[SCIENCE]

A portrait of current practice in Scottish schools

HMIe

improving Scottish education

[FOREWORD]

Science: A portrait of current practice is part of a series of portraits by HMIE which builds on the messages of the *Improving Scottish Education* report. This portrait reviews the extent to which current practice in science is successfully promoting the four capacities of Curriculum for Excellence.

The report shows that in many pre-school centres and schools, children and young people already display some of the attributes, skills and capabilities of the four capacities of Curriculum for Excellence. The pre-school centres and schools exemplified in this portrait highlight effective practice across Scotland. Inspection findings indicate there are many strengths in science education. Our children and young people benefit from an encouraging learning environment which promotes positive attitudes to science. Improvements being made to learners' experiences in science are developing aspects of their investigative and collaborative team working skills well. Increasingly in science, the motivation of children and young people is being enhanced through partnership working and links with national and local science facilities. Such experiences are also developing well their citizenship skills and awareness of environmental issues and the impact of science on society. The science literacy results in the *2007 Scottish Survey of Achievement (SSA) Science, Science Literacy and Core Skills* are encouraging. They show that children and young people have the ability to apply their understanding of science to socially relevant contexts. Attainment remains strong in the early stages of primary school, and at Standard Grade, Intermediate 2, Higher and Advanced Higher levels across the separate sciences. Attainment at Intermediate 1 and Access 3 is improving.

International measures of attainment in science demonstrate that children and young people in Scotland perform well by international standards. However, the disappointing performance in *2007 SSA Science, Science Literacy and Core Skills*, in which too few learners were achieving the levels expected of them in knowledge and understanding, highlights that there are continuing areas of weakness. The challenge ahead is to improve learning and teaching approaches through promoting thinking and deeper understanding of scientific ideas. Children and young people need to be more active in their learning with greater independence, responsibility and awareness of themselves as learners and what they need to do to improve. They need to develop a wider range of practical investigation and inquiry skills, as well as literacy, numeracy and ICT skills, in relevant science contexts. Curriculum planning needs to ensure that we meet the needs of all children and young people, building on their prior learning and experiences, and providing appropriate support and challenge to help them make good progress.

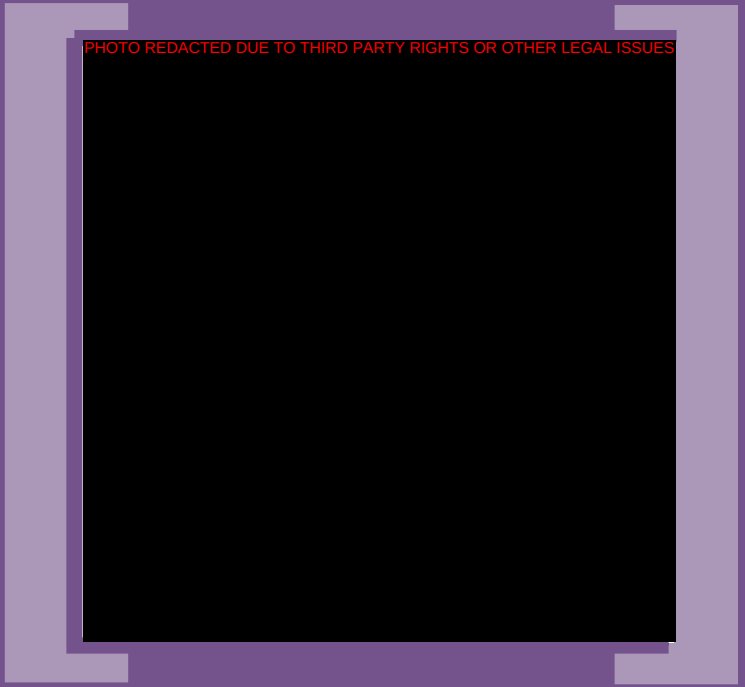
Science is at the heart of our ambitions for Curriculum for Excellence, which aims to bring about transformational change and ensure the best possible education for our children and young people. Improving children's and young people's experiences in science is a key priority for Curriculum for Excellence.

[FOREWORD]

The Scottish Government is developing a new strategic framework for science. Science is essential for sustainable business growth in Scotland in the key sectors that underpin our economy, while finding answers to global issues that impact on our daily lives. In that context, high quality science education will deliver the science workforce we need in the future. It will also encourage all our children and young people to develop as scientifically literate citizens with a life-long interest in science.

This portrait identifies how staff might contribute more to developing successful learners, confident individuals, responsible citizens and effective contributors in science. It includes a set of reflective questions relating to each of the four capacities. These will help staff review their practice as part of self-evaluation and to plan for excellence in learning, teaching and meeting needs in science, and in turn will help ensure positive outcomes and maximise success for children and young people.

Graham Donaldson
HM Senior Chief Inspector



[CONTENTS]

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Science: A portrait of current practice is one in a series of portraits by HMIE, depicting current practice in key aspects of the Scottish curriculum. The portrait series is an initiative by HMIE, flowing from the *Improving Scottish Education* report[1]. It is intended to promote improvements in Scottish education by drawing on the findings of inspections to stimulate reflection and debate. From time to time, portraits will be enhanced to include case studies of effective practice, usually to coincide with a good practice event in that subject. This is an enhanced portrait.

An important purpose of the portrait series is to relate existing pedagogy and curricular provision to the aspirations of Curriculum for Excellence [2]. By stimulating debate about teaching for effective learning, the portraits will challenge us all to review the extent to which current practice is successfully promoting the four capacities in all children and young people. The series sits alongside *How good is our school? The Journey to Excellence* [3] in focusing on the two key dimensions of excellence:

- engaging young people in the highest quality learning activities; and
- focusing on outcomes and maximising success for all children and young people.

This portrait is based on evidence obtained from visits to pre-school centres, primary and secondary schools during the period 2004 to 2008. These visits included both general inspections and other visits to explore practice. Inspectors evaluated the quality of learning, teaching, meeting learning needs and achievement. They also evaluated attainment in science in a representative sample of primary schools across Scotland in inspections which took place between May 2007 and April 2008. A detailed commentary on attainment in science 2004-2008 is provided in Appendix 1. This portrait also draws upon the work shared at the HMIE/Learning and Teaching Scotland (LTS) conference in November 2008, *Curriculum for Excellence Good Practice Conferences: Science – Working Together for Active Learning.* It illustrates ways in which teachers work successfully with children and young people to develop each of the four capacities of Curriculum for Excellence. It identifies how staff might contribute more to developing successful learners, confident individuals, responsible citizens and effective contributors. In particular, teachers can help children and young people to achieve their potential by ensuring that they build meaningfully on prior learning and by providing regular opportunities for children and young people to investigate their environment. It is through observing, exploring, investigating and recording that children and young people develop a secure understanding of the key concepts and big ideas of science. They require opportunities to express themselves and discuss social, moral and ethical issues in a supportive environment, so that they can develop their knowledge and understanding of science and insights into its impact on society and themselves.

