IMPROVING SERIES

IMPROVING ACHIEVEMENT IN SCIENCE

IN PRIMARY AND SECONDARY SCHOOLS

HMIe
improving Scottish education

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IN PRIMARY AND SECONDARY SCHOOLS

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HM Inspectorate of Education
Denholm House
Almondvale Business Park
Almondvale Way
Livingston
EH54 6GA

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FOREWORD

This is the second in a new series of reports from HMIE designed to promote improvement in Scottish education. The focus of this report is on improving the effectiveness of science education in primary and secondary schools.

The report shows that areas of strength in Scottish science education are being sustained and there have been improvements in a number of key aspects. Attainment has remained strong in the early stages of primary school and at S3 to S6 across the separate sciences. The introduction of new levels of award has widened access to certificated provision for large numbers of pupils and uptake of these courses has been high and increasing. Additional funding, provided through the Scottish Executive's Science Strategy, has often been well-used to improve facilities and resources for science and to build teachers' confidence and competence.

However, there also continues to be significant weaknesses and, regrettably, some of these are long-standing. Pupils continue to under-achieve at the upper stages of primary and at S1/S2, and continuity and progression between primary and secondary is still often poor. Too many pupils are either under-challenged or fail to see the relevance of the science they are studying to their own lives. The content of many science courses, particularly Standard Grade Science, has increasingly become out of date and is not meeting the needs of all pupils effectively.

There is no doubt that science education faces a challenging agenda in the present context. It needs to fulfil two quite different purposes simultaneously, both to the highest possible standard. On the one hand, it needs to provide inspiration and a sound preparation for the longer-term learning and development of young people who will go on to embark on higher study and careers in science-related areas. On the other hand, science education in schools also needs to ensure that all young people are equipped with the knowledge, understanding, skills and attitudes that will enable them to engage positively with scientific issues and debates as they occur in their daily lives. Furthermore, provision has to do all of this in a context in which scientific knowledge is expanding exponentially and new disciplines of study are appearing at an ever-increasing pace. We know that traditionally our science education has tended to be better at the preparation of specialists than the development of all young people as scientifically literate citizens. This report shows that we need to continue to do more to redress that balance, so that both purposes are fulfilled with equal effectiveness, whilst also raising standards overall.

The report aims to set out a clear agenda for improvement for schools, local authorities and national bodies. It should be of particular relevance to the group who are reviewing the science curriculum 3-18 in relation to *A Curriculum for Excellence*. Through that process, we have an excellent opportunity to tackle some of the more intractable issues, where progress has so far been difficult to achieve. Improving achievement in science remains a key priority if our young people are to become well-informed and effective citizens, capable of contributing to the social and economic prosperity of Scotland in the 21st century.

Graham Donaldson
HM Senior Chief Inspector of Education
February 2005

CONTENTS

INTRODUCTION

This report is based on inspections of science in primary and secondary schools carried out between September 2000 and March 2004. In addition to schools inspected as part of the generational cycle, HMI also visited other primary and secondary schools to observe and describe aspects of best practice. The report also draws on other major sources of evidence about pupils' attainment, including results of examination awards from the Scottish Qualifications Authority (SQA), the Assessment of Achievement Programme (AAP),[1] the Programme for International Student Assessment (PISA)[2] and Trends in International Mathematics and Science Study (TIMSS).[3]

The focus of this report is action for improvement. The starting point is the existing good practice which many schools are using to strengthen pupils' learning and to raise achievement. A number of previous reports have identified strengths and areas for improvement in aspects of science provision. In particular, this report builds upon the earlier HMIE findings in *Effective Learning and Teaching in the Sciences* (1994), *Improving Science Education 5-14* (1999) and *Standards and Quality in the Sciences 1995-2000* (2000).

Particular questions addressed through the report include the following:

- How good are attainment, courses, learning and teaching, ethos and leadership?
- Is there any evidence of improvement?
- What are the strengths of existing good practice?
- Where is the scope for further improvement?

Each section of the report identifies strengths and issues common to both the primary and secondary stages. Comment is made on features applicable to specific stages. The report also provides a series of prompt questions which schools should find helpful in evaluating and improving their own practice.

In this report, the term 'Science' refers to Science in primary schools, the integrated Science course in S1/S2 and Standard Grade Science. The term 'science' is used as a generic term referring to all the sciences (biology, chemistry, physics and Science). The term 'separate sciences' refers to biology, chemistry and physics.

[1] Every three years, AAP surveys performance at three or four stages in a range of scientific knowledge and skills. The most recent AAP survey on science was in 2003 and surveyed pupils' performance at P3, P5, P7 and S2. Further information on the AAP survey is available on the website of the Scottish Executive Education Department (SEED). SQA provides information on its website as well as annual reports from examiners on performance at Standard Grade and on awards of National Qualifications (NQ) in a number of science subjects.

[2] PISA is an international survey of 15-year-old pupils' standards of literacy in reading, mathematics and science, particularly in relation to young people's capacity to use their knowledge and skills in order to meet real-life challenges. Forty-one countries participated in PISA 2003, including all 30 OECD countries. Further information about the PISA survey is available from the PISA website.

[3] TIMSS is an international survey which measures trends in mathematics and science performance at P5 and S2. Surveys in science were carried out in 1995 and 2003. In 2003, twenty-five countries took part in the P5 study and 46 countries in the S2 study.

1

ATTAINMENT

The evidence about attainment in science across primary and secondary education presents a very mixed and quite complex picture. The situation is complicated by a number of factors, including the lack of national assessment data for 5-14 Science, which make it more difficult to monitor standards over time. As pupils progress through secondary education, they can choose to study one or more science subjects, including biology, chemistry and physics. Again, this makes it more difficult to track the progress of cohorts of pupils over time.

Overall attainment is:

- relatively strong from P1 to P4 and in the separate sciences at S3 to S6; and
- in need of significant improvement in Science at P5 to S2 and in Standard Grade Science at S3/S4.

How good is attainment in science at each stage in your school?

Evidence from earlier AAP science surveys indicated that standards had been particularly disappointing at P7 and S2. The AAP 2003 survey in science enabled some comparisons to be made of attainment at P7 and S2. Overall, the results again showed no evidence of significant improvement from 1999 in pupils' performance at Levels C, D or E. This comparison between 1999 and 2003 needs to be treated with a degree of caution as, in the intervening period, changes were made to the national 5-14 guidelines for science and the assessment tasks used in the two surveys were not entirely compatible. Nonetheless, the broad indication is that no significant improvement had occurred nationally. In the 2003 TIMSS survey, Scotland's mean score was significantly above the international average at both P5 and S2. However, at P5, the mean score in science was significantly lower than it was in 1995 and, at S2, it had not improved significantly.

Are pupils under-achieving at particular stages in your school?

In the PISA 2003 survey of scientific literacy amongst 15-year-old pupils, Scotland scored well above the OECD mean and was placed in the top third of OECD countries. SQA results over recent years indicate that, overall, pupils continued to perform well in Standard Grade and NQ courses in the separate sciences. In sharp contrast to this, however, results in Standard Grade Science remained unacceptably low.

Evidence from inspections showed considerable scope for improvement in pupils' attainment in science. This was particularly the case at the later stages of primary school and in S1/S2. In primary schools and in secondary schools in S1/S2, the overall quality of attainment was found to be good only in the majority of schools and it was seldom very good. It showed some important weaknesses in around 40% of primary schools and 33% of secondary schools. When compared with standards reported by HMI during the period 1995-2000, the figures show a small overall improvement in primary schools and an even smaller improvement in S1/S2. The situation had worsened in Standard Grade Science where the overall quality of attainment had important weaknesses in 39% of schools compared with 25% of schools in 1995 to 2000.

