# PRIMARY HORIZONS

## Starting out in science

wellcome trust

The Wellcome Trust is an independent biomedical research-funding charity that aims to improve human and animal health. We work with leading researchers to inform the direction of our education programme and to generate wider discussion in the education community.

This report, based on a scoping study carried out for the Wellcome Trust by Queen's University Belfast and St Mary's University College Belfast, sets out to explore teachers' views and experiences of primary science across the United Kingdom and to identify ways in which it could be improved. The publication of *Primary Horizons* comes at an important time, with suggestions of a decline in children's attitudes towards science in the later primary years. Reversing such a trend will require action from across the science education community to ensure the needs of both teachers and pupils are met.

Full report available at
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# Overview

1. A high proportion of primary teachers feel they lack the confidence, expertise and training to teach current science curricula effectively.
2. Good-quality continuing professional development is considered key to improving primary teacher confidence; teachers who have carried out any professional development in science appear more confident in nearly all aspects of science teaching.
3. Teachers view making science more relevant to children's everyday lives as key to engaging them with science and helping them to become active and informed citizens, able to understand and take decisions about the impact of scientific and technological developments.
4. Use of 'creative contexts' such as role-play, stories, cross-curricular teaching and real open-ended investigation is currently limited in primary science, with female teachers more likely than males to use many of these approaches.
5. Funding for primary science varies between regions and between schools within the same region. Within schools, funding for resources may vary widely between core subject areas. Further research is needed into the extent of these differences and into minimum levels of funding required to provide high-quality primary science teaching.

# Executive summary

"It is possible to store the mind with a million facts and still be entirely uneducated."
Alec Bourne

**Children's early years are key to shaping society's attitudes towards science. By the time children reach secondary school, they will have experienced seven years of schooling and will have well-developed attitudes to science. While this could be of great benefit where attitudes are positive, several recent studies, for example by Murphy & Beggs (2003a)[1], suggest that children's attitudes towards science are declining in the later primary years.** In an age of rapid advancement in science and technology, such a trend is clearly worrying, not just because of the need to ensure a continuing supply of highly trained and competent scientists but also, and perhaps more crucially, because of the importance of equipping young people to understand the impact of science on their lives and to take decisions based on this understanding.

In the late 1980s and early 1990s, new curricula[2] were introduced across the UK that defined for the first time what aspects of science should be taught at primary level. While most people agree that great steps forward have been taken since this time, there are now concerns that too much emphasis has been placed on scientific content at the expense of skills and enjoyment, and that teachers have not been adequately supported to provide a positive learning experience for their pupils.

This report summarises the key features of research carried out for the Wellcome Trust by the Graduate School of Education at Queen's University Belfast and the Science Department at St Mary's University College Belfast to scope the experience of primary science education across the United Kingdom. Thought to be the largest piece of research undertaken into UK primary science education, the study sets out to explore teachers' views and experiences of primary science and to identify ways in which it could be improved.

Previous studies, for example by Harlen *et al.* (1995)[3], have highlighted primary teachers' lack of scientific background knowledge and lack of confidence in teaching science. The current study showed that such views are strongly supported by primary teachers themselves, with half of all respondents pointing towards lack of knowledge, expertise, confidence and training as their main concern in teaching science. Other key issues identified by teachers included lack of financial resources, time and in-class support, an overloaded science curriculum and large class sizes. Other stakeholder groups also identified the lack of opportunities for open-ended investigation and the lack of confidence to facilitate open-ended investigation as two key issues facing primary science.

Teachers found both English and mathematics easier to teach than science and mainly attributed their lack of confidence in science to poor background knowledge and limited training. Professional development appeared to exert a profound influence on levels of confidence; teachers who had carried out continuing professional development (CPD) in science were more confident in nearly all aspects of science teaching. Interestingly, those from larger schools tended to be more confident than teachers from smaller schools, perhaps reflecting greater opportunities for support from colleagues or to engage in CPD.

Where topics common to science curricula in all four home nations were considered, there were surprising discrepancies between what teachers and pupils regarded as difficult. Teachers were most comfortable teaching content-driven topics such as the life cycle of a flowering plant, and had less confidence when trying to explain more conceptually challenging topics such as sources of energy. In contrast, many children find the complex terminology involved in learning the parts of the flower one of the most difficult tasks they encounter in primary science classes[4].

