schools teaching Welsh as a second language follow courses leading to qualifications at the end of key stage 4. For this reason, Welsh has not been included in some tables.

Chart 3: Inspection grades for standards in secondary school sixth forms



28 Standards in science at key stage 4 and in the sixth form are generally similar to those in mathematics, but significantly worse than those in English and the average for all subjects.

29 Where standards in secondary school science departments are judged to be good or better, the most common good features include learners':

- recall of important scientific facts and the secure knowledge and understanding of scientific concepts that they can apply in familiar and unfamiliar situations; and
- high-quality practical and investigative work, including detailed planning, skilful manipulation of apparatus, careful collection of accurate results, analysis of results to recognise patterns and form conclusions, and evaluations that assess the validity of results.

30 Where standards are judged to have important shortcomings, the reverse of the above is generally the case. In addition, learners:

- are bored, show little engagement with the topics being taught and, as a result, may become disruptive; and
- do not know how well they are progressing or know what they need to do to improve.

Examination results in science

31 The following table shows the attainment in science at GCSE compared with English and mathematics over the last four years. Attainment in science has been broadly similar to that in mathematics, but significantly lower than in English. Attainment at GCSE in English and mathematics shows a greater rate of increase compared to science.

Table 1: The percentage pupils aged 15 who achieved an A*- C grade at GCSE in science, mathematics and English over the last four years[9]

	2004	2005	2006	2007
Science	48	48	49	49
Mathematics	46	48	50	50
English	55	55	58	59

32 In recent years, chemistry is performing best of the sciences at A-level, followed by physics, then biology. The following table shows the trends over the last three years.

Table 2: The percentage of grades A-B at A level in biology, chemistry, physics and all A-level subjects combined over the last three years

	2005	2006	2007
Biology	46	43	48
Chemistry	55	54	57
Physics	50	49	47
All subjects	50	50	51

33 Over the last three years, the percentage of students achieving grades A and B at A-level in chemistry is higher than the average for all subjects. Physics is generally similar to all A-level subjects, although it is beginning to fall behind. The percentage achieving grades A and B in biology is below the average for all A-level subjects.

34 GCSE to A-level value-added data[10] for schools shows that, in general, pupils' achievement in biology is similar to physics and chemistry when students' previous performance is taken into account.

35 At GCSE, girls outperform boys in almost all subjects, although the gap is small in science. The following table shows the difference in attainment between boys and girls at GCSE compared with mathematics, English and Welsh over the last three years. Although girls outperform boys in all of these subjects, the difference in science is smaller than in mathematics and significantly smaller than in Welsh or English.

Table 3: The percentage difference between boys and girls who achieved an A*-C grade at GCSE in science, mathematics, English and Welsh over the last three years[9]

	2005	2006	2007
Science	3	1	1
Mathematics	4	4	4
English	18	18	17
Welsh	18	20	19

[9] Data source: RE2
[10] The Welsh Education Database provides each school with a measure of value-added achievement for each subject by relating pupils' performance at A-level with their previous performance at GCSE.

36 The following table shows the numbers of boys and girls studying biology, chemistry and physics at A-level over the last three years. The relative number of boys and girls studying chemistry is similar, while girls heavily outnumber boys in biology.

37 However, the most marked imbalance in numbers is in physics, where boys outnumber girls by about four to one. This imbalance adds to the perception of physics being a subject mainly for boys and may have a demotivating effect on girls, preventing many of them from choosing to study A-level physics. The reasons for such gender imbalances are complex and are discussed in detail in ‘Closing the gap between boys’ and girls’ attainment in schools’ (Estyn 2008).

Table 4: The numbers of boys and girls studying biology, chemistry and physics at A-level over the last three years[11]

	2005		2006		2007	
	Boys	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
Biology	967	1,363	884	1,314	918	1,231
Chemistry	903	793	844	843	817	803
Physics	908	228	880	266	879	213

38 Girls achieve better grades than boys in biology, chemistry and physics at A-level. The following table shows the difference in attainment between boys and girls at A-level over the last three years. With one exception, the difference in biology and chemistry has been within five percent. However, apart from 2007, girls achieved significantly better grades than boys in physics.