A good measure of the effectiveness of a secondary science department is given by the proportion of the S3 cohort who choose to study one or more science subjects and who subsequently go on to achieve success at an appropriate level based on their prior attainment. Effective departments tend to have a high uptake, reflecting good quality course provision and teaching at earlier stages. Pupils also tend to achieve well. Science departments can use this uptake factor to monitor and evaluate changes in subject and course popularity and achievement over time.

What proportion of your S3 cohort study, and achieve success in, biology, chemistry, physics or Science and has this improved over the last few years?

1

ATTAINMENT

Features of attainment at different stages

Pupils at P1 to P3 were generally making good progress in developing knowledge, understanding and skills appropriate to their stage. For example, they could group similar materials and relate their basic properties to everyday uses. They could describe the growth of plants and some could explain the life-cycles of familiar animals. In some schools, pupils were able to give examples of forces, including the behaviour of magnets. Supported by their teacher, they could carry out simple practical investigations quite well, observing main features and changes, and recording their findings as a picture or display.

Pupils at P4 and P5 often showed good knowledge and understanding of the science they had covered, which was usually appropriate to their stage of development. For example, they could often name and describe planets of the solar system, outline the water cycle, and sort animals into main groups. They often knew more about specific forces such as friction and gravity, and some could build and explain simple electrical circuits. Pupils were beginning to carry out investigations with greater independence, and recording their findings more often in written and numerical form using formats provided by the teacher. They were beginning to appreciate the need for fair testing.

Pupils at P6 and P7 often performed well in their coursework, but this often did not represent a significant enough advance on what younger pupils were achieving. They could usually explain a wider range of scientific ideas, such as how water could be purified, or how plants reproduced and benefited the environment by producing oxygen. In some schools, pupils showed well-developed understanding of the basic properties of electricity, light and sound, and how different forms of energy could be inter-converted. In general, however, pupils had limited understanding of energy and forces. By these stages, pupils were generally more confident in applying the basic practical skills of observation, measurement and recording. The majority of pupils could now explain how to conduct a fair investigation although they often had limited experience of carrying out such investigations.

Are P6/P7 pupils being sufficiently challenged and developing appropriate knowledge, understanding and skills?

Pupils at S1 and S2 often performed well, and sometimes very well, in their coursework but again this was often insufficiently demanding. They displayed satisfactory knowledge and understanding across some of the main areas of science, and had acquired a considerable vocabulary of scientific terms. However, there were often significant weaknesses in their understanding of key areas of modern science, including genetics and heredity, evolution, microelectronics and aspects of the universe and space exploration. Most coped well with basic practical work which involved the following of instructions and the use of a variety of scientific equipment. Pupils' skills of observation and measurement, and in recording their results using given formats, were often good. The majority of S2 pupils were aware of the need to 'be scientific' when carrying out experiments, for example by controlling variables and repeating measurements. There were, however, weaknesses in pupils' experience and understanding of planning, carrying out and interpreting open-ended investigations.

Features of attainment at S3/S4

- From 2000 to 2004, entries in Standard Grade biology had increased by 2%. In chemistry, entries had declined by 7%, in physics by 5% and Science by 46%. The decrease in entries for these courses, and particularly Science, was largely accounted for by the substantial increase in numbers of S4 pupils presenting for Access and Intermediate courses. (Figure 1)

- At Intermediate 1, the total entries in biology, chemistry and physics had increased substantially from 70 in 2001 to 5300 in 2004. Over the same period, entries at Intermediate 2 had increased from 40 to 1680.

For the 70% of pupils who choose not to continue their study of biology, chemistry or physics in S3/S4, how well are you preparing them for the science they will experience as citizens of the 21st century?

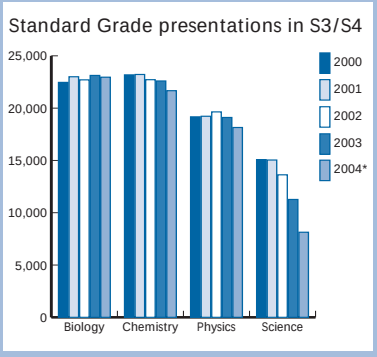

Figure 1

* All 2004 data are pre-appeal

1

ATTAINMENT

- At Standard Grade, the proportion of pupils presented who gained grades 1-2 (Credit) in biology, chemistry, physics and Science over the period from 2000 to 2004, showed no significant trends. (Figure 2)

- On average, around 90% of pupils presented in biology, chemistry and physics achieved grades 1-4 (Credit and General) in Standard Grade while around 60% achieved these grades in Science. There were no significant trends.

- At Intermediate 2, overall success rates were high in 2003 and 2004, with on average, 85% of entries in biology, 81% in chemistry and 92% in physics achieving A-C grades.

- At Intermediate 1, the average percentage of pupils achieving A-C grades in 2003 and 2004 was 52% in biology, 48% in chemistry and 45% in physics.

- The number of pupils attaining Access 3 passes in biology, chemistry or physics by the end of S4 increased from around 200 in 2002 to 1400 in 2004.

Features of attainment at S5/S6

- Over the past five years, entries at Higher in science subjects had declined. In biology, including human biology, entries had decreased by 4%, in chemistry by 7% and in physics by 6%. Entries in other sciences, including geology and biotechnology, remained very low. (Figure 3)

- Between 2000 and 2004, the proportion of pupils achieving A-C grades at Higher had shown a steady improvement in biology and human biology, but varied only slightly from year to year in chemistry and physics. (Figure 4)

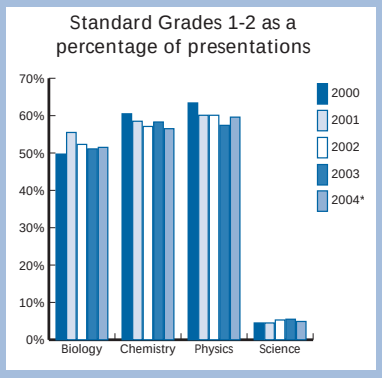

Figure 2

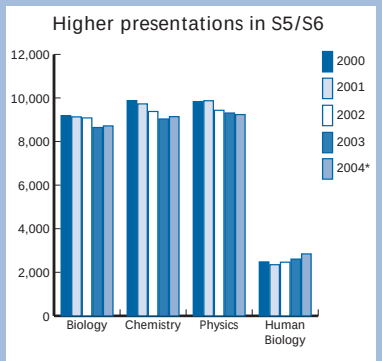

Figure 3

- 'No Awards' at Higher had shown a decline over the past five years in biology, human biology, chemistry and physics. On average, these accounted for 20% of presentations in biology and human biology, 15% in chemistry and 17% in physics.
- Between 2000 and 2004, entries at Advanced Higher and CSYS (in 2000) had shown a significant increase in all three sciences. Entries increased by 26% in biology, by 11% in chemistry and by 29% in physics. (Figure 5)
- From 2001 onwards, performance at Advanced Higher had been consistently good, with around 75% of pupils presented achieving A-C grades.
- From 2000, entries for Intermediate 1 separate science courses in S5/S6 had increased initially, then tended to decline in 2004. Biology had the highest uptake with 181 entries in 2004, while numbers presented for Intermediate 1 courses in chemistry, physics, geology and MER remained relatively low.
- The proportion of S5/S6 pupils achieving A-C grades at Intermediate 1 averaged 78% of presentations in biology, 73% in chemistry and 70% in physics.
- At Intermediate 2, entries for biology, chemistry and physics had shown a steady increase from 2000 to 2004. In 2004, uptake was high with about 4000 entries for biology, 1500 for chemistry and 1900 for physics. Entries for geology, MER and biotechnology remained very low. (Figure 6)
- At intermediate 2, the proportion of S5/S6 pupils achieving A-C grades in 2000 to 2004 averaged 62% in biology, 60% in chemistry and 58% in physics.