Primary science education should of course not just be concerned with knowledge, but also with the acquisition of scientific concepts and the development of scientific and thinking skills. It should aim for young people to develop attributes such as perseverance, independence, cooperation and curiosity. Ultimately it should seek to develop the sorts of skills that will help young people to become active and informed citizens as well as equipping them with the underpinning conceptual knowledge. This last idea is often known as 'scientific literacy'. Nearly a third of all teachers in the study suggested that the best way to develop children's scientific literacy is to make science more relevant to their everyday lives.

**1** Murphy C, Beggs J. Children's perceptions of school science. School Science Review 2003; 84(308): 109–116.

**2** The National Curriculum for England and Wales, the 5–14 National Guidelines in Scotland, and the Northern Ireland Curriculum.

**3** Harlen W, Holdroyd C, Byrne M, Confidence and Understanding in Teaching Science and Technology in Primary Schools. Edinburgh: Scottish Council for Research in Education; 1995.

**4** Murphy C, Beggs J. Children's perceptions of school science. School Science Review 2003; 84(308): 109–116.

There are various ways in which teachers can relate science to pupils' everyday lives, both inside and outside the classroom, and creative approaches can be extremely effective in this regard, enabling young people to approach science from fresh perspectives[5-6]. In the current study, considerable gender differences were observed between teachers in their use of creativity, with female teachers more likely than males to use role-play and stories, to focus on thinking skills, to relate science to everyday life or to integrate science with other curricular areas.

Cross-curricular approaches to science teaching can be highly motivational for both teachers and pupils but are often constrained by national curricula, particularly, as with England and Wales, where science forms a separate curriculum subject. While the National Primary Strategy in England states that 'there is no requirement for subjects to be taught discretely – they can be grouped, or taught through projects'[7], the current research found that science is poorly integrated with other curricular areas. Given the particular value of history in bringing science to life, exemplified among adults by works such as Bill Bryson's *A Short History Of Nearly Everything*[8], the study demonstrated that few teachers brought history into their science teaching.

Open-ended investigation in primary science provides perhaps the most important opportunity for children to develop scientific thinking and manipulative skills, and a lack of real open-ended investigative work is considered by many to be one of the reasons why science fails to grab children's interest in the later primary school years[9]. Teachers interviewed as part of the study admitted these activities are time consuming and seemingly in competition for time with the more urgent preparation for national tests. The report also suggests lack of confidence may be deterring teachers from including more open-ended investigative work in their classes.

More than half of the teachers surveyed in the study lacked confidence in using Information and Communications Technology (ICT) in science teaching. This is despite the fact that use of the internet in primary science education is increasing rapidly and ICT is thought to be a key route to support both the skills and attitudes, and more knowledge-based aspects of primary science. Ball (2003)[10] describes four ways in which ICT is used in primary science: as a tool, as a reference source, as a means of communication and as a means for exploration. The current research suggests systematic professional development is essential if these four uses are to be achieved.

Young people often respond very positively to constructive feedback that tracks their progress and informs their development. Teachers in this study agreed that both teachers and children find this sort of 'formative assessment' (also known as 'assessment for learning') more enjoyable than 'summative assessment', where the main purpose is to give a quantitative grading. Once again, the use of formative assessment appears to be related to professional development; in most cases only teachers who had undertaken professional development were likely to include investigations, mind mapping and individual target setting as part of their assessment in science.

An interesting relationship was also apparent in the findings between teachers' assessment style and whether schools had received extra funding for science; teachers who said their schools had received extra funding for science, i.e. outside core funding, appeared to be more likely to discuss and question, or to use peer assessment as part of their assessment techniques. This relationship would warrant further analysis.


**5** National Advisory Committee on Creative and Cultural Education. All Our Futures: Creativity, Culture and Education. NACCCE; 1999. www.dfes.gov/naccce/index1.shtml [accessed 30 June 2005].

**6** Centre for Applied Theatre Research, University of Manchester. Making it Live: An Evaluation of Pulse (phase 1): a performing arts and science initiative with young people funded by the Wellcome Trust. (Not yet published.)