In this report, the term ‘science’ is used as a generic term to refer to what children and young people experience in pre-school, primary and S1/S2 science as well as all the sciences in S1-S6 including biology, chemistry, physics, science, biotechnology and managing environmental resources (MER).

[SCIENCE AND CURRICULUM FOR EXCELLENCE]

[Q] How can science help to develop successful learners, confident individuals, responsible citizens and effective contributors?

Improving Scottish Education was published by HMIE in March 2006. It suggested building on the strengths in Scottish education to meet the needs of children and young people and improve their levels of achievement so that they are able to meet the challenges of a global society. It identified a number of important strengths in Scottish education and priorities for improvement. Some of those strengths and priorities for improvement were also identified in *Improving Achievement in Science in Primary and Secondary Schools* (HMIE, 2005)[4]. Some of the shared strengths emphasised in these reports were:

- children and young people perform well by international standards;
- many schools have a supportive climate for learning and positive relationships between staff and children and young people; and
- skilled teaching staff are committed to doing the best for children and young people.

Some of the shared themes identified for further improvement in these reports were to:

- improve learning by engaging and challenging all children and young people more and encourage in them a greater sense of responsibility and independence in learning;
- be inclusive and address the needs of all learners, including lower-attaining children and young people and boys; and
- continue to raise attainment, for example through providing better balance, continuity and progression in the development of learners' knowledge, understanding and higher order skills and by improving assessment and consolidation of learning.

Building the Curriculum 1[5] defines the place of science within the curriculum and highlights - *'The most important goal for science education is to stimulate, nurture and sustain the curiosity, wonder and questioning of young people and children.'* (page 30). Scotland's economic future is increasingly dependent on science. A sound science education from age 3-18 therefore has social, economic and environmental significance in our rapidly changing and increasingly technological world. We need to meet the demand for trained scientists required to build a vibrant and sustainable economy. We also need to develop scientifically literate citizens by extending children's and young people's understanding of environmental and socially relevant scientific issues. This will develop their capacity to engage with confidence in informed debate and to make rational decisions based on evidence relating to such issues.

SIGNPOST TO SUCCESSFUL LEARNERS

Successful learners often display the following characteristics. They:

- are motivated and enthusiastic about learning which in turn impacts positively on their wellbeing;
- provide explanations supported by evidence or justifications;
- make reasoned evaluations based on the strength of evidence available;
- apply knowledge to evidence from observations, experiments, inquiries and investigations to formulate hypotheses, draw conclusions and make predictions and generalisations;
- think creatively and independently by designing procedures and carrying out experiments to investigate and solve problems;
- link and apply different kinds of learning to a range of issues arising from the application of science in society at local, national and global levels;
- are aware of the pace and significance of developments in science and can evaluate the impact of these; and
- use science as a means of developing and using a range of skills in critical thinking as well as literacy, numeracy and information and communications technology (ICT).

[Q] What do we do well currently in science to develop successful learners?

At all stages, children and young people learn well when they are clear about what they are learning and why. Well-planned opportunities for children and young people to be active in their learning help them to achieve success, for example through working together to design an experimental procedure, sharing the results of experiments and commenting constructively on each other's work. In many pre-school centres, primary schools and secondary science departments, teachers and other staff were successful in developing a positive ethos for learning where both teachers and learners had high expectations for engagement in learning and successful achievement. Staff interacted effectively with children and young people, giving them encouragement and promoting a positive attitude to science.

In pre-school centres, children were making good progress in their understanding of simple scientific experiences. Most children had access to a widening range of experiences as they developed their skills of inquiry and systems for organising and understanding their world. Staff frequently encouraged children's natural curiosity which in turn helped them find satisfying answers to their questions.

At all stages, learners are most successful and make good progress when the science experiences involve them in:

- a balanced range of learning and teaching approaches, with children and young people actively involved in a variety of activities including experiments and the use of real materials, artifacts and living things;

- developing knowledge, understanding and higher order skills focusing on outcomes to ensure coherence and progression in learning and achievements;
- developing practical investigation and inquiry skills within a range of relevant and real-life contexts with an appropriate emphasis on planning, collecting evidence, observing and measuring, recording and presenting, and interpreting and evaluating;
- consolidating and applying learning;
- choosing challenging topics to study in depth in open-ended investigations and projects;
- exploring recent developments in science, moral, ethical and environmental issues and science applications in society;
- forging links between science and other areas of learning including literacy and numeracy, sustainable development, health and wellbeing and enterprise; and
- experiences that have been developed jointly by teachers and staff across stages and sectors so that teachers are building progressively on prior achievements.

Building the Curriculum 3[6] provides further guidance on planning programmes to demonstrate the principles of curriculum design: challenge and enjoyment; breadth; progression; depth; personalisation and choice; coherence; and relevance.

Hands-on practical experimental and investigative learning activities form the key to developing successful learners in science. Developing thinking through investigations encourages children and young people to be open to new ideas which in turn can be tested through experimentation. Practical work allows children and young people to develop the ability to think creatively and independently while designing experiments with controls and designing procedures to solve problems.

Here are some comments from learners who are clear about the benefits of practical work.

" Practical work has more of a meaning. We can get more involved - it's more interesting rather than just writing all the time."

" Practical work makes it make sense. I like it when you can see what it all means - when it all comes together."

" The teacher asks us to predict the results of experiments and it's great seeing who was right."

" I like practicals when you get to start from scratch - you get a sense of achievement from making it work."

" You can read something over and over and it does not make sense until you do the practical work."

Commendably, primary school teachers were increasing the time children spent on practical work. Several schools inspected were developing effective links between science and other areas of learning.

In many secondary science departments, teachers were reviewing and developing the S1/S2 science courses. Many departments were increasing the range and variety of investigations and enhancing the development of skills by using a 'thinking skills' approach. They had identified the need to increase the pace of learning and provide more support and challenge to young people. Many departments were emphasising the relevance of topics, to sustain learners' motivation and to meet their needs better.

As a result, in these departments, inspectors noted young people were developing more independence in their learning.

Primary-secondary curriculum links

In one education authority, an education officer had taken a lead role in developing a common science programme across all associated school groups. A secondary science teacher collaborated with primary colleagues in delivering lessons. All P7 children attended a science club at the secondary school during class time. Teachers developed a consistent approach to developing thinking skills to improve progression. The P7 transfer report to secondary teachers included information on children's achievements in knowledge and understanding and investigation skills across a range of contexts. Teachers in the secondary school used this information to build on children's prior experiences and achievements and to provide appropriate challenging learning experiences and support where required.

Children and young people themselves have identified a range of factors which make a difference to their learning in science. The following points were made when things were going well.

" The science week was great fun when all the visitors came to the school. We got lots of workshops - science is everywhere! It affects every aspect of life."

" Our physics teacher has all the course notes and powerpoints on the departmental intranet. That way we get more time to discuss things in class and we don't need to copy notes."

" We get to work at our own pace and we don't have to wait for everyone."