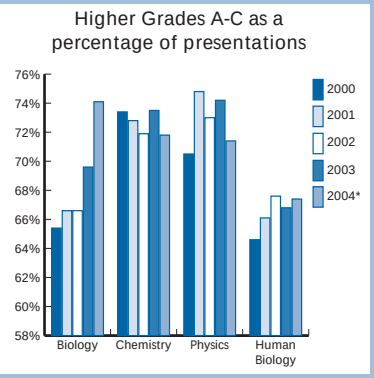

Figure 4

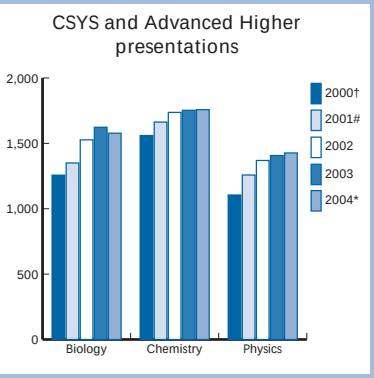

Figure 5

† CSYS entries only

Combined CSYS and AH entries

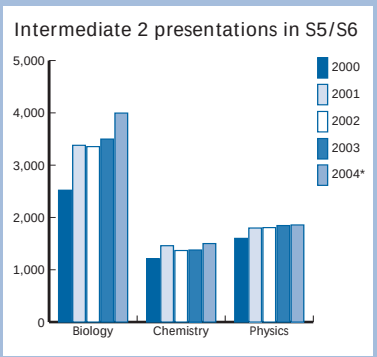

Figure 6

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ATTAINMENT

Main areas for improvement

Despite many examples of good attainment observed in individual schools and lessons, significant weaknesses were observed in too many cases.

In many primary schools there was a lack of attention to progressively developing pupils' knowledge, understanding and skills. As a consequence, there were common weaknesses in pupils' skills of practical investigation, including planning, observing and measuring, and recording, presenting and interpreting their findings. Sometimes, teachers gave too little attention to ensuring that pupils observed and measured accurately. This made the drawing of conclusions and the advancement of pupils' learning more difficult. Significant gaps were often evident, too, in pupils' knowledge and understanding of key aspects of science, particularly in the area of energy and forces. Even where school science programmes were better developed, pupils were still under-achieving. This was usually because tasks were not appropriately matched to their prior attainment, or because pupils' learning was not being revised and consolidated.

How well do you ensure appropriate progression of pupils' investigative skills as well as knowledge and understanding?

In S1/S2, courses generally provided better progression in pupils' knowledge and understanding. However, many schools were failing to develop pupils' understanding of key areas of contemporary science and were therefore failing to prepare them for the science they would encounter as citizens of the 21st century. Teaching approaches often restricted pupils' initiative and independence in carrying out practical investigations, and skills of planning and interpreting results were generally less well developed than other practical skills. Whilst most pupils performed well in the work they were given and some achieved high standards, not enough of them were achieving their potential. The most common reasons for this were:

- insufficient account taken of pupils' previous learning and attainment, including what they had already learned in primary school;
- some tasks set for pupils were either too difficult for them or insufficiently challenging; and
- insufficiently high teacher expectations of the pace of pupils' learning and of the quality of presentation of their written work.

Do science courses in your school provide appropriately challenging tasks for all pupils, taking account of their prior learning and skills?

In S3/S4, around half the pupils presented for Intermediate 1 courses did not achieve a course award at grades A-C although they may have gained success in individual units. Where schools had replaced Standard Grade Science with Intermediate 1 courses, teachers had not always ensured that sufficient account was taken of pupils' prior attainment or learning needs. In Standard Grade Science, only around 5% of pupils gained a Credit level award, reflecting a lack of exposure to learning outcomes at this level.

How successful are your S3/S4 courses at motivating pupils and ensuring they gain appropriate awards?

2

COURSES[4]

During the period covered by this report, many primary schools were in the process of improving their programmes of work in science. Much of this improvement was in response to the publication of Improving Science Education 5-14 and the consequent revision of the national 5-14 guidelines for Environmental Studies in 2000.[5] In many cases, primary schools had adopted well-structured commercial science schemes or frameworks developed by education authorities. Primary school programmes were good or very good in 54% of schools compared with 42% over the period 1995 to 1998. In the period between November 2002 and November 2003, 70% of the primary schools inspected had good or very good programmes. This recent improvement in primary science programmes should now begin to produce benefits in terms of pupils' learning and attainment.

In secondary schools, science departments had focused their efforts on the implementation of National Qualification (NQ) courses for S3 to S6 pupils. These were generally very well developed. There had been significant improvements in the overall quality of separate science courses. At S3 to S6, 57% of courses were very good and 39% were good compared with 40% and 55% respectively over the period from 1995 to 2000. Improvements to Science courses in S1/S2 had taken place more slowly. At S1/S2, 6% of courses were very good and 75% were good, compared with 10% and 60% respectively. At all stages, the additional funding and support provided for schools and education authorities through the Scottish Executive's Science Strategy for Scotland[6] has played an important part in the improvement of courses.

4 Courses are typically called programmes at the primary stages.

5 *The National Guidelines 5-14: Environmental Studies* were first published in 1993 and subsequently revised in 2000.

6 *The Science Strategy for Scotland* was published by the Scottish Executive in 2000 and included commitments to improve aspects of science education in schools.

Features of effective courses at all stages

Effective courses:

- took appropriate account of pupils' progress and prior experience and attainment;
- were well planned to make good use of time, and ensure steady progress and time for revision;
- had clear learning objectives and assessment criteria which were shared with pupils and used to guide teaching;
- included relevant and challenging content, including practical work, that captured pupils' interest and developed the full range of investigative skills; and
- emphasised recent developments in science and their applications, including the benefits and risks to society.

To what extent do courses in your school have these key strengths at each stage?

2

COURSES

Features of effective courses at P1 to P7

Effective courses helped pupils make appropriate progress in each of the main areas of science covering Earth and space, living things and the processes of life and energy and forces. Pupils' experiences of science were frequent enough to enable them to retain and build upon prior learning. Some schools gave a clear place to science in the curriculum by requiring pupils to write up their science work in jotters, rather than on sheets of paper, which in turn improved standards of presentation. Teachers gave equal importance to developing pupils' investigative skills and their knowledge and understanding. Teachers received clear guidance on the work to be covered and practical advice on tackling specific activities. Their plans specified what pupils were expected to learn, and in the best cases teachers shared these objectives with pupils. Worksheet materials were used sparingly and reviewed critically to ensure that tasks were relevant and challenging for pupils. Teachers were careful to involve pupils in using everyday materials, artefacts and specimens. They made good use of the school grounds and visits to places of interest such as country parks, museums and science centres. These approaches helped pupils to view science as important and relevant, and to develop positive attitudes towards the environment. Pupils frequently engaged in experiments that developed a range of investigative skills as well as encouraging initiative and independence.

As a teacher, do you feel well informed about what your pupils are expected to learn in science?

As a teacher, do you stress often enough the importance and benefits of science to society?

Main areas for improvement in courses from P1 to P7

Whilst programmes of work in science were good or better in the majority of primary schools, there were some important weaknesses in a large minority of cases. The most common weaknesses were:

- science lacked a clear place in the curriculum, and was too infrequent to enable pupils to make connections with earlier work;
- insufficient continuity and progression in the development of pupils' knowledge, understanding and skills, sometimes resulting in unnecessary repetition of earlier work; and
- a lack of balance across the key areas of science, leading to gaps in pupils' knowledge.