Table 5: The percentage difference between boys and girls who achieved an A-B grade at A-level in biology, chemistry and physics over the last three years[11]

	2005	2006	2007
Biology	3	6	2
Chemistry	4	5	3
Physics	14	13	2

[11] Data source: Welsh Education Database (WED) ‘Pawb yng Nghymru’

Science teaching

39 The distribution of inspection grades for teaching shows a similar pattern to standards, as discussed at page 7 of this report. The following charts compare the quality of teaching in science at key stage 4 and in the sixth form with other core subjects and the average for all subjects over the last three years:

Chart 4: Inspection grades for teaching at key stage 4

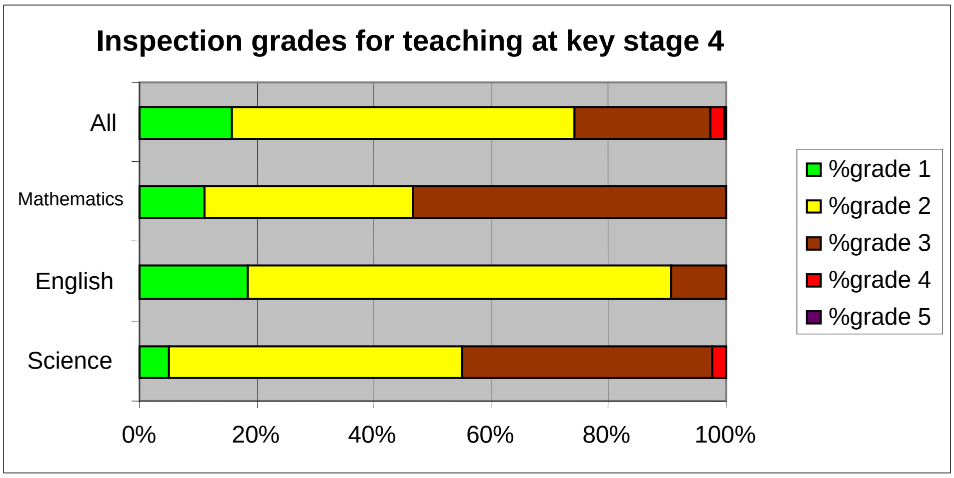
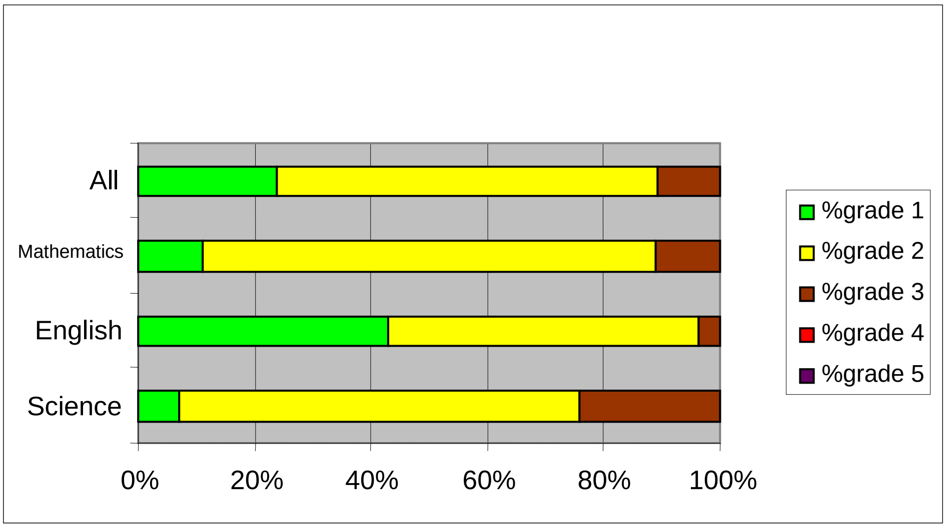


Chart 5: Inspection grades for teaching in sixth forms



40 At key stage 4, teaching in science is better than in mathematics, but below English and the average for all subjects. Teaching of science in sixth forms is worse than in mathematics and significantly worse than in English and the average for all subjects. In particular, science teaching has fewer outstanding features than mathematics, English and the average for all subjects at both key stage 4 and in the sixth form.

41 Where teaching of science in secondary schools is judged to be good or better, teachers:

- have in-depth subject knowledge of the topics taught and have the confidence to engage learners actively in open-ended discussions, to answer their questions and to link the work imaginatively to everyday life or current newsworthy concerns;
- motivate learners through their own enthusiasm for the subject and by organising visits to places of interest and out-of-school-hours clubs, and using a wide variety of teaching strategies and resources, including ICT; and
- plan regular opportunities to develop learners' practical, investigative and problem-solving skills.