" We get to make information posters on new topics so we can see the point of what we are learning."

" I like it when we are asked our opinion and get to discuss what we think."

" The teachers encourage us to take responsibility - they make it clear what we have to learn and expect us to carry out work for ourselves."

In primary and secondary schools, children's and young people's skills, including higher order skills, were being developed in a broad range of activities. Increasingly their experiences were being enhanced through opportunities for learning out-of-doors, field trips, and visits to science centres and local facilities.
They participated in science clubs, visiting interactive science exhibits and science workshop activities and working in school grounds and on local environmental projects. These activities increased their interest and enthusiasm for science as well as their motivation and engagement. They were developing awareness of environmental issues and knowledge of real-life uses of science and scientific values and attitudes.

Participating teachers were benefiting from high-quality continuing professional development provided by the Scottish Schools Equipment Research Centre (SSERC) in partnership with universities, professional organisations and industry.

Through taking part in the residential and day courses, they were developing skills in interactive approaches to science learning and teaching with strong links to Curriculum for Excellence. Many schools were developing productive partnerships with Scotland's Science Centre Network[7], which plays an important role in engaging children and young people in the world of science and in developing the skills and confidence of teachers. Stimulated by these experiences, teachers were engaging children and young people in a range of real-life contexts which emphasised the relevance of science to their own lives and to society as a whole.

[Q] Planning for excellence: how might science contribute more to developing successful learners?

In pre-school centres, there was scope for children to have more choices in activities and to persevere in their discoveries of properties of materials and their uses in play and real-life situations.

In primary schools, links between mathematics and scientific investigations should be stressed. Children and young people need more experience of consolidating and revisiting key ideas in their learning. Managers and teachers should develop a more reliable picture of learners' attainment in science. Recent developments in assessment for learning, whilst enhancing aspects of learning and teaching, had yet to address the need for a more consistent and reliable picture of learners' progress.

Inspectors found some good curricular links in science between primary schools and associated secondary schools but in most schools this was poorly developed.

This, together with the lack of reliable assessment information gathered at the primary stages, affected continuity in learning when young people entered S1.

In secondary schools, too often, young people were not sufficiently active in their learning. Teachers used questioning well to consolidate learners' knowledge but did not always use it effectively to promote thinking and develop understanding. Young people identified the following issues that affected their learning in science.

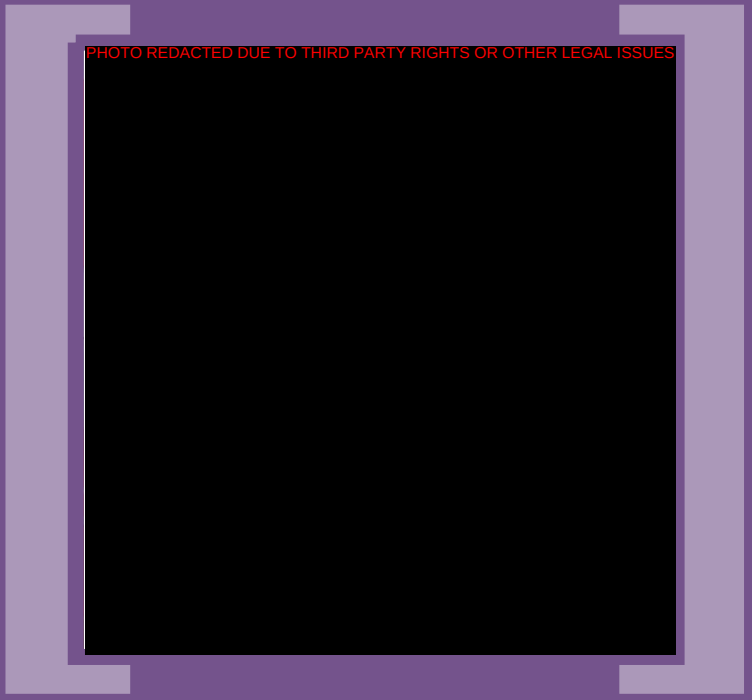
> *" The teacher talks too much - we just have to listen and copy down notes all the time."*

> *" We don't get enough choice. The teacher should let us choose a topic and take account of our opinions and ideas. We want it to be more relevant to our planned careers."*

At all stages, teachers were developing their use of ICT to enhance teaching and learning. However, learners' use of ICT to collect, analyse and present scientific data was often limited.

As part of bringing about improvement, it may be helpful to reflect on the following.

- How well have we built on children's and young people's prior learning to raise levels of achievement, including building on learning through play from pre-school into primary school, and from primary to secondary school?
- How can we more effectively involve children and young people in their learning?
- How well does our questioning promote thinking, develop understanding and require children and young people to give reasons for their answers?
- How well do we provide an appropriate balance between formative and summative assessment with a clear focus on the purposes of learning?
- How effective is our practical work in developing investigative skills and creative thinking?
- Do we provide sufficient opportunities for children and young people to create and develop experimental procedures and solve problems? Do we too often give children and young people set instructions for experiments that have predictable results?
- Do children and young people have appropriate access to ICT to collect, analyse and present scientific data?
- Do we help children and young people to link and apply different kinds of learning to address interdisciplinary questions as well as moral and ethical issues arising from the application of science in society at local, national and global levels?
- What more can we do in our school to raise the levels of achievement and attainment, particularly of lower attaining children and young people?
- How well do we address gender issues through, for example, adapting our approaches to learning and teaching, contexts for learning and range of resources to motivate boys and girls?
- How well do we plan opportunities for personal achievement and the development of skills for life and skills for work in the context of science?



[CONFIDENT INDIVIDUALS]

SIGNPOST TO CONFIDENT INDIVIDUALS

Confident individuals often display the following characteristics. They:

- relate to others and manage themselves by working on a wide range of science inquiries, investigations and projects;
- demonstrate self-awareness by reflecting on the impact of new scientific evidence on their own understanding and views;
- assess risk and benefit in order to make informed decisions;
- achieve success in practical and research tasks, problem solving, data analysis and evaluation, discussion and debate; and
- can express and justify their views on science-based issues of importance to society.

[Q] What do we do well currently in science to develop confident individuals?

Across stages and sectors, many staff create a positive learning environment which helps to develop learners' self-respect and awareness of others. In primary and secondary schools, teachers develop children and young people as confident individuals by providing activities well-matched to their abilities, interests and aspirations. Approaches to meeting learning needs in science are improving in secondary schools. Teachers are providing a wide range of experiences supported by high quality resources.

When staff are clear about expected standards, recognise and share learners' success and achievements, for example, by appropriate use of praise or displays of work or recognising success in assemblies, they build the confidence of children and young people. By discussing their strengths and areas for development with them, teachers help them to make informed decisions to improve their learning.

Involving parents in science learning

A nursery school developed children as confident individuals through a home-school partnership initiative. Building on the strengths of previous partnership working, parents and nursery staff were involved in researching, resourcing, monitoring and evaluating science resource boxes. These were used to develop the science process skills of observation, classification and communication. The resource materials motivated and captivated children's curiosity and encouraged discussion of science at home. Children displayed excitement when it was their turn to take a box home. In both the nursery and at home, children were involved in practical tasks, and in discussing, analysing and presenting their findings from the tasks.