In your school, do pupils spend sufficient time on science and experience it frequently enough?

Are pupils able to build steadily on key knowledge, understanding and skills in each of the key areas of science as they progress through the school?

Features of effective S1/S2 courses

Effective S1/S2 courses took account of pupils' prior learning in primary school, including their skills of literacy and numeracy. This helped teachers to set realistic expectations of individual pupils from the start of S1. In some cases, education authorities had developed coherent programmes of study from P1 to S2, which were being implemented across primary and secondary schools. This was most effective where all associated primary schools had met and agreed programmes of study in order to ensure greater consistency of pupils' experiences. Cluster planning of this sort enabled secondary schools to build on pupils' prior learning thus avoiding the need for a 'fresh start' approach. In the best practice, schools had worked closely with their associated primary schools to agree which aspects of science would be taught at each stage. In a few cases, secondary teachers were directly involved in providing science lessons for primary pupils or in working alongside primary colleagues. Such steps reduced the need for unnecessary repetition of work when pupils entered secondary school. This created time to include more up to date aspects of science, further investigative work and opportunities to talk about science. Many courses included science 'thinking skills' which helped pupils to solve problems, analyse and evaluate evidence and draw conclusions. In a few cases, primary teachers had agreed to begin this approach in P6/P7 or even earlier.

Is there sufficient collaboration between associated primary and secondary schools to ensure that the needs of all pupils are suitably addressed?

Do all S1/S2 pupils undertake tasks which are suited to their previous attainment? If not, what strategies should be adopted to address this?

2

COURSES

The best courses included the following features:

- agreed content coverage across a cluster of schools;
- key areas of contemporary science, including genetics, microelectronics, astronomy and earth science, and up to date examples of applications of science in society;
- practical work weighted towards open-ended investigations, supported by the teaching of 'thinking skills';
- effective strategies to meet the needs of different groups of pupils, including the most able and those with additional support needs; and
- suitably challenging, varied and purposeful forms of homework.

Features of effective courses at S3 to S6

Effective science departments ensured that the courses they taught prepared pupils thoroughly to meet the requirements of external examinations set by SQA. Departments provided staff with helpful written guidance on course structures, time-lines, resources, learning and teaching approaches and assessment. They also made available a range of additional materials and resources which staff used selectively to consolidate and extend pupils' learning as necessary. Arrangements documents, which included learning objectives, were often shared with pupils. This allowed them to take greater responsibility for their own learning. All these strategies helped to ensure consistency of approach across classes and that the course structures followed closely SQA advice and assessment requirements. Effective courses took due account of the need to cover key course elements and included regular opportunities for pupils to practise and develop appropriate investigative skills. Homework tasks were given regularly to consolidate learning and replicated the types of questions offered in external examinations. In the best departments, courses included opportunities to consider the benefits and risks associated with applications of the sciences, including moral and ethical implications.

At S3/S4, a significant number of schools had replaced Standard Grade Science with Intermediate 1 or Access 3 courses in one or more of the separate sciences. In some, but not all, cases these courses were proving successful in meeting pupils' needs, mainly because the content was more relevant and up to date. Early indications were that, in some schools, pupils were responding positively to these courses and were showing improved motivation and progress. Teachers were being well supported in the implementation of these courses by the provision of good quality national exemplary materials. Other schools had taken advantage of curriculum flexibility and successfully replaced Standard Grade courses in the separate sciences with equivalent Intermediate 2 courses. These courses, run over two years, gave teachers more time to consolidate understanding and to include optional activities such as fieldwork and visits. This had also freed up some time by removing the need to cover Standard Grade content which did not articulate directly with Higher provision in the sciences.

Has any replacement of Standard Grade Science with Intermediate 1/Access 3 led to an improvement in pupils' motivation and attainment?

At S5/S6, schools had responded very well to implementing NQ courses thus enabling them to meet a wider range of pupils' needs and aspirations. Most schools offered biology, chemistry and physics at two or three levels and an increasing number offered human biology because of its vocational relevance. A few schools had also introduced new courses in biotechnology and managing environmental resources.

In many schools, senior managers, guidance staff and principal teachers made effective use of attainment information to advise pupils on course choices appropriate to their prior levels of attainment. This information included the use of grade-point averages from Standard Grade to help predict minimum targets for pupils in S5/S6. In effective schools, staff took time to explain course admission procedures and used induction time well to share key information and expectations with pupils. In the best courses, teachers ensured that all aspects were covered and that delivery went beyond minimum SQA assessment requirements. This was true both of knowledge and understanding and the development of investigative skills.

Is your school's presentation policy in S5/S6 sufficiently robust to ensure that pupils are following the most appropriate courses, linked to their prior attainment and career aspirations?

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COURSES

Main areas for improvement in courses at the secondary stages

The greatest need for improvement continued to be at S1/S2 where there were important weaknesses in about a quarter of schools. Failure to capture pupils' interest and to challenge them at these stages was constraining the uptake of sciences at later stages and pupils' subsequent attainment.

The most significant weaknesses at S1/S2 were:

- insufficient planned progression due to a lack of collaboration between associated primary and secondary schools in implementing an agreed science programme suitable for P1 to S2;
- a lack of structured and effective approaches to differentiation which ensured that all pupils experienced regular success and achieved their potential;
- insufficient emphasis on modern aspects of science, and on developing the full range of investigative skills through practical work;
- excessive, and unselective use of, worksheets;
- less frequent and challenging homework than in other subjects; and
- too little use of ICT by pupils to support their learning, and in processing and presenting scientific information and data.

At S3/S4, important weaknesses continued to be found in a number of Standard Grade Science courses. These weaknesses included too little use of direct, interactive teaching, an over-emphasis on worksheet-based activities and limited practical work. In addition, too many courses failed to provide Credit level work for higher attaining pupils. Much of the content, examples and approaches in the course were now dated and inappropriate. The replacement of Standard Grade Science with NQ courses had not been entirely successful in meeting the full range of pupils' needs. The high failure rate, including No Awards at Intermediate 1 was of particular concern.

In the separate sciences at Standard Grade, too many pupils were attempting both Credit and General levels with inappropriate prior experience and attainment. Sometimes, pupils who were clearly experiencing difficulty, were routinely expected to undertake Credit level work. This was inappropriate to their learning needs. At S5/S6, too many pupils were still opting to study, and fail, courses which were too demanding for them. Despite the availability of Intermediate 2 courses, it was disappointing that the proportion of No Awards at Higher had shown only a slight decline in some courses and no change in others.

Curriculum development and associated continuing professional development (CPD)

Across the sciences, and particularly at S3 to S6, it is proving increasingly difficult to keep the content of courses up to date and relevant to the needs of society. The existing model of curriculum development, which allows for subject updating on a 10- to 20-year cycle, is unable to take account of the unprecedented rate at which developments in science and technology are taking place. All science courses contain content which is out of date or which does not use recent evidence to reflect current understanding of contemporary issues. A more responsive model for curriculum development needs to be found which will allow a cycle of continuous updating and reform to be implemented.[7] It is relatively easy to devise a modern science curriculum. The challenge is to turn well-intentioned aspirations for the science curriculum into reality in every classroom or laboratory where science is taught.

[7] *A Curriculum for Excellence: Ministerial Response* was published by the Scottish Executive in November 2004.