**7** Department for Education and Skills. Excellence and enjoyment: A strategy for primary schools. DfES; May 2003.www.dfes.gov.uk/primary/publications/literacy/63553/ [accessed 30 June 2005].

**8** Bryson B. A Short History of Nearly Everything. London: Black Swan; 2004.

**9** For example, Campbell B, Pupils' perceptions of science education at primary and secondary school. In: Behrendt H, Dahncke H et al. Research in Science Education – Past, Present and Future. London: Kluwer Academic Publishers; 2001. Also see footnote 4.

**10** Ball S. ICT that works. Primary Science Review 2003; 76: 11–13.

One of the challenges for effective science teaching is to make all topics accessible to both boys and girls; more boys than girls still choose to study maths and sciences in post-16 education and beyond. Interestingly, while most of the teachers in this study said they feel that levels of interest in science at primary level are similar between boys and girls, nearly half also admitted that they try hard to get girls more involved in science. Views about the extent to which girls engage in primary science were varied. Many teachers of older primary children felt girls are more passive, while others maintained that personality, rather than gender, determines engagement in science. Still others believed that girls are more methodical than boys in their approach to practical work. Overall, girls' and boys' performance on national science tests were felt to be similar.

Funding is an important consideration for all schools. In addition to core funding, many schools generate or receive additional funds through resourcefulness or generosity. While most teachers recognise that funding is not the answer to all their education concerns, they acknowledge that exciting and high-quality science teaching does require some good resources. This study found disparities between funding for science in different schools, and between funding for science and different subject areas. Extreme examples suggested that one school received only £500 per year for science, compared with £10 000 for English, while another, with 240 pupils, only received £120 for science. Further research into the extent of these disparities between and within schools in each home nation would certainly be valuable.

In addition to funding, schools can also benefit from the support of primary science initiatives such as those pioneered by Higher Education Institutions and others. Many of these projects incorporate innovative teaching approaches such as concept cartoons and co-teaching between science student teachers and classroom teachers. These have undoubtedly benefited children and teachers in the project schools although benefits often fail to reach the UK school population as a whole.

In the light of the findings described, the report sets out a number of recommendations. It is clear that primary teachers should be provided with more opportunities for career-long professional development in science. The hope is that the Science Learning Centres will play a valuable role in this respect. These centres aim to enable primary and secondary teachers to enhance their professional skills by engaging with contemporary scientific ideas and training in effective teaching approaches and modern scientific techniques.

Greater emphasis should be placed by all across the science education community on: making primary science more relevant to children's everyday lives; using creative approaches; developing children's thinking, questioning and investigative skills; and facilitating more and better use of ICT.

Curriculum content, opportunities for cross-curricular working and assessment methods should be reviewed to ensure there are sufficient opportunities to harness children's enthusiasm and develop their understanding and skills rather than just factual recall.

Finally, this report calls for further research into the funding of school science to ensure teachers have sufficient resources to carry out their roles effectively.

The success of all of these recommendations will rely on greater collaboration between stakeholders across science education to ensure the needs of all teachers in all schools are met.

# Recommendations

**1. Greater emphasis needs to be placed on stimulating enthusiasm for science** so that fewer children lose interest towards the end of their primary education. Developments should include making primary science more relevant to children's everyday lives and placing a greater focus on children's thinking, questioning and investigative skills. More meaningful and enjoyable primary science could lead to a better uptake of science at secondary levels and potentially increase the number of people choosing to enter science-related careers.

**2. Primary teachers should be provided with more opportunities for career-long continuing professional development in science.** Most primary teachers are not science specialists and would benefit from greater support to help them develop their science teaching skills and increase their confidence. Policy makers, teacher educators and CPD providers should work in partnership to ensure a national, structured programme is in place to provide teachers with opportunities to explore today's science and investigate new ways to make school science more exciting. Such opportunities must reach teachers in all schools to avoid missing those in small schools who currently feel less confident to teach science. Providers should also liaise to address certain 'neglected' areas such as integrating science with other curricular areas and supporting teachers to make science more relevant to everyday life. The Science Learning Centres will have an important role, enabling primary teachers to enhance their professional skills by engaging with contemporary scientific ideas and training in effective teaching approaches and modern scientific techniques.