Discussing outcomes and targets

One secondary school shared the intended outcomes of learning in all lessons. In S1/S2, young people would 'traffic light' the outcomes at the beginning of the unit to highlight prior knowledge. They were then asked to do the same at the end of the unit. Young people who had marked some outcomes red, signifying their uncertainty about achieving them, were then given a mini-tutorial with the teacher. Young people who had marked outcomes green, signifying their confidence that they had achieved them, were asked to explain their thoughts to those who had marked them amber to improve their understanding. The teacher discussed with young people individually their reasoning for marking the outcomes red, amber or green. This helped the teacher to identify the concepts young people did or did not understand and to agree appropriate next steps in learning.

One girl in S5 clearly described the approach in her school: "After an assessment we complete our learning logs with our 'study buddies' in the class. This is when we complete a sheet to show our strengths in the topic and identify the areas we need to look at again before we move on to the next topic. Then we discuss our learning logs during our individual progress meetings with our teacher. She discusses our good points with us and helps us to identify how we can improve on the bits we have struggled with. At these progress meetings we discuss our targets for the grade we are aiming for in our prelim or final exam."

Developing literacy skills in science

Teachers in one secondary science department had identified that many young people in their S1 and S2 classes had weaknesses in their literacy skills and that this limited their progress in science. The science teachers worked with teachers in the English department to develop their approaches to supporting young people in writing to express a point of view in science. The young people learned how to structure their work to introduce the topic, state their view, put forward solutions and to sum up in a conclusion. They learned the importance of using scientific terminology accurately and of providing evidence to support the points they made.

[Q] Planning for excellence: how might science contribute more to developing confident individuals?

In pre-school centres, staff did not always take account of children's development and previous experiences when they selected the range of science resources for activities in the playroom. They often needed to provide more support to allow all children to develop their skills more effectively. In primary schools, weaknesses in assessment meant that tasks seldom took account of children's prior progress and attainment in science. Consequently, significant numbers of children were either over-stretched or under-challenged.

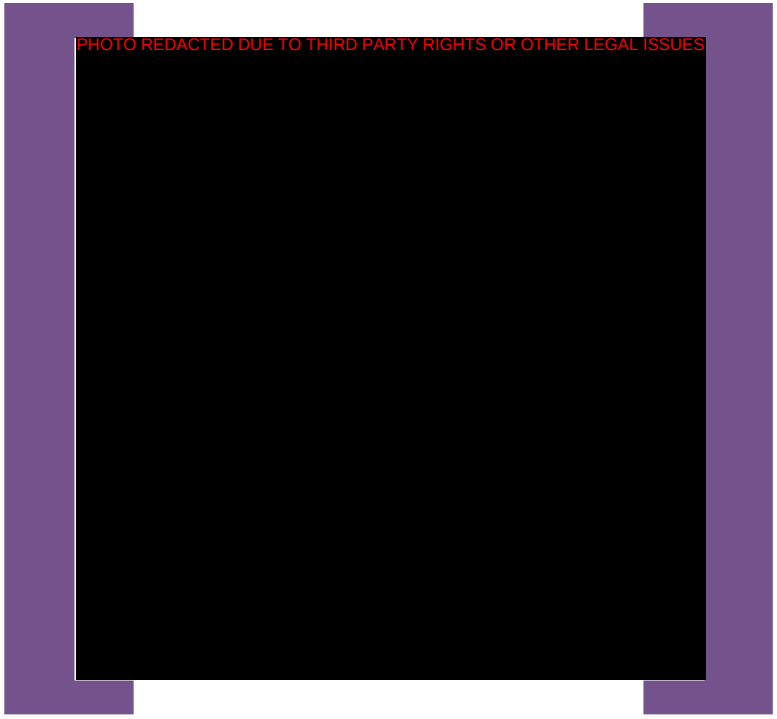
In many primary and secondary schools, teachers of science had worked effectively with support for learning teachers to develop their learning and teaching approaches in order to provide appropriate support and challenge for all children and young people.

[CONFIDENT INDIVIDUALS]

However, this was not always the case. In other schools, children and young people were not sufficiently supported or challenged and insufficient account was taken of their prior experiences and achievements.

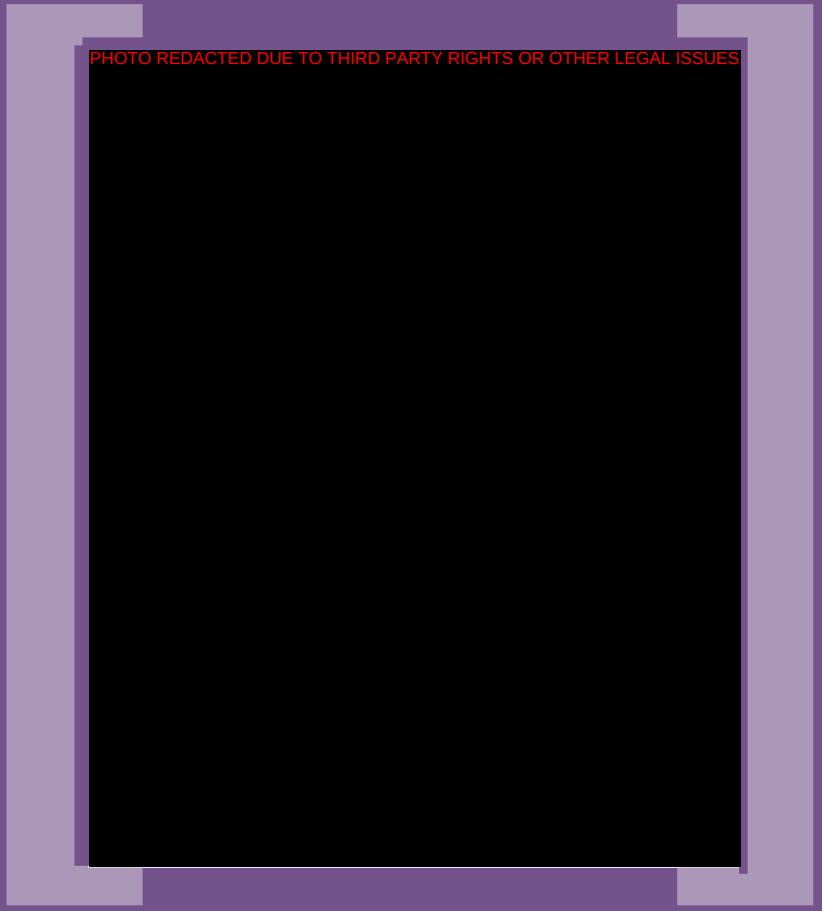
Many secondary science departments were developing their approaches to monitoring children's and young people's progress. However, teachers were not always providing sufficiently clear feedback to them about what they needed to do to improve their learning, or encouraging them to set their own targets.