42 Where teaching is judged to have important shortcomings, teachers:

- lack the confidence in their own knowledge and pedagogic skill and rely too much on teacher presentation, with insufficient opportunities for pupils to explore scientific ideas, share viewpoints or solve problems;
- fail to challenge learners to achieve high standards and do not use questioning to check that learners develop a deep understanding of science and its applications; and
- do not assess learners' work enough or provide them with the feedback they need to improve.

Staffing and recruitment

43 There is a shortage of qualified, specialist physics and, to a lesser extent, of chemistry teachers. The proportion of physics and chemistry teachers with relevant qualifications (a degree and initial teacher training in that subject) is low compared to that of biology teachers[12]. In order to make the best use of these specialists, their timetables are predominantly filled with teaching A-level and higher-tier GCSE physics or the physics aspects of GCSE courses. This means that lower-tier GCSE science and key stage 3 science are mainly taught by teachers with a biology background. This practice does not always help to provide a sound knowledge base for or motivate learners who could potentially progress to study physical sciences at a higher level.

44 Poor teaching of the key concepts of physics at key stage 3, particularly the topics of forces and electricity, can lead to pupils having long-standing misconceptions that persist to key stage 4 and beyond. Research, such as that by the Centre for Research in Primary Science and Technology (CRIPSAT) at the University of Liverpool, has resulted in case studies of good practice in science teacher education development across Europe[13] that seeks to ensure that teaching methods avoid perpetuating these misconceptions.

---

[12] See for example, the DfES/NFER research report 'Mathematics and Science in Secondary Schools: The Deployment of Teachers and Support Staff to Deliver the Curriculum (Department for Education and Skills Research Report RR708)'.

[13] For example, INSET: a survey of preparation for teaching science. Case studies. CRIPSAT 2007

45 Even so, very few science teachers who are not physics specialists have received in-service training in the teaching of physics topics to improve their subject knowledge and pedagogic skills. The only training in the teaching of physics the majority of these teachers will have received is on PGCE courses provided by initial teacher education and training (ITET) colleges. These courses cannot adequately prepare non-specialist to teach physics topics at key stages 3 and 4, as trainees are in college for only 12 weeks of the course.

46 Almost half of headteachers surveyed reported that they had to re-advertise for physics teachers or had recruited science teachers who were not fully qualified to teach A-level physics. Most stated that recruitment of physics teachers, and chemistry teachers to a lesser extent, was more difficult than for almost all other subjects. Recruitment of teachers who can teach science in Welsh is particularly difficult.

47 Differential incentives are already well established in the recruitment of trainee teachers in shortage subjects, including physics and chemistry. However, this has not been successful in encouraging recruitment and retention of physics and chemistry teachers in Wales or the take-up of physics in-service training by non-specialist teachers.

48 The disproportionately low numbers of physics and chemistry teachers compared to biology teachers seems set to continue. Current numbers of science trainee teachers in ITET colleges in Wales are shown in the table below:

Table 6: Numbers of trainee science teachers in Wales (2007-2008)

Biology	Chemistry	Physics
82	46	32

49 The number of trainee science teachers in ITET colleges following biology courses remains high. However, numbers following chemistry and physics courses are much smaller. Recent recruitment campaigns, particularly high-profile media advertisements, have been largely unsuccessful in increasing the number of science graduates applying for physics and chemistry places in ITET colleges. None of the learners interviewed during this survey was considering a career in science teaching.

50 In order to secure long-term improvements in standards in science, a better balance of specialist subject teachers across the sciences is needed. Meanwhile, high-quality generic and subject-specific continual professional development courses are required to improve the quality of teaching of physics at key stages 3 and 4 by non-specialists.

Pathways in science at key stage 4

Recent developments in science courses

51 Revised programmes of study for science are being introduced at key stages 1 to 4 as part of the new National Curriculum in Wales 2008[14]. Science remains a core subject for all pupils at key stage 4.

52 A range of new GCSE examination specifications was introduced in September 2006. The revised specification places greater emphasis on the development of skills. GCSE science double award has been replaced by GCSE science, normally examined in Year 10, followed by GCSE additional science, which is examined in Year 11. GCSE applied science and GCSEs in the three separate sciences are the main alternative options.