2

COURSES

As a consequence of the almost exponential growth of scientific knowledge and associated investigative skills, it has not proved possible for science teachers to keep professionally up to date with developments in their subjects. Many science teachers in their 40s and 50s are required to teach content which they may not have covered in their university training, either because it was outwith their specialist field or because new knowledge has been acquired. This problem will only continue to grow with each new generation of science teachers. Understandably, science teachers require to have opportunities for hands-on experience of new and innovative protocols before they will allow pupils to practise such techniques in class. Some teachers have taken advantage of very good opportunities for subject updating provided by professional bodies, higher education and industry. These include residential summer schools as well as shorter events, aimed mainly at subject and pedagogical updating. However, many teachers are unable to take advantage of these kinds of opportunities. There is a need for a clear strategy to ensure that all teachers of science in Scotland benefit from high quality professional updating of this kind.

The age structure of the science teaching force is also a matter of concern. About 75% of science teachers are over the age of 40 and more than one in three are over the age of 50. Many will retire in the foreseeable future and will need to be replaced. Applications to teach physics and chemistry are barely enough to meet current demands and this problem will only worsen as more science teachers retire. In addition to attracting sufficient science teachers, it is also important that teacher education institutions ensure that their pre-service programmes prepare new teachers for the likely demands of any outcomes of the review of science 3-18.

What opportunities for professional development in service have you taken part in recently?

3

LEARNING AND TEACHING, ASSESSMENT AND MEETING PUPILS' NEEDS

Learning and teaching

The overall quality of learning and teaching continued to be a strength with significant improvements being made in a number of areas, particularly in aspects of teaching in primary schools and in the separate sciences at S3 to S6. The quality of teaching was good or better in almost all secondary science departments. It was very good in 26% of departments compared with 15% over the period 1995 to 2000. The quality of pupils' learning was good or better in around 79% of departments which is about the same as the period between 1995 and 2000. However, departments exhibiting very good learning had increased from 15% to 22%. Overall, the quality of pupils' learning was poorer in S1-S4 Science courses where around 30% of departments showed important weaknesses.

Features of effective learning and teaching

Pupils learned most effectively when the learning environment was stimulating and when teaching was lively, interesting and relevant to pupils' prior knowledge and experience of the world around them. Increasingly, effective teachers were finding innovative ways of introducing topics. These helped to capture pupils' interests, to ascertain their prior knowledge, including misconceptions, and to provide a purposeful context for the associated tasks which followed. Such introductory activities, all set in appropriate scientific contexts, involved pupils in tasks such as:

- completing concept maps;
- reading and analysing newspaper articles;
- hypothesising about the outcome of investigations; and
- commenting critically on demonstrations carried out by their teacher.

To what extent do the learning and teaching approaches help prepare pupils for the science and technology they will encounter as citizens in the 21st century?

3

LEARNING AND TEACHING, ASSESSMENT AND MEETING PUPILS' NEEDS

All these activities helped pupils understand the importance of the science they were learning to their future role as citizens, living and working in an ever more complex scientific and technological environment.

Over recent years, the quality of teaching had improved in a number of ways. Teachers were making more effective use of interactive teaching, both to explain new ideas and procedures and to consolidate pupils' understanding. This involved teachers in engaging pupils in effective questioning and discussion which helped gauge prior knowledge and understanding and allowed the teacher to set tasks which challenged pupils at an appropriate level. Discussion was best when the teacher asked open-ended questions, designed to make pupils think about scientific concepts and to allow them to acquire and practise the vocabulary and language of science. In the most effective situations, teachers interspersed short pulses of direct teaching with tasks which extended or consolidated pupils' understanding. This helped increase the pace of progress where pupils' interest was flagging or introduced fresh challenge where pupils had completed tasks. Although opportunities existed for pupils to discuss and debate social, moral and ethical implications of the sciences, as yet this had not become a regular feature of many classes.

How effectively do teachers interact with pupils to explain new areas of content and to engage them in open-ended questioning and discussion?

At all stages, pupils learned best when they were clear about the purpose of lessons and knew what was expected of them, including the standards to be attained. Teachers achieved this in a variety of ways. For example, they shared with pupils both written course objectives and, at the start of lessons, objectives and agreed timelines for completion of specific tasks. These factors helped pupils take responsibility for aspects of their learning, appropriate to their age and stage.

Are your pupils given regular opportunities to be actively involved and to take responsibility for aspects of their learning?

Learning activities were most stimulating when they engaged pupils actively, whether in carrying out practical investigations or in developing thinking skills associated with problem solving, reasoning, drawing conclusions, analysing and evaluating evidence and hypothesising. Pupils at all stages were able to work in small teams to plan, carry out, analyse and report the results of open-ended investigations which helped them develop a better understanding of the scientific process. The teaching of thinking skills, particularly at S1/S2, had become firmly established practice in many schools across the country. This gave pupils opportunities to work independently and to apply critical thinking in a range of unfamiliar contexts.

In the most effective schools and science departments, staff had agreed policies and procedures for learning and teaching which they applied consistently with all their classes. This was the case, for example, in situations where:

- lessons had a clear, beginning, middle and end;
- all pupils used the same format to record the detail of scientific investigations they had carried out;
- teachers had clear expectations about standards of written work, including homework, and how it should be checked and commented upon; and
- teachers used praise to reward success and build confidence.

This was most successful where pupils were engaged in evaluating course delivery and where teachers responded positively to their comments.

To what extent do all staff contribute to, and implement consistently, key policies and procedures which improve learning and teaching, build self-confidence and raise attainment?

3

LEARNING AND TEACHING, ASSESSMENT AND MEETING PUPILS' NEEDS

Teachers and pupils were increasingly using information and communications technology (ICT) to improve learning and teaching at all stages. Teachers were using data projectors and electronic whiteboards to enhance the quality of their presentations and to involve pupils more actively in their learning. The use of such interactive approaches had improved the dynamics of the classroom through sharing information more directly with the whole class. This stimulated and engaged pupils, and the high quality of the images and situations encouraged them to ask thoughtful and perceptive questions which sometimes challenged their teachers. At all stages, pupils also used computers for a wide range of purposes, including accessing the Internet, word-processing, graph-drawing, interfacing and giving presentations.

To what extent are staff and pupils using ICT to improve learning and teaching?

Main areas for improvement in learning and teaching

- In many schools, teachers did not share course and lesson objectives with pupils or indicate the amount of time that should be devoted to particular tasks. As a consequence, pupils were often unclear about what they were expected to achieve and worked at a relatively slow pace.
- Some teachers spent too little time carrying out direct teaching, interacting with pupils as they worked, and questioning them to check and develop their understanding of key ideas.
- Pupils were given too few opportunities to discuss science issues, including those which had social, moral and ethical implications. They would have benefited from being encouraged to talk about science in order to improve their use and understanding of scientific vocabulary.

Do all teachers in your department or school share lesson objectives with pupils, carry out direct teaching effectively and allow pupils to discuss science issues?

The use of assessment to support learning

In most primary schools, approaches to assessment in science had some important weaknesses, and were sometimes unsatisfactory. However, many primary schools were making good use of the advice offered by the *Assessment is for Learning* programme and were beginning to adopt more systematic approaches to assessment generally. In S1/S2, assessment practices were not well developed and there were important weaknesses in about a third of schools.

When compared with standards reported by HMI during the period 1995 to 2000, approaches to assessment at the 5-14 stages showed little overall improvement. Many schools had still to find effective ways to relate pupils' performance to national 5-14 levels of attainment, although the situation was gradually improving at S1/S2. Schools as a whole often made insufficient use of assessment information to set appropriate targets for pupils. Teachers usually kept clear records of pupils' attainment at S1 to S4, but many overlooked the important messages they contained about pupils' progress. Thus, they continued to present some pupils with coursework that was either too difficult or too easy for them. In secondary schools, approaches to assessment in SQA courses at S3 to S6 were usually good or very good.