Children and young people develop confidence through working well independently and as part of a team. However, they often had too few opportunities to discuss and reflect on ideas, their experiences and learning.



As part of bringing about improvement, it may be helpful to reflect on the following.

- How well do we build relationships and use praise to encourage children and young people?
- How effective are we in providing challenge and support for all children and young people?
- How effective are our approaches in developing children's and young people's independent learning skills, self-reliance and capacity to manage their own learning?
- How can we encourage our children and young people to reflect on the impact of new evidence on their own understanding and views?
- How effectively do we encourage children and young people to assess risk and benefit in order to take informed decisions and actions?
- How effective is our feedback to children and young people in making them aware of their strengths and next steps in learning?
- How well do we ensure that children and young people know clearly what skills they have and how to use them effectively for different purposes?
- How well do we help children and young people to grow in confidence by engaging them in challenging, enjoyable experiences and contexts which build well on their prior learning?
- How well do we recognise and share children's and young people's success and achievements?



[RESPONSIBLE CITIZENS]

SIGNPOST TO RESPONSIBLE CITIZENS

Responsible citizens often display the following characteristics. They:

- develop the scientific values of respect for living things and the environment, respect for evidence and the opinions of others, honesty in collecting and presenting data and openness to new ideas;
- understand the cultural significance and importance of science;
- make informed choices and decisions on issues relating to the impact of science in society;
- evaluate environmental, scientific and technological issues, based on their knowledge, understanding and analysis of evidence; and
- develop informed, ethical views of complex scientific issues.

[Q] What do we do well currently in science to develop responsible citizens?

Science makes an important contribution to learners' understanding of citizenship. In pre-school centres, staff provide appropriate opportunities for children to develop respect for living things including using their gardens to explore mini-beasts in their natural environment. In primary and secondary schools, many teachers develop children and young people as responsible citizens by making good use of current issues in science reported in newspapers and scientific publications to allow them to evaluate environmental, scientific and technological issues.

Well-planned research tasks help children and young people to become skilled at finding and evaluating information from a variety of sources, including the Internet. They develop a strong sense of responsibility when teachers encourage them to discriminate between reliable and misleading information which is not supported by scientific findings.

Increasingly, teachers were developing effective links with industries, conservation groups and universities to provide opportunities for children and young people to participate in field work, engage with visiting speakers and to work in industry. These experiences were helping children and young people to see the relevance of science to society and to future employment. Through their approaches to fieldwork and investigative projects, many children and young people were learning to respect living things and the environment, and develop responsible scientific values.

Developing science outcomes through eco-school activities

Many pre-school centres and primary schools use their eco-school garden developments to provide children with stimulating and relevant contexts for science. Children in a nursery met with young people from the local secondary school. They worked together to draw plans and create a garden with flowers, herbs, vegetables, picnic tables and a digging area for the children for cultivation. Children in P2 used their garden to help them identify seasonal plants. In other classes, they grew plants such as tomatoes and bedding plants and sold them in an enterprise activity. Other children had created and maintained a wormery and had produced a DVD of the process. Children were able to make links with other areas of learning, including recycling and conservation, through using materials for composting and rainwater for watering plants. They eagerly took responsibility for maintaining their areas of the garden.

Ensuring relevance and purpose of science tasks

Primary 6 children explored reef biodiversity, animal kingdom classification and conservation through an interdisciplinary approach. A computer game was the starter for engagement and simulation. Using the interactive whiteboard, children took on the role of the diver and interacted with underwater sea creatures. One of the follow-up tasks involved children working in groups to research food chains and habitat destruction through global warming. They felt that experiencing the reef as a diver was very motivating and helped them see the relevance and purpose of the associated tasks.

Independent and cooperative learning on topical science issues

Teachers in a secondary science department wanted to provide more opportunities for young people to be active in their learning through more independent and cooperative studies. They introduced a 'science reporter' activity for S1 and S2 young people. Each week, they had to research newspapers and the Internet to identify an issue or topic for discussion in the class. They then chose their favourite topic to produce a poster as a cooperative learning task. This activity was followed by a research and reporting task, where young people created an article of their own which they could enter into a competition. Winning articles were presented in the school science magazine. Teachers emphasised the importance of focusing on the science concepts behind the stories.

Ethical debates

Primary 7 children had read a newspaper article about a family who had decided to have another baby to try to help their sick son. The teacher helped the children understand the underlying science ideas by explaining about variation of physical characteristics in families. They went on to discuss how characteristics are passed on from parents to their children and how family members can act as donors. They were then able to debate the ethical issues around the appropriateness of having a baby to save a sibling. The teacher supported their discussion well and encouraged them to consider the pros and cons of the situation. They then used an interactive voting tool to share their views.

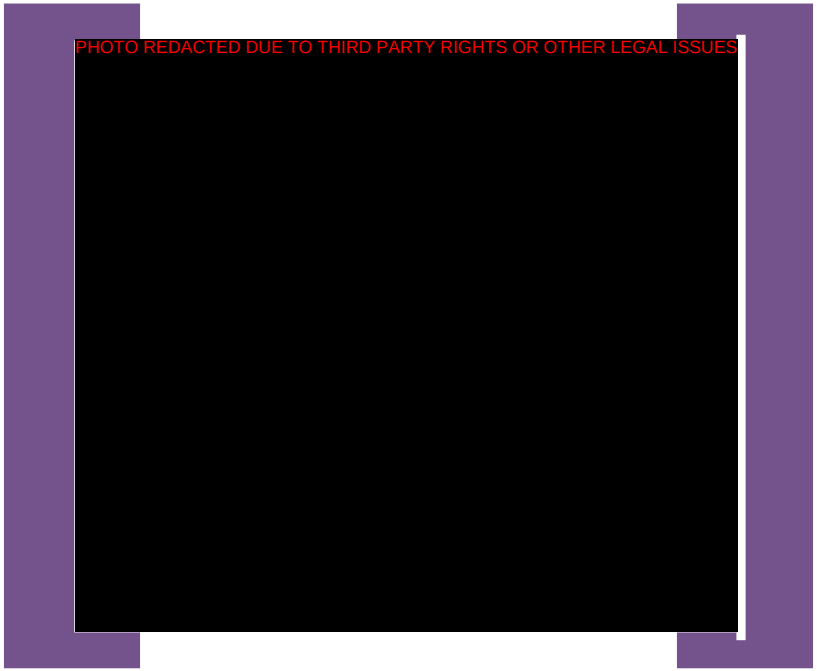
[RESPONSIBLE CITIZENS]

Ethical debates

Young people in S1 carried out a survey of other young people's views on the use of stem cells. They then researched the topic and presented arguments for and against stem cell use in a public debate. Using voting tools to gather the views of the audience, they analysed the results to determine if opinions had changed following the debate. The young people said that they enjoyed the task because it was challenging and fun and made them realise that it could affect all their lives.