Trends in the uptake of science courses

53 The following table shows the entries for GCSE science courses over the last three years:

Table 7: Entries for science GCSE courses*

GCSE course	2005	2006	2007
Science: Double Award	67.5%	65.5%	63.2%
Science: Single Award[15]	15.9%	20.7%	12.6%
Biology	9.0%	9.1%	9.4%
Chemistry	8.8%	8.8%	9.2%
Physics	8.8%	8.9%	9.2%
Applied science	3.9%	8.5%	10.9%

* Figures show percentage of cohort and do not add up to 100% because some pupils take more than one course

54 The percentage of pupils entered for GCSE science double award had shown a small but steady decrease over recent years. This trend went against the expectation that the most pupils would increasingly study the equivalent of two GCSEs in science. At the same time, entries for GCSE science single award had increased, although the increase ceased in 2007, mainly due to the increase in entries for GCSE applied science.

[14] National Curriculum for Science in Wales: 2008
[15] Since September 2006, the equivalent qualification to Science: Single Award is GCSE Science. This can be examined either at the end of Year 10 or Year 11.

55 Entries for the separate sciences have slightly increased over recent years. Very small numbers (less than 2% of cohort) are entered for the following science GCSE subjects: astronomy, electronics, geology, environmental science, rural science and Science for the 21st Century. Science at Entry level is also available for lower-ability science learners.

56 Many schools now offer more than one option at GCSE level, but other schools do not. The key stage 4 science curriculum at schools that offer only one option (usually GCSE science and additional science) is not varied enough to meet the needs of all pupils. Many small secondary schools find it difficult to offer more than one pathway in science at key stage 4 because of staffing and timetabling restrictions.

57 GCSE or other level 2 provision in further-education colleges in Wales is limited. GCSE science courses are generally provided only for re-sitting (for learners to improve their GCSE grades).

GCSE science and additional science

58 The new GCSE science and additional science courses that replace the previous GCSE science double award are currently in their second year of operation. The new specifications:

- prepare pupils adequately for A-levels in science, although not as well as GCSEs in the three separate sciences;
- cater for pupils of a wider range of abilities; and
- promote the development of key skills, environmental awareness and scientific literacy more effectively than the previous GCSE science double award.

59 The new GCSE science and additional science courses are appropriately designed to develop a good understanding of science-related issues through enquiry and research-based learning. The greater emphasis on skills of enquiry and research in the new specifications is effective in developing important lifelong learning skills. Many schools are adapting their key stage 3 science schemes of work to incorporate enquiry and research-based opportunities in order to develop these skills at an early stage in preparation for the GCSE course.

60 The new specifications replace investigation-based coursework with practical tasks. Increased flexibility has been offered by introducing a choice of practical or project-based tasks. The modular structure offers both flexibility and transparency in that pupils find out their current level of attainment at the end of each module and can discuss the possibility of re-sitting one or more examinations to improve their grades.

61 The early indications are that the new GCSE science and additional science specifications are developing pupils' scientific literacy, practical, key and lifelong learning skills well. It is too soon to compare examination results as the first cohort has yet to complete the course.

GCSE applied science

62 GCSE applied science is one of the fastest growing GCSE course in Wales. It differs from other GCSE science courses in that its scientific content is related to everyday situations and it takes a more vocational approach. It conforms to the statutory requirement for science for all pupils at key stage 4 and, since 2006, pupils do not need to be disapplied from the National Curriculum to study it.

63 GCSE applied science is generally offered to average to lower-ability science learners who would normally be unlikely to achieve a C grade in GCSE science and additional science. The chart below for GCSE applied science[16] in Wales for 2007 shows that few able science learners are entered for the course.

Table 8: Cumulative percentage of pupils achieving each grade in GCSE applied science in Wales in 2007

Grade	A*	A	B	C	D	E	F	G
Cum %	0.0	0.0	3.1	36.4	72.8	90.0	96.2	98.5

64 The assessment requirements of GCSE applied science are demanding in terms of marking and tracking pupils' progress. The assessment criteria and portfolio guidelines provided by awarding bodies were unclear until 2006, which resulted in some poor outcomes. Since then, assessment criteria and guidelines have been clarified, enabling teachers to provide more thorough support for pupils, and this has improved outcomes in the assessment of portfolios.

65 In the schools we visited, outcomes in GCSE applied science tend to be better than those of similar pupils following other GCSE science courses and lead to an increase in the school's core subject indicator, particularly where attainment in science has been a limiting factor. The portfolio-based assessment model is better suited to pupils, particularly those of average to lower ability who are less suited to examination-based assessment.