To what extent, at 5-14, are assessments based on specific and measurable outcomes for pupils' learning?

3

LEARNING AND TEACHING, ASSESSMENT AND MEETING PUPILS' NEEDS

Features of effective assessment in supporting learning

The following good practice was noted in some primary schools.

- Teachers set down succinctly the key knowledge, understanding and skills they expected different groups of pupils to learn, and how this learning would be assessed.
- Pupils were told what criteria would be used in assessing their work.
- Teachers used a variety of approaches to assess pupils' progress, including questioning, observing skills, examining written and other examples of pupils' work, and end-of-topic tests.
- The success of different groups in achieving particular learning targets was recorded systematically, along with any individual pupil aptitudes or development needs.

The following good practice was noted in a number of secondary schools.

- In S1, teachers used information provided on pupils' attainment in English language and mathematics in primary school to help inform their expectations of pupils' achievement in science.
- In S1/S2, teachers used end-of-topic tests and practical investigations to assess pupils' knowledge, understanding and skills and related performance to different 5-14 levels of attainment.
- Teachers regularly discussed pupils' progress and liaised with guidance staff and others to help support those who were under-performing.
- Pupils' grade point averages (GPAs) from Standard Grade examinations in S4 were used in setting appropriate minimum targets for pupils in S5/S6.

To what extent do you use pupils' results in assessments to set appropriate future work for them?

In your primary school, are these features evident in your use of assessment in science?

- To ensure consistent standards, teachers moderated samples of colleagues' assessments of pupils.
- There was a clear policy on the correction of pupils' classwork and homework which was monitored in practice by the head of department.
- Heads of departments maintained up to date records of pupils' attainment in each class and analysed this information to help evaluate the quality of learning and teaching, and to identify patterns or trends in attainment.

Main areas for improvement in assessment

- Most primary schools required more rigorous and systematic approaches to assessing pupils' learning in science.
- At P1 to S2, many schools required to develop their assessment practices in order to match pupils' performance to national 5-14 levels of attainment.
- At P1 to S4, many schools required to make better use of assessment information to ensure realistic but challenging targets for all pupils.
- Heads of departments and senior managers in secondary schools needed to give greater importance to monitoring pupils' attainment in S1/S2 science.

In your department, is pupils' classwork and homework, at all stages, regularly checked and commented on by teachers?

Are clear assessment records kept centrally for all classes, and regularly discussed with staff to help evaluate learning and teaching?

3

LEARNING AND TEACHING, ASSESSMENT AND MEETING PUPILS' NEEDS

Meeting pupils' needs

At the primary stages, only a little over half the schools inspected were effective in meeting the needs of pupils through their science programmes. This represents no improvement in the position in 1995 to 2000. In secondary schools, almost all departments inspected were effective in meeting the needs of pupils from S3 to S6 through the courses offered in biology, chemistry and physics. The introduction of NQ courses had helped departments to cater more effectively for a wider range of pupils' needs at these stages. However, just under half the departments had important weaknesses in how they met the needs of S1/S2 pupils through their science courses. This is an improvement on the position in 1995 to 2000 where 65% of departments had significant weaknesses.

Features of meeting pupils' needs effectively to support learning

In the best primary schools, teachers ensured that tasks and activities were well matched to pupils' needs and intellectual maturity. They planned practical work to ensure the progressive development of investigative skills and linked new science concepts to pupils' everyday knowledge and experience. They gave pupils hands-on experience of real artefacts and materials and made regular and purposeful use of the immediate environment of the school to provide a meaningful context for pupils' learning. They deployed classrooms assistants effectively to support pupils' learning. Teachers also took care to strike an appropriate balance between whole class teaching to introduce tasks, and group work, where tasks were flexibly designed to ensure a close match with pupils' prior attainment.

At S1/S2, some departments had made good progress in adapting science courses to provide better differentiation of learning objectives, activities and resources. They had also modified assessments and homework in order to meet pupils' varying needs more effectively. In general, most science teachers provided good support in class to help pupils experiencing difficulties in their learning.

Learning support staff sometimes provided invaluable help for pupils, both through working alongside teachers in class and offering suggestions about how best to adapt course materials to support and challenge pupils. Some schools had introduced setting, mainly at S2, to help staff match the pace and challenge of learning to pupils' needs and prior attainment. These arrangements were most effective where staff kept pupils' progress closely under review and provided opportunities for movement within groups as pupils' attainment levels changed. They also worked best where teachers adapted their approaches and where course materials were used selectively to meet pupils' needs.	To what extent have you met pupils' needs through grouping pupils by attainment or using alternative learning and teaching strategies?
In the most effective science departments, staff set consistently high expectations for presentation of written work and provided regular, helpful feedback to pupils on ways of improving their work. A few departments had involved pupils in setting individual targets, sometimes making suggestions about how best to improve their performance.	To what extent do you ensure that pupils' written work is of a consistently high standard and what type of feedback do you give pupils about how to improve aspects of their work?
In the separate sciences at S3/S4, almost all departments provided good or very good support for pupils. They achieved this through direct interaction with individuals or groups and through the provision of good quality course materials, including print and ICT resources. Many teachers also provided additional support through after-school or lunchtime study clubs. Increasingly, schools had adopted some form of setting or grouping within classes to address the wide range of learning needs. This worked best where higher attaining sets were suitably challenged, sometimes by tackling more advanced problems or more demanding investigations.	

3

LEARNING AND TEACHING, ASSESSMENT AND MEETING PUPILS' NEEDS

At S5/S6, almost all departments offered a suitably wide range of NQ courses to allow pupils to make progress from their prior levels of attainment. The inclusion of more vocational courses such as human biology, biotechnology, geology and MER gave pupils further opportunities to meet their needs and interests. In the most effective departments, staff devoted considerable time to ensuring that pupils were following courses which would allow them to achieve success and to meet their career aspirations. Induction procedures were used to set expectations for the year and to share information about course structure, assessment procedures and targets to be achieved. Such sharing of responsibility for learning was a vital element of successful departments. Where pupils were suitably challenged, tasks gave them opportunities to achieve success and to develop a wider range of core skills, including using ICT for a variety of purposes. This was particularly true at Advanced Higher where investigative work allowed pupils to be more creative and to work with a degree of independence.

Main areas for improvement in how pupils' needs are met

At P1 to S2, the following key areas required improvement.

- In many schools, even where courses were planned to allow for differentiation, all pupils undertook the same tasks at broadly the same pace, so that some found the work undemanding while others struggled to cope.
- In some cases, too little use was made of learning support staff to provide advice on how best to modify course materials and to provide direct assistance for lower-attaining pupils.

At S3 to S6, the following key areas required improvement.

- In NQ courses, too many pupils were attempting and failing to achieve success, mainly because course objectives were too demanding for them based on their prior attainment. They would have been better advised to follow a course at a more appropriate level.

What is the nature of your induction procedures for pupils starting new courses?

Have you consulted with your learning support staff about the various ways in which they can offer advice and assistance about how best to meet the needs of pupils?

To what extent do you use your own school's evidence about likely success rates in NQ courses based on their attainment at earlier stages in your school?

4

ETHOS

The quality of relationships between pupils and teachers continued to be a significant strength of primary schools and secondary science departments. In the best schools and science departments, all staff worked very effectively as a team. They contributed to policies and development tasks and set high standards in all aspects of their work. A key factor in this was the way in which all staff applied strategies consistently. This allowed them to establish an effective working environment which motivated, supported and encouraged pupils to work to the best of their abilities. Pupils, regardless of their prior attainment or the courses or programmes they were following, were equally valued and expected to achieve.