**3. Policy makers should provide schools with budgetary guidelines to ensure their science activities are appropriately funded.** This study found inequality in funding for science in different schools and between subjects within schools. **More detailed research should be undertaken to explore the nature of funding for primary science.**

**4. Primary teachers should be further supported to make effective use of information and communication technology (ICT) in their science teaching.** Although the use of the internet in primary science education is increasing rapidly, many teachers are not confident about using this and other forms of ICT for teaching science.

**5. There should be a review of curriculum content to provide greater opportunities for teachers to focus on topics likely to develop scientific skills and generate enthusiasm.** It is hoped that primary science will benefit from the latest moves in secondary science to reduce course content in favour of developing broader skills. Complex scientific terminology should be used only when appropriate, for instance, when answering children's specific questions, when explaining the more scientific use of otherwise familiar terms (e.g. insulation) or when children introduce complex language themselves (such as names of dinosaurs).

**6. Assessment programmes should be reviewed to ensure children are tested on scientific understanding and skills rather than simply factual recall.** Further research should be carried out into the effects of national tests in science upon opportunities for children to develop investigative, questioning and thinking skills.

**7. The links between science and other subjects should be made more explicit and strengthened** to help bring science to life and develop transferable skills.

**8. There should be wider use of creative and innovative approaches such as role-plays, stories and co-teaching between existing teachers and specialist science training teachers.** Many of these techniques have been shown to improve teachers' confidence and skills to teach science and to spark children's interest and enthusiasm.

**9. All new teachers should be provided with a solid background in scientific skills and understanding as part of their training.** Initial teacher training programmes need to show new teachers how to make science more relevant to the lives of the children they teach and to provide practical expertise in how to plan, design and run simple science investigations.

The success of all of these recommendations will rely on **greater collaboration between stakeholders across science education to ensure the needs of teachers in all schools are met.**

# Introduction

The United Kingdom has an enviable global position at the forefront of scientific research. In a society where scientific and technological advances are playing an increasing role in shaping our lives, the education of today's young people will be crucial in determining not only whether this position continues but also in ensuring that young people develop the skills that will help them to make informed decisions about the impacts of these developments on their lives.

Children are natural explorers, curious about the world around them. Their scientific questioning starts at a very early age: "Where do rainbows come from?", "Why does the moon change shape?", "How do I hear sounds?". Today, educationalists are starting to realise the importance of cultivating and harnessing this natural curiosity in their science lessons. But despite relatively high attainment in national tests, there is growing concern that what is actually being measured is often children's ability to memorise facts rather than to develop skills and understanding[11].

The Parliamentary Office of Science and Technology Postnote in September 2003[12] highlighted several key issues for primary science education including: declining pupil interest in science; the balance between teaching factual knowledge and the skills of scientific enquiry; the effects of national tests; and the importance of teachers' scientific knowledge and confidence.

Such issues are reflected in both research studies and inspection reports across the UK. The decline in young people's interest in science has now been highlighted by several studies, including the 2003 *Trends in International Mathematics and Science Study* (TIMSS), which reported a fall in the proportion of ten-year-olds in England who said they enjoyed science lessons from 80 per cent in 1995 to 68 per cent in 2003[13]. The need to address teachers' scientific knowledge and confidence has similarly been emphasised by several sources, including inspection reports from both England and Scotland[14-15]. National tests have been widely criticised by the Welsh inspectorate, and the Chief Inspector of Schools in Wales has highlighted the risks of teachers concentrating too much on science activities 'that focus too narrowly on questions similar to those in the national tests', thereby leaving too little time for 'practical and problem-solving activities'[16]. The importance of providing sufficient opportunities for scientific enquiry has also been highlighted as a priority by the Northern Ireland Department of Education[17].

Others have blamed the growing emphasis on literacy and numeracy for marginalising science. At the primary level, reading, writing and arithmetic often dominate the curriculum, and with a heavily content-driven science curriculum there may be few opportunities for children to think creatively, consider social and ethical issues, 'explore, and investigate their own questions, or further their own intellectual development'[18].