66 Overall, the GCSE applied science course is particularly relevant to average to lower-ability science learners because it;

- relates science to everyday life well;
- motivates learners and often improves their attendance; and
- prepares pupils well for a range of post-16 vocational science-related courses.

---

[16] Results published in Welsh Education Database group applied science and vocational science qualifications together. The results for 2007 are predominantly Applied Science GCSE, but also include BTEC First Certificate in Applied Science Level 2.

GCSEs in the three separate sciences

67 Many schools offer the separate sciences (biology, chemistry and physics) at GCSE to higher-ability science learners. The main reason for this is to give gifted and talented pupils an appropriate level of challenge and a broader knowledge base for further science studies at post-16.

68 A few large secondary schools provide up to 30% curriculum time for the separate sciences by placing one of them in a non-core option block. However, this is very difficult for smaller schools due to staffing and timetable restrictions. The majority of schools that offer the separate sciences do so in the curriculum time allocation of double science (18%-20% curriculum time) so that three GCSEs are taught in the time usually allocated for two. The limited time available means that, in order to get adequate coverage of the specification content, the courses are taught with an emphasis on theory with little opportunity for practical work other than assessed practical work. This reduction in practical work may demotivate learners and may discourage them from following further science study.

Pathways in science at post-16

A-level courses in the separate sciences

69 Nearly all secondary schools with sixth forms offer A-level biology, chemistry and physics. The table below shows that the number of entries in each of the separate sciences has decreased over the last three years. This contrasts with an increase in the total number of entries for all subjects at A-level in Wales[17].

Table 9: Number of students entered for each of the separate sciences in Wales over the last three years:

	2005	2006	2007
Biology	2,330	2,198	2,149
Chemistry	1,696	1,687	1,620
Physics	1,136	1,146	1,092

70 Biology remains the most popular of the separate sciences at A-level, followed by chemistry. The number of students entered for biology is approximately double the number entered for physics. Where A-level students choose only one science subject at A-level, they frequently choose biology. Pupils choosing chemistry and physics tend also to choose at least one other science subject. A-level students report that the increase in demand between GCSE and A-level is greater in science than in other subjects. This is particularly true of students who have previously followed GCSE science double award rather than the three separate sciences.

Other learning pathways in science at post-16

71 Only a few secondary schools in Wales offer A-level applied science courses, so the learning pathway for applied science beyond GCSE in schools is often restricted. GCSE applied science is not designed as a progression route to A-level study in the separate sciences.

72 Some further-education colleges offer a good range of courses which open up learning pathways for applied science and related subjects beyond GCSE. These include A-level in applied science, and the national diploma in applied science (level 3). However, there is very little provision in science at levels 1 and 2 in any science-related subject in further-education colleges.

[17] Data source is Welsh Examinations Database (WED) 'Pawb yng Nghymru' booklet, published annually by WJEC.

Collaboration at 14-19

73 The work in establishing effective option menus[18] in most 14-19 networks in Wales is at an early stage. The most effective option menus clearly segregate subjects and courses into domains[19], showing clear progression, possible pathways and employment options at each level of study. They also show where collaborative arrangements exist between providers.

74 Analysis of 14-19 option menus shows that collaboration between providers in science and science-related subjects remains very limited. Recent Estyn reports[20] have noted some of the difficulties involved in collaboration, including competition between providers for learners, the lack of common timetables and weak strategic planning across a geographical area.

75 A-level class sizes in physics in secondary schools are often very small. Many schools run A-level physics classes containing only one or two pupils. As a result, these classes are expensive to run. Prior to the introduction of modular A-level syllabuses, some teaching of Years 12 and 13 together was possible, thus reducing the staffing cost. However, this is no longer possible within the current AS/A2 modular framework.

76 Many teachers specialising in physics spend a large proportion of their time teaching small numbers of A-level students, when large key stage 3 classes are taught by non-specialists. None of the schools we visited collaborated with other schools or colleges in the delivery of the sciences at A-level. This means that value for money is poor and opportunities for stimulating interaction for students are limited.

77 Many schools encourage learners to continue their studies into the school's sixth form and do not provide clear, full and unbiased information about the science options available to them in other providers. This often limits the options to a narrow choice of courses, particularly in schools with small sixth forms. Network co-ordinators and learning coaches do not always understand all of the possible learning pathways in science[21] and so are unable to provide good advice to learners, schools and colleges or, in particular, to encourage better communication and collaboration between and among schools and colleges.