In your school, what strategies are used to promote a consistent approach to setting high standards for pupils' achievement, attendance and behaviour?

Effective features of ethos

Pupils worked best in an environment which was interesting and challenging and where there was a feeling of mutual respect between teacher and pupils. Many teachers worked hard to make their classroom or laboratory environment stimulating through, for example, the display of interesting scientific artefacts, pupils' best work, topical newspaper or magazine articles and photographs. This worked best where displays were changed regularly to reflect current topics and where pupils were involved in creating or displaying materials. Where classes had carried out fieldwork in the local environment or visited other places of scientific interest, this often provided them with additional resources and ideas which they could follow up in class, thus making a better link with the world outside the school. Artefacts or displays were linked to purposeful and appropriately challenging tasks which required pupils to observe, discuss and answer questions.

To what extent have you created an interesting and challenging environment which stimulates and motivates pupils?

4

ETHOS

Teachers who were interested in pupils as individuals, used praise appropriately, and who were seen to be supportive and fair, gained the respect of their pupils. Where pupils were given positive and constructive feedback, whether oral or written, they gained in confidence since they were clear about what they had done well and what they needed to do to improve. During questioning, effective teachers matched questions well to individual pupil's needs. This allowed them to give positive feedback to pupils, all of whom gained some degree of success. Many schools had adopted a range of measures to recognise and reward pupils' efforts and achievements and to promote positive behaviour. In many classrooms and laboratories, pupils had discussed and agreed sensible measures to ensure a safe and healthy working environment in which the rights of other learners were respected. In some science departments, pupils and teachers had signed contracts or partnership agreements which acknowledged each other's expectations and commitments.

In what ways do you praise and give constructive feedback to pupils to build self-esteem and reward effort and success?

Where teachers made lessons interesting, relevant and challenging, pupils were motivated to learn and to perform well. From the moment pupils arrived in class, time was valued and teachers explained what had to be achieved and reinforced the standards of work which were expected. These values were transmitted to, and accepted by, pupils who responded by remaining on task and by producing high quality written work. In these situations, it was rare to find any signs of graffiti on jotters or furniture. Teachers regularly monitored pupils' classwork and homework, both to acknowledge good standards and to make suggestions for improvement. Headteachers and principal teachers often used this approach successfully to ensure consistency of standards across classes and over time.

How do you ensure that high standards are set and maintained across classes and over time?

In primary schools, where the class teacher was responsible for co-ordinating pupils' learning across the curriculum, it was easier to ensure that pupils were treated fairly and consistently, and that provision met their needs. This included those pupils with additional support needs and from different cultural backgrounds. In secondary schools, it was more difficult to ensure that pupils were treated fairly and consistently across the much wider variety of subjects and teachers. This was particularly true in S1/S2 science, where there was usually only a single course, often with little differentiation, for all pupils to follow. The situation was better at S3 to S6 where a wide range of science courses at different levels was available to meet the needs of almost all pupils. In schools where teachers valued all pupils and courses equally, pupils' expectations were uniformly high as were standards of achievement.	Are all pupils treated fairly and are all courses equally valued by staff?
In both primary schools and secondary science departments, many teachers were committed to working with pupils outwith the formal classroom setting. For example, teachers ran or helped with extra-curricular activities, including science clubs, sporting activities, visits to science centres, and field trips, including visits overseas. This approach, which allowed pupils and teachers to work together in a less formal situation, had many benefits which carried over to the more formal work of the classroom. Teachers gained additional insight into the often unrecognised strengths, needs and talents of individual pupils. Similarly, pupils saw their teachers in a different light. On return to the classroom, teachers and pupils benefited from the improved working relationship. In both primary schools and science departments, teachers sometimes invited parents or other guests to come and talk to their classes about aspects of science and the environment.	What contribution do your staff make to pupils' broader achievements and what impact does this have on their attainment?

4

ETHOS

Main areas for improvement in ethos

Unmotivating coursework and over-concentration on mundane and unchallenging tasks, particularly in S1-S4 Science classes, often contributed to pupils' poor behaviour and attitude to work. In a significant number of schools, mainly secondary, this resulted in the behaviour of a small minority of pupils in particular classes sometimes disrupting the learning of other pupils. This was mainly confined to S1-S4 Science classes, and was particularly evident amongst boys in some S2 classes. In these classes, pupils were frequently not working purposefully on task, showed insufficient respect for teachers and other pupils and were often inappropriately dressed to work in a science laboratory. In some cases, teachers did not deal effectively with indiscipline in order to minimise disruption to other pupils.

Situations of indiscipline were most common where there was a lack of consistency in how teachers responded to their classes and where there was insufficient focus on promoting and rewarding positive behaviour. In these cases, there were often weaknesses in basic classroom management. These included a failure to establish how and when pupils entered and left classrooms, allowing pupils to shout out answers indiscriminately and ignoring pupils when they were not working on the tasks set for them. This was often compounded by learning and teaching which lacked relevance, rigour and challenge.

What steps have you taken to address situations where pupils' behaviour is known to disrupt the learning of others?

5

LEADERSHIP

In secondary schools, principal teachers of biology, chemistry or physics provided good or very good leadership in almost all departments. Leadership in relation to S1/S2 and other Science courses was good or better in 79% of departments, and showed considerable improvement on standards reported by HMI during the period 1995 to 2000 where it was good or better in 65% of departments.

Effective education authorities had provided strategic support for their schools, making use, for example, of specific funds for Science Strategy projects. They used this money, for example:

- to second teachers to work as development officers in primary and secondary schools and to encourage cooperation between staff in both sectors;
- to develop resources, contributing to a shared national pool of materials and ideas, as part of the Improving Science Education 5-14 project;
- to provide opportunities for continuing professional development (CPD); and
- to provide science equipment and other resources, including ICT, for their schools.

What beneficial impact has the additional funding for Science Strategy projects had on pupils' experience and attainment in your school?

5

LEADERSHIP

Features of effective leadership

Effective leaders created a working environment in which all staff and pupils felt valued, shared a common set of goals and were willing to reflect on their individual and collective achievements. Staff worked very well as a team and had consistently high expectations of pupils' attainment and behaviour. Such leaders demonstrated up to date knowledge of national developments in science and education more generally. Their clear vision for school or departmental improvement was communicated effectively to others. They had established systematic approaches to monitor and evaluate the quality of classroom practice and pupils' attainment at all stages. Whilst guiding and supporting staff, effective leaders did not avoid tackling difficult issues which affected the quality of pupils' learning and attainment. They encouraged staff to be innovative and to evaluate their own work critically. Where the need for improvement was evident, they ensured that necessary action was taken.

Development tasks were well planned and focused on ways of improving teaching and learning rather than on products such as worksheets and assessment materials. Key outcomes were achieved within agreed timescales and impacted positively on pupils' work. Overall, they had created a culture in which staff felt valued and not threatened, and in which teachers were willing to support and learn from each other's best practices.

To what extent has your headteacher or head of department/faculty created a culture of self-evaluation in which staff feel valued and are willing to support and learn from each other's best practices?

Main areas for improvement in leadership

In some primary schools, school managers did not ensure that pupils' experiences in science were sufficiently frequent and of appropriate quality. Weaknesses arose when staff were unclear about the science, including key knowledge and skills, that pupils should be taught. In too many primary schools, insufficient attention was paid to assessing and recording pupils' attainment in science. This made it difficult for school managers to track pupils' progress and monitor the school's overall performance in science. It also led to secondary teachers in S1 being uncertain about pupils' prior attainment.

To what extent are these issues in your school? If so, how will you address them?