[Q] Planning for excellence: how might science contribute more to developing responsible citizens?

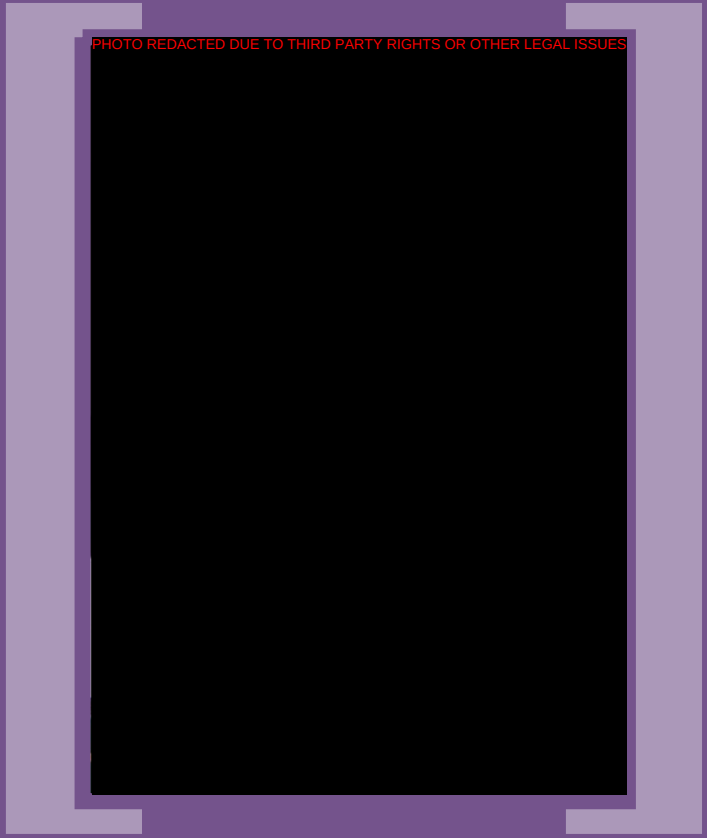
Across all sectors, the use of debates and class discussions to help children and young people develop informed, ethical views of topical issues in science was not a common feature of learners' experiences in science.



[RESPONSIBLE CITIZENS]

As part of bringing about improvement, it may be helpful to reflect on the following.

- How well do we focus on areas of topical science?
- How well do we develop responsible scientific values and encourage children and young people to respect living things and the environment?
- How well do we develop learners' responsibility in their approaches to fieldwork and projects?
- How effective are opportunities for children and young people to develop informed views on social, environmental, moral and ethical issues relating to science, and to communicate these clearly?
- How well do we plan for opportunities for children and young people to take part in regular debates and discussions on a range of scientific topics which interest and motivate them?
- How well do we provide opportunities for children and young people to develop arguments, opinions and viewpoints?
- How effective are we in ensuring that children and young people fully understand the role of science in the world in which they will live and work as adults?



[EFFECTIVE CONTRIBUTORS]

SIGNPOST TO EFFECTIVE CONTRIBUTORS

Effective contributors often display the following characteristics. They:

- have an enthusiasm for collaborative learning and group tasks;
- listen and respond to others and build on others' suggestions and ideas;
- collaborate effectively in teams during inquiry and investigation tasks and discussions;
- take the initiative and lead in developing strategies to solve problems and experiment;
- apply critical thinking to interpret data, make deductions and draw conclusions based on reliable scientific evidence;
- communicate effectively in a range of ways including orally and through scientific report writing; and
- solve scientific problems and challenges.

[Q] What do we do well currently in science to develop effective contributors?

Across all stages and sectors, many teachers and other staff engage children and young people effectively in a range of discussions to develop them as effective contributors. In pre-school centres and primary schools, staff develop children's talking and listening skills well in science contexts. For example, they encourage children in the early stages to discuss appropriate clothing related to weather conditions. Staff often respond well to topics that interest children, for example, discussing how they could encourage dog owners to be more responsible citizens. In primary and secondary schools, teachers develop discussions best using open-ended questioning which encourages children and young people to think about scientific concepts and allows them to acquire and practise the vocabulary and language of science. Increasingly teachers are recognising the value of children and young people working together to discuss and share ideas and to develop their responsibility for contributing to their own and others' learning.

Many schools had children and young people working in groups, including in science team challenges and research tasks. In these situations, they enthusiastically took on their specified roles and responsibilities to ensure that their teams met deadlines and the requirements of the tasks. Teachers were often well aware of the strengths of children and young people as effective contributors and ensured they had opportunities to develop their skills, for example as resource managers or as team leaders.

Here are some examples of what children and young people say when they are clear about the benefits of working collaboratively.

> *" I like working in groups - it's good when everyone brings their own ideas and everyone knows what to do."*
>
> *" I like group work where we have to research and present to the class. Other pupils say it in a way so that you learn better."*
>
> *" I like it when we work together and we allocate different tasks to everyone. There is a better chance that the experiment will work and that you'll understand."*

Increasingly, children and young people were communicating the results of their investigations and research projects through presentations. These often involved oral presentations to their peers, which were enhanced by slide presentations, some with animations, photographs and DVD clips. At all stages, children and young people were developing their written communication skills well through scientific reports of experiments and investigations. In biology, young people were developing their extended writing skills through essays required at Higher and Advanced Higher level study.

Using ICT to understand the world and promote effective contributors

Children in a nursery worked in small groups to explore natural materials found in their garden. They explored and investigated things using a range of ICT equipment and chose the method which they thought was best suited to collect data to present their findings to their peers. One group chose a digital camera and another chose a digital microscope. Children worked well together and took turns to operate the equipment. Both groups used the interactive whiteboard to share their information with the class. Their presentations included images of twigs, leaves and flowers.

Enterprising group work

Primary 6 children were assigned to teams to work as a 'company' to design a fairground ride. The teacher linked the activity well to the planned visit to a local fun theme park. Each company applied their knowledge of circuits and safety considerations to their design. The children identified the features they wanted to build in such as sounds and light as well as an energy source. They discussed what materials they needed to use as conductors and insulators. After reaching agreement, they worked together to produce a diagram of their design using appropriate scientific symbols for the components of the electrical circuit. Each company presented their design to the rest of the class.The other children evaluated the designs in terms of whether the circuit for the ride would work and had appropriate safety features built in. Children found this approach very motivating and were able to identify how they should work better together as a group in future activities.