More than 15 years since primary science curricula were first introduced into all four home nations, what is now needed is a greater focus on sparking children's interest and enthusiasm, developing their skills and understanding, and giving them a sense of the relevance of science to their everyday lives. If future generations are to choose to enter scientific careers and to engage with the issues raised by developments in science and technology, the education community must confront the challenges for primary science as well as those in secondary education and beyond. The good news is that many primary teachers are already leading the way, providing top-quality science education. Several initiatives are also in place to support teachers and pupils, not least the Wellcome Trust and DfES-funded Science Learning Centres but also the valuable work supported by organisations such as the AstraZeneca Science Teaching Trust, Creative Partnerships and others. Moving forward will rely on a comprehensive programme of continuing professional development (CPD) to provide support for all primary teachers and may require changes at a policy level. Underpinning the success of any reforms will be the engagement of and collaboration between stakeholder groups across the science education community.

**11** Murphy C, Beggs J. Children's perceptions of school science. School Science Review 2003; 84(308): 109–116.

**12** Parliamentary Office for Science and Technology (POST). Postnote: Primary Science. London: Parliamentary Office for Science and Technology; 2003.

**13** Ruddock G et al. Where England stands in the Trends in International Mathematics and Science Study (TIMSS) 2003. In: National report for England, Slough: National Foundation for Educational Research; 2004. www.nfer.ac.uk/timss2003 [accessed 30 June 2005].

**14** Ofsted. Ofsted Subject Reports 2002/03: Science in Primary Schools. London: Ofsted; 2004.

This scoping study, carried out for the Wellcome Trust by Queen's University Belfast and St Mary's University College Belfast, set out to explore teachers' views and experiences of primary science learning and teaching across the UK and to identify ways in which primary science for both teachers and children could be improved.

**The key objectives of the study were to:**

- **identify current challenges, good practice and opportunities in relation to the following focus areas:**
    - children's attitudes to school science
    - classroom practice in primary science
    - use of formative assessment
    - creative contexts for science teaching
    - inclusion in science classrooms
    - relationship between science and other curricular areas
    - additional sources of funding outside mainstream funding
- **explore how scientific literacy can be best developed in the primary classroom**
- **review a range of small- and large-scale science initiatives in primary schools and provide an overall assessment of their impact for primary science**
- **make recommendations for future primary science education initiatives.**

**15** HM Inspectors if Schools. Improving Science Education 5–14. Edinburgh: HM Inspectors of Schools; 1999.

**16** Estyn. The Annual Report of the Chief Inspector of Education and Training in Wales: Primary Schools. Cardiff: HM Inspectorate for Education and Training in Wales; 2003.

**17** Department of Education for Northern Ireland. A Survey of the Science and Technology Area of Study in a Sample of Northern Ireland Primary Schools (2000–2001). Bangor: DENI; 2002.

**18** De Boo M, Randall A. Celebrating a Century of Primary Science. Hatfield: Association for Science Education; 2001.

# Research methods

This scoping study was designed to investigate the main challenges and opportunities for primary science education across the four nations of the United Kingdom. The aim was to provide an overview rather than a detailed picture of the exact proportions of particular views held by members of the science education community. The research methodology was designed to collect information in a way that would map and incorporate the richness and complexity of attitudes towards primary science.

Information was gathered from:

- literature reviews
- surveys of teachers and higher education institution personnel
- focus group discussions involving groups of teachers
- a cross-sector consultation conference.

Two literature reviews were undertaken to provide a context for the study. One review focused on primary children's perceptions and attitudes towards science. The other explored the impact of higher education institution science initiatives in primary schools in the UK.

Teachers were surveyed by telephone interviews conducted by MORI while higher education personnel responded to email questionnaires.

**Quantitative research**

The first part of the telephone survey focused on factors that may have some influence on teachers' attitudes towards science, such as gender, length of service, science background, science support and position in school (for example, science coordinator). The rest of the survey was designed to collect data relating to school factors, assessment of science, teacher confidence in developing children's knowledge and skills in science, different approaches to science teaching, and teacher attitudes towards science learning and teaching. Teachers were asked to indicate their responses on a Likert five-point scale.

There were also two open questions. In the first, teachers were invited to comment on what they considered to be the main issues facing primary teachers in their science teaching. In the second, teachers were asked to speculate about how primary science teaching could better support children to develop the sorts of skills they need to become active and informed citizens.