In a minority of secondary departments, individual responsibilities for the corporate management of Science courses were still not specific enough. This resulted in a lack of proper accountability for Science as compared with the separate sciences. Typical outcomes of this were that:

- 5-14 developments were given lower priority;
- overall attainment in S1/S2 science received much less attention than attainment in SQA courses; and
- improvement plans for science were relegated to a minor position within more extensive plans for biology, chemistry and physics.

Senior managers often compounded these problems by not including sufficient discussion of them in departmental reviews.

In both primary and secondary schools, managers and heads of department often gave too little attention to monitoring the quality of classroom practice in the teaching of science. They rarely visited classes to formally observe practice or sampled pupils' written work to check standards and consistency of approach. This made it difficult for them to identify and spread best practice, and to target advice and support where necessary. In some secondary departments, records of pupils' progress in each class were not kept systematically enough, or used to set targets for pupils or identify pupils requiring additional support or challenge.

Some education authorities had not given a clear lead to ensuring the steady development of pupils' learning in science as they progressed from primary into secondary school. As a result, primary schools in a cluster failed to agree a common science programme with the result that many secondary science departments covered work in S1/S2 that was more appropriate to pupils at the primary stages. As a consequence, pupils were under-achieving in science.

How well are your education authority support services, school managers and heads of department working together to ensure primary-secondary collaboration in science?

6

CONCLUSION, MAIN STRENGTHS AND MAIN AREAS FOR IMPROVEMENT

Conclusion

Overall, it is clear that a number of areas of strength in Scottish science education are being sustained and there have been improvements in some key aspects. Pupils are benefiting from improved teaching approaches in both primary and secondary schools. Science courses and programmes have strengthened in both sectors and increasing numbers of pupils have benefited from the wider range of certificated provision, particularly at S5/S6. Attainment has remained strong in the early stages of primary school, and at Standard Grade, Intermediate 2, Higher and Advanced Higher levels across the separate sciences.

However, there continues to be significant weaknesses, particularly at the upper stages of primary and at S1/S2 where too many pupils are either under-challenged or fail to see the relevance of the science they are studying to their own lives. For the large numbers of pupils who do not progress to studying separate sciences beyond S2, it is of paramount importance that they understand and can make reasoned decisions about developments in science and technology which will affect them as citizens of the 21st century. Too many pupils are taking, and failing, NQ courses because they are at a level which is too demanding for them, based on their prior attainment. Schools need to improve the advice they give to such pupils in order to prevent failure and demotivation.

The content and approaches of the Standard Grade Science course are now badly out- of- date and in need of revision. The course has never proved to be wholly effective in meeting the needs of pupils who did not want to specialise in the separate sciences. In most schools, Science courses have tended to focus on Foundation and General level work and, in many schools, Credit level work was not made available to extend and challenge pupils. Over recent years, increasing numbers of schools have replaced Standard Grade Science with Intermediate 1 and Access courses in the separate sciences. This has met with varying degrees of success. The high failure rate, including No Awards at Intermediate 1, is of particular concern.

Across the sciences, and particularly at S3 to S6, science courses contain content which is out of date and which needs to be replaced. A more responsive model for curriculum development needs to be found which will allow a cycle of continuous updating and reform to be implemented. As a consequence of the almost exponential growth of scientific knowledge and associated investigative skills, it is proving difficult for science teachers to keep professionally up to date with developments in their subjects. The lack of any national mechanism to deliver high quality professional updating to all science teachers is a major barrier to progress in Scotland.

In many schools, there are significant inconsistencies in pupils' experience of science. Managers at all levels in schools and education authorities have a key role to play in monitoring and evaluating pupils' classroom experiences. Where they identify good practice, they need to promote it more widely both in and across other schools. Where they identify unacceptable inconsistencies, for example in expectations, class management or standards of pupils' work, they need to target advice and support as necessary. Most importantly, schools need to promote a culture of self-evaluation where staff reflect on their practices and those of others and, as necessary, improve aspects of learning and teaching.

Main strengths

The main strengths in the provision of science were as follows.

- Overall good attainment at P1-P4 and in the separate sciences at S3 to S6.
- High uptake of separate science courses at S3 to S6 with steadily increasing uptake of courses at Access 2 and 3, Intermediate 1 and 2, and Advanced Higher.
- Improved science programmes in primary schools and well-developed NQ courses in secondary schools.
- Improved standards of science teaching in both primary and secondary schools, particularly with regard to the use of interactive approaches and ICT.
- Good working relationships between teachers and pupils in almost all primary schools and secondary science departments, with pupils being treated fairly and effective use being made of praise.
- Effective leadership in most secondary science departments, including improved leadership of S1 to S4 Science courses.
- Some good use made of Science Strategy money by many schools, education authorities and other agencies to improve facilities and resources for science and to build teachers' confidence and competence through providing support and continuing professional development.

Main areas for improvement

Schools and education authorities need to take steps to:

- improve the overall quality of experience of, and attainment in, Science at P5 to S2, Standard Grade Science, and Access and Intermediate 1 biology, chemistry and physics;
- ensure that associated primary and secondary schools work together to agree and implement a science programme which:
  - allows progressive development of knowledge, understanding and skills, particularly investigative and thinking skills;
  - promotes interactive approaches to learning and teaching, including the use of ICT;
  - broadens assessment procedures to include a better balance between formative and summative assessment and allows teachers to readily match pupils' performance to national 5-14 levels of attainment;
  - meets all pupils' needs more effectively, particularly in S1, through using a broad range of differentiation strategies to ensure challenge and support as appropriate;
  - encourages discussion of social, moral and ethical issues; and
  - includes key areas of contemporary science to help prepare all young people for the science they will encounter as citizens of the 21st century.
- improve advice for pupils, based on school, local and national evidence, about the NQ courses they should follow in order to maximise the chance of gaining success in external awards;

6

CONCLUSION, MAIN STRENGTHS AND AREAS FOR IMPROVEMENT

- identify and promote innovative learning and teaching strategies which motivate teachers and pupils, promote interactive learning, improve pupils' experiences, and raise attainment;
- ensure that teachers set high expectations for the attendance, behaviour and work rate of all pupils they teach and that these expectations are shared regularly with pupils;
- ensure that all staff adopt consistent approaches to effective classroom management and establish systems which promote and reward positive behaviour;
- promote a culture of self-evaluation where staff reflect on their practices and those of others and, as necessary, improve aspects of learning and teaching; and
- ensure that managers monitor and evaluate classroom practice in order to identify and spread best practice, and to target advice and support where necessary.

Appropriate bodies at national level (including SEED, SQA and LT Scotland), working as necessary with higher education and education authorities, should:

- ensure that the review of science 3-18 being undertaken in response to *A Curriculum for Excellence* addresses key issues raised in this report, in particular the need to:
- update the content of existing science courses at all stages to reflect current understanding of contemporary issues and to ensure suitable progression from stage to stage;
- develop the science curriculum to better meet the needs of all learners in order to prepare them to make informed decisions about the science they will encounter as citizens of the 21st century;
- devise a mechanism to allow the continuous updating and reform of the curriculum at all stages to take account of ongoing developments in science and associated technologies;
- provide attractive, challenging and relevant courses for all pupils, including those who decide not to specialise in science;
- promote the study of the sciences so that enough people study science to a standard which will enable the future needs of the country to be met;
- ensure that there are sufficient well-qualified science teachers to meet future demands and that teacher education institutions take account of the outcomes of the review of the curriculum in the pre-service training of teachers; and
- establish a sustainable national mechanism to deliver high quality professional updating to all teachers of science to allow them to keep up to date with developments in their subjects.

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