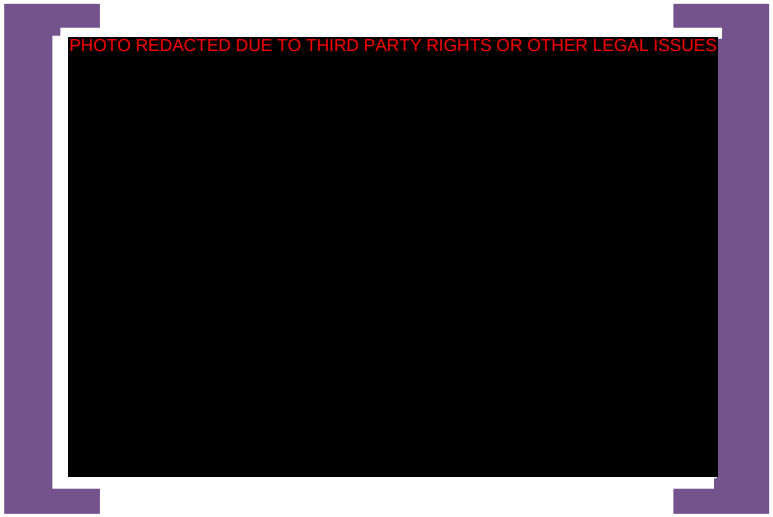
[EFFECTIVE CONTRIBUTORS]

Team work and investigation skills

All S1 young people in one secondary school participated in a year group science challenge. Each group had to build a model or devise an experiment to demonstrate an aspect of science that interested them. They made a stall to display their research and presented their project to a panel of judges from universities and industry, as well as at a parents' evening. The young people were creative and enterprising in their approaches and many were well supported by industrialists throughout their project. The young people demonstrated outstanding knowledge and understanding in their chosen topics which included 'the big bang theory', eco-fuels and forensics. They confidently presented their findings using a variety of multimedia applications. Teachers reported that young people had never been as enthused by science, including those who previously had had limited success in class assessments.

[Q] Planning for excellence: how might science contribute more to developing effective contributors?

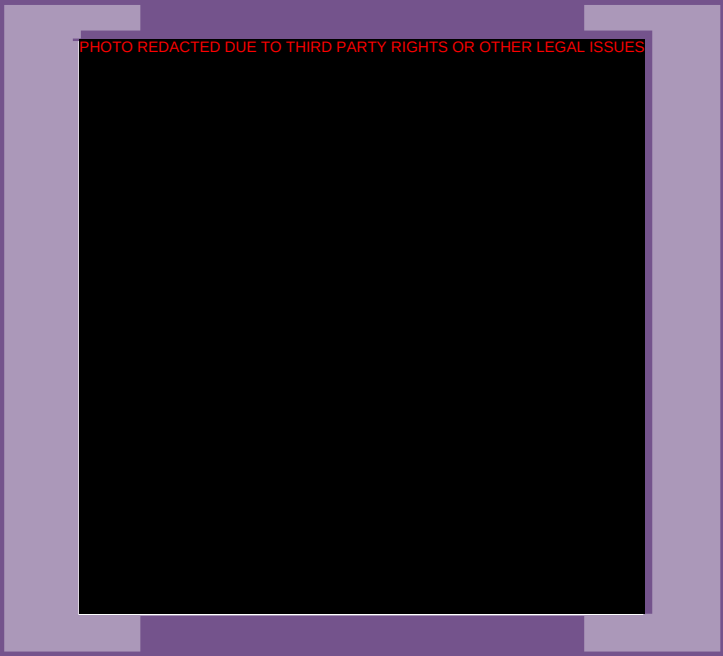
Across all sectors, staff were developing collaborative learning approaches though there was scope to provide more opportunities for children and young people to develop as effective contributors.



[EFFECTIVE CONTRIBUTORS]

As part of bringing about improvement, it may be helpful to reflect on the following.

- How can we improve our approaches to cooperative learning, in which children and young people are required to work together on joint tasks rather than just alongside each other?
- How well do we develop group work skills and encourage children and young people to listen and build on others' ideas and suggestions?
- How effectively do we encourage children and young people to take the initiative and lead in developing strategies to solve problems and challenges and design practical investigations and experiments?
- How can we improve opportunities for children and young people to apply critical thinking to reach conclusions based on reliable scientific evidence and report their findings to others in a variety of ways?



[CONCLUSION]

Teaching for effective learning in science has many strengths. In many of the schools inspected, children and young people already displayed some of the attributes, skills and capabilities of successful learners, confident individuals, responsible citizens and effective contributors. The pre-school centres and schools exemplified in this portrait highlight effective practice across Scotland. We also need to improve some things. In addition to the advice offered throughout this portrait, pre-school centres and schools should now consider the following points for action in taking forward their strategies for improving science education.

- Learning and teaching approaches should promote thinking and develop deeper understanding of science concepts and knowledge as well as provide opportunities for consolidation of learning.
- Children and young people should be active in their learning, including having opportunities for being independent and responsible for their progress in learning.
- Curriculum planning and review should continue to ensure science programmes demonstrate the principles of curriculum design and focus on meeting the needs of all children and young people as defined by the four capacities in Curriculum for Excellence.
- Children and young people should develop a wide range of experimental, investigation and inquiry skills within relevant and real-life contexts.
- Children and young people should apply their learning in hands-on practical activities, including learning out-of-doors to develop their awareness of the impact of science on their own lives and society at local, national and global levels.
- Children and young people should develop and use their skills in critical thinking as well as literacy, numeracy and ICT. They should use ICT to collect, analyse and present scientific data.
- Assessment, tracking and monitoring learners' achievements should be consistent and inform planning while ensuring that children and young people are appropriately supported and challenged.
- Stronger curricular links between pre-school centres and primary schools and between primary and secondary schools should be in place to ensure continuity in learning and to build effectively on learners' prior experiences.
- Feedback to children and young people should make them aware of their strengths and what they need to do to improve their learning.
- Children's and young people's experiences should include discussing and reflecting on ideas to help them develop informed views on social, moral and ethical science issues.

By using the experiences and outcomes in science creatively, teachers of science can take forward Curriculum for Excellence and enhance their provision for learners. This is a tremendous opportunity for science education in Scotland. Science teachers and educators can transform the quality of learning experiences for children and young people and increase their achievements and ensure they develop as scientifically literate citizens with a life-long interest in science.

[COMMENTARY ON ATTAINMENT IN SCIENCE IN PRIMARY AND SECONDARY SCHOOLS, DRAWING ON EVIDENCE FROM INSPECTIONS 2004-2008]

International measures of Scottish learners' attainment confirm important strengths. Scotland continues to perform at a consistently very high standard in the Programme for International Student Assessment (PISA) through its survey of 15 year olds. However, the *2007 Scottish Survey of Achievement (SSA): Science, Science Literacy and Core Skills*[8] indicated that a significant number of children and young people were not achieving expected levels of knowledge and understanding, particularly in P7 and S2. Achievement in science literacy was stronger than science knowledge and understanding at all stages and levels. These findings were consistent with results from international surveys, where Scotland's performance is generally strong in science literacy.

The SSA in science found that at P3, a majority of children (54%) were well established in knowledge and understanding of science when measured against appropriate national 5-14 levels. Attainment was much weaker at P5 and by P7 only 6% of children were achieving the expected level. In S2, just over 15% of young people were well established or better at the expected level. Girls performed better than boys at P3 but boys performed better than girls at all levels from C onwards at P5, P7 and S2 in knowledge and understanding. Direct comparison of tasks used in both surveys indicates that there has been no change in science achievement in knowledge and understanding between the last national science attainment survey in 2003 and 2007.