The email survey was intended for higher education institutions involved in initial teacher training for primary teachers. The aim was to assess the nature and impact of a selection of small- and large-scale primary science initiatives, including information about funding, the nature of the work, the challenges encountered, and the outcome and perceptions of those involved. A total of 100 questionnaires were sent out by email and 30 returned. The data was followed up with interviews and email communication to explore particular areas in more detail.

Many primary initiatives are developed outside higher education institutions but it was not possible to include these within the scope of the study.

### Qualitative research

The focus group discussions involved groups of teachers from all UK regions. They were designed to provide feedback on issues arising from the telephone survey questionnaire and the literature review. Teachers were invited to suggest science-teaching issues that had not been addressed in the survey and to suggest possible ways forward for primary science.

Seven focus group discussions took place: three in England, one in Wales, one in Scotland and two in Northern Ireland. There was a combination of teachers of younger (Key Stage 1 and equivalent) and older (Key Stage 2 and equivalent) primary pupils. Group sizes ranged from six to ten teachers.

No major discrepancies were found between overlapping areas in the focus group discussions and telephone interviews; however, many themes emerged from the focus group discussions that the telephone survey had not uncovered. This was expected since the focus groups provided opportunities for open discussion.

The aim of the two-day cross-sector consultation conference was to bring together teachers and other stakeholders from across primary science education to consider key issues arising from the telephone survey and focus group discussions. Participants included policy makers, LEA advisers (and equivalent), teachers, teacher educators, CPD providers and other representatives from the UK science education community. It also provided an opportunity to compare and discuss regional differences.

### The teacher sample

300 primary teachers participated in the telephone interviews; 150 were from England, 50 from Scotland, 50 from Wales and 50 from Northern Ireland.

One-third of the teachers were men. This is a much higher percentage than for the wider population of primary teachers but could be explained by the fact that almost half of the sample (49 per cent) was made up of school heads and 15 per cent were vice-principals.

According to the General Teaching Council for England's Annual Digest of Statistics for 2004-2005[19], 45 per cent (>84 000) of primary teachers in England are over 45 years old. In the current study, more than half the teachers interviewed (53 per cent) had been teaching for more than 20 years, while relatively few (7 per cent) had been teaching for less than five years. One-third (31 per cent) of the total sample indicated that they acted as the school science coordinator.

**19** **General Teaching Council for England. Annual Digest of Statistics: Registered Teacher Profiles 2004/2005. London: GTC; 2005.**

# Research findings

**1. What stimulates children's interest in science?**

It is during the primary years that children's attitudes towards science and technology are nurtured, and later carried over into secondary school and adulthood. While this could be of great benefit where attitudes towards science are positive, there are growing concerns that children are becoming disengaged with science in the later primary years. A recent survey by Murphy and Beggs (2003a)[20] found that older pupils (10-11 years) enjoy science less than younger ones (8-9 years) despite the older group being more confident about their ability to do science. Although this decline does not appear to be linked to overall attitudes to school [Morrell and Ledermen (1998)[21] found that attitudes to school remain more positive than attitudes to science and the gap grows as students grow older], it does appear to be international, with explanations ranging from content-driven science curricula, to ineffective science teaching and social factors.

In contrast to these studies of student views, most of the teachers surveyed in this study (89 per cent) felt that primary children love science lessons. It made no difference whether the school was urban or rural, large or small, nor did the children's age group have a bearing. Teachers also noted that both girls and boys enjoyed science lessons equally.

"I think science is one of the subjects which all children enjoy and it should be given more prominence."

There is evidence that increasing the amount of practical, investigative work in science would fuel children's positive experience of science in primary school (Murphy *et al.* 2004[22]). Teachers in this study agreed it was the practical aspects of science children found most attractive, although many reported a decline in enthusiasm when children are asked to record their work.

"…Children absolutely adore doing practical work in science… but I feel they detest when you say 'Right, we are going to write a report now about what we did' but teachers are also under pressure to provide evidence of what they have done and that is the problem. I feel after I have done something really good and the children have had fun and they have learned a lot…oh no they have to go and write this down now."