---

[18] Option menus contain information on all the courses provided for 14-19 year-olds in a Learning Network. With a few exceptions, each Local Authority has its own Learning Network.

[19] Mathematics, science and technology together make up 'Domain 1' within Learning Network option menus. There are four other domains.

[20] Choice and flexibility for 14-19 learners (Estyn 2008) and Collaboration between schools with sixth forms and further-education colleges to deliver flexible high quality provision that expands choice and achieves value for money' (Estyn 2006)

[21] Pathways in GCSE Science from September 2006: Learning Pathways 14-19 published by ACCAC provides an effective overview of the many alternative pathways in science available to 14-19 learners.

Leadership in secondary school science departments

78 Leadership and management in science departments are significantly worse than in the other core subjects. The main shortcomings in leadership of science departments are:

- a lack of vision and strategic direction for the department; and
- limited monitoring, self-evaluation and planning for improvement.

79 The table below shows how leadership and management in science compare to the other core subjects according to secondary school inspections since September 2004. Leadership and management in fewer than half of science departments were judged to be good or better.

Table 10: Leadership and management in core subject departments

	Science	Mathematics	English	Welsh
Proportion graded 1 or 2	47.5%	63.7%	79.1%	60.9%

80 Almost all secondary schools in Wales have a head of science. However, many schools have also posts of responsibility for biology, chemistry and physics. Heads of science in many schools do not have clear, subject-specific job descriptions with clear allocation of responsibilities within the department. In many cases, this has led to a lack of clarity of roles and inconsistency in policy and practice across the individual sciences.

81 Heads of science sometimes find it difficult to provide a strong lead for improving standards because they lack the relevant subject and pedagogic knowledge across all the subjects in their department. The in-service training they receive does not adequately meet the particular challenges and demands they face.

82 Secondary science heads of department have access to a range of middle management training provided by local authorities, consortia and commercial training providers. However, the majority of these are generic, and are designed for all middle leaders, including subject leaders and pastoral year group or key stage leaders.

83 Heads of science meetings or conferences run by local authority advisers or consortia have become far less frequent. Where they happen, they can be effective in developing an understanding of new course requirements and end-of-key-stage assessment and moderation arrangements. However, most meetings are mainly concerned with administrative issues and do not develop wider general and subject-specific leadership skills that will encourage innovative teaching methods and curriculum planning.

84 In England, National and Regional Science Learning Centres provide training activities and support for science teachers and heads of science departments. Increasingly, these centres are working with the Association of Science Education,

the Royal Society and other partners to provide professional development opportunities for science teachers. The absence of similar centres in Wales means that teachers have less subject-specific professional development than their counterparts in England.

Appendix: scientific literacy

"Scientific literacy is not just measuring science as it may be defined within the curriculum of participating countries, but the scientific understanding which is needed in adult life. Scientifically literate people can identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues." [22]

In our survey visits, 14-19 learners were asked to answer 10 questions designed as a rough measure of their scientific literacy and understanding of global phenomena. Most showed a good understanding suggesting that the new GCSE science specifications are helping to improve scientific literacy.

Good features

Almost all learners:

- understand that green plants use up carbon dioxide during photosynthesis;
- have a basic understanding of the term balanced diet and know that a balanced diet must contain enough, but not too much from each of the different food group;
- recognise that a balanced diet and regular exercise are necessary elements of a healthy lifestyle;
- have a basic understanding of the term global warming (a rise in the temperature of the atmosphere, melting of the polar ice caps, rising sea levels);
- can list more than one thing we can do to slow down global warming; and
- list a number of renewable and non-renewable energy resources.

Most learners:

- can name three or more food groups (fats, carbohydrates, proteins, etc.);
- know that infectious diseases can be passed from one person to another and can name at least two infectious diseases; and
- understand that greenhouse gas emission is a cause of global warming (about half name carbon dioxide).

[22] 'Achievement of 15-year-olds in Wales: PISA 2006 National Report' (NFER)

Shortcomings

Many learners:

- confuse food groups with the 5-a-day campaign for healthy eating;

- directly attribute individual extreme weather events to global warming – very few understand that one-off events provide insufficient evidence and that an increased frequency in these events provides more compelling evidence;

- are unable to relate environmental change to appropriate time-scales; and

- do not understand the term *sustainable development*.

Only a few (sixth form) students are aware of counter-arguments to global warming being caused by human activity.

Only very few learners can explain that global warming is caused by greenhouse gases trapping solar energy.