Smaller sub-groups of children and young people were assessed on science literacy and investigative skills. Performance in these aspects was much better overall than in knowledge and understanding. There were no consistent gender differences noted in science literacy achievement. Children and young people from less deprived areas achieved higher levels than those from the most deprived areas in both knowledge and understanding, and science literacy. This is similar to other subjects where children and young people from less deprived areas consistently perform better.

Inspectors found that learners' attainment in the primary schools inspected often had weaknesses, set against appropriate national 5-14 levels. Attainment was generally satisfactory up to P4 but declined thereafter through P6 and P7.

Particular features of children's attainment in primary schools included the following.

- Children were well motivated and often enthusiastic about science. They remained on task and cooperated well during group activities.
- Children's knowledge and understanding was strongest in Living Things and The Processes of Life, and weakest in Earth and Space, including aspects of materials.
- Many children could recognise a fair test. However, their skills of scientific investigation were too limited.
- Children's ability to recognise patterns in numerical results from experiments was poor, despite having studied similar number patterns in mathematics.

[APPENDIX 1]

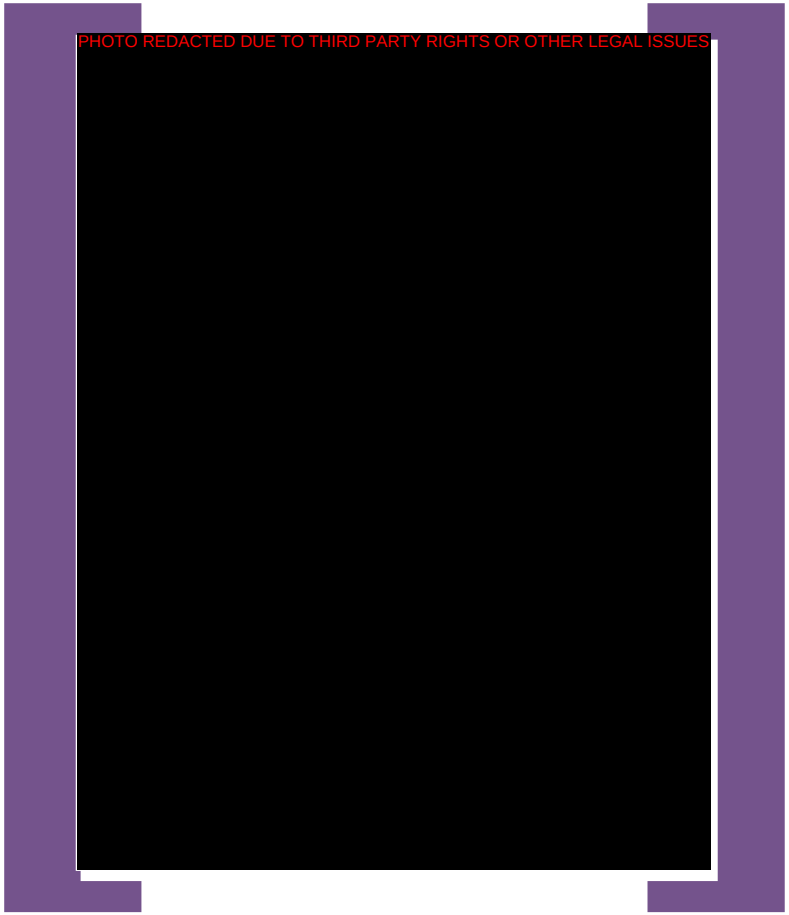
- Children's skills in making reasoned evaluations and informed choices were often weak. For example, children would often express strong views about climate change but were confused in their knowledge and understanding of the likely causes. They could easily name animals that had become extinct but showed little understanding of how food chains could have been involved.

Particular features of attainment in secondary schools, including results in awards by the Scottish Qualifications Authority (SQA) within the Scottish Credit and Qualifications Framework (SCQF) for the period 2004 to 2008 (2008 pre-appeal data), are included below.

- At S1/S2 science, the majority of young people were making good progress in their learning. Most young people were developing a good range of practical and investigation skills. However, too often, young people did not demonstrate secure knowledge and understanding.
- At S3 to S6, all of the sciences continued to be popular with young people, with biology being the third most popular subject at all levels of National Qualifications (NQs). SQA results[9] over recent years indicate that overall, young people continue to perform well in Standard Grade and other NQs in the separate sciences.
- At Standard Grade, on average, around 50%-60% of young people presented for biology, chemistry and physics achieved SCQF level 5, grades 1-2 (Credit) and around 90% achieved SCQF levels 4 and 5, grades 1-4 (Credit and General). Only around 10% of young people presented for Standard Grade Science achieved grades 1-2 (Credit) and around 60% achieved grades 1-4 (Credit and General).
- At Intermediate 2, SCQF level 5, on average 68% in biology, 75% in chemistry and 65% in physics achieved A-C grades and performance had improved. In biotechnology, on average 64% achieved A-C grades with on average 73% achieving in managing environmental resources (MER). However performance in these two subjects was variable.
- At Intermediate 1, SCQF level 4, the average percentage of young people achieving A-C grades was 62% in biology, 65% in chemistry and 56% in physics and overall had improved. In MER, performance was variable with on average 75% achieving A-C grades.
- At Access 3, SCQF level 3, performance had improved with on average 82% in biology, 76% in chemistry, 57% in physics and 73% in MER achieving an award.
- At Higher, SCQF level 6, the percentage of those presented achieving A-C grades had improved slightly in biology (71%), human biology (66%) and chemistry (75%) but remained steady in physics (73%).
- Performance at Advanced Higher, SCQF level 7, was consistently good with around 75% of young people presented achieving A-C grades.

[FOOTNOTES]

1. *Improving Scottish Education*. HM Inspectorate of Education 2006.
2. *Curriculum for Excellence (CfE)* outlines the purposes and principles of the curriculum 3-18 to provide a framework within which improvements to Scottish education can and should be made. CfE aims to focus classroom practice around the four capacities to be developed in children and young people: successful learners, confident individuals, responsible citizens and effective contributors.
3. *How good is our school? The Journey To Excellence*. HM Inspectorate of Education 2006.
4. *Improving Achievement in Science in primary and secondary schools*, HM Inspectorate of Education, 2005.
5. *Building the Curriculum 1 – the Contribution of Curriculum Areas*, The Scottish Executive, 2006.
6. *Building the Curriculum 3: A framework for learning and teaching*, The Scottish Government, 2008.
7. *Review of the contribution of the Scottish Science Centres Network to formal and informal science education,* HM Inspectorate of Education, 2007.
8. *2007 Scottish Survey of Achievement (SSA) Science, Science Literacy and Core Skills*, The Scottish Government, 2008.
9. Principal Assessor and Course reports for Science, Human Science, Chemistry, Physics and Science are available at http://www.sqa.org.uk/



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