Children's interest can also be stimulated by making science more relevant to their lives, integrating science with other subjects, and using creative contexts such as role-plays and stories. These areas are considered in more detail in question 6.

**2. How can children's scientific literacy be improved?**

There is much debate about what constitutes 'scientific literacy' and about the nature of science that should be taught at school (Murphy *et al.* 2001)[23]. In this report the term 'scientific literacy' refers to the skills that primary children need to help them to become active and informed citizens, together with the conceptual knowledge that underpins their development.

In an open response question included as part of the telephone survey, teachers were asked to give their opinions about what they felt would best assist children to become active and informed citizens (Figure 1).

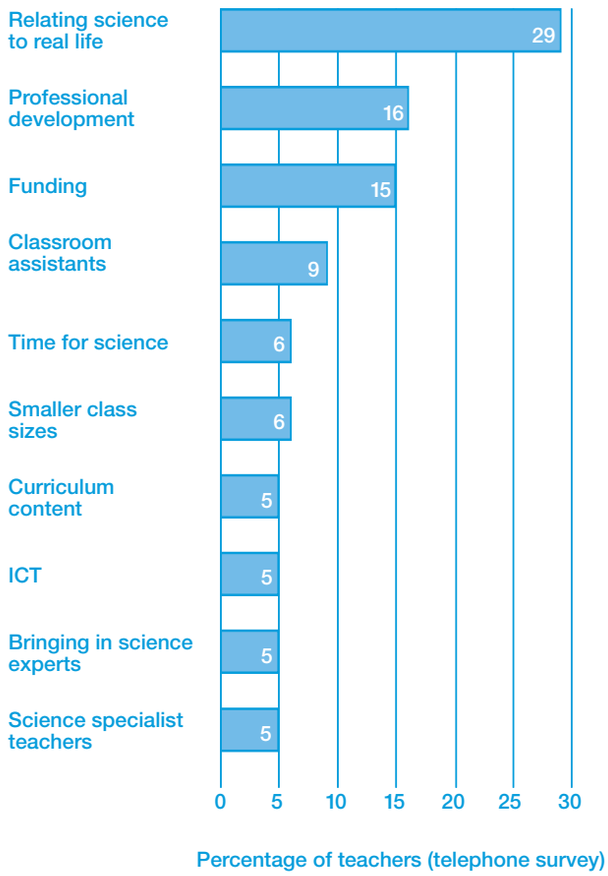
**20** Murphy C, Beggs J. Children's perceptions of school science. School Science Review 2003; 84(308): 109–116.

**21** Morrell PD, Lederman NG. Students' attitudes towards school and classroom science: are they independent phenomena?. School Science and Mathematics 1998; 98(2): 76–83.

**22** Murphy C et al. Students as 'catalysts' in the classroom: the impact of co-teaching between science student teachers and primary classroom teachers on children's enjoyment and learning of science. International Journal of Science Education 2004; 26(8): 1023–1035.

**23** Murphy C et al. National Curriculum: Compulsory school science – is it improving scientific literacy?. Educational Research 2001; 43(2): 189–199.

**Figure 1. Teacher views on ways to improve children's scientific literacy.**




Nearly a third of all teachers believed the best way to help young people to become active and informed citizens is to make science more relevant to real life. This was also one of the top two areas for improvement identified by teachers, teacher educators, CPD providers and policy makers as part of the stakeholder conference.

"If children see real purpose to what they're doing, relate it to real life, they will learn it more successfully."

There are clearly a wide range of ways to make science more relevant to children's lives, from using creative approaches such as role-plays inside the classroom to taking children outside the classroom on field trips, industry-linked visits or visits to local science centres. One teacher told the story of her own son coming home from school and rushing to the cutlery drawer in the kitchen, taking out a fork and banging it with the expectation that it would sound like the tuning fork he had seen in school that day. He was distraught when it failed to reproduce the sound, yet his mother commented it was the first time he had come home with any desire to tell her about anything that had happened in school.

Interestingly, the survey of primary science higher education initiatives highlighted a gap in provision in the area of supporting teachers to make science more relevant to children's everyday lives. This is particularly noteworthy as many teachers are not confident in this area (see question 4).

After relating science to children's everyday lives, teachers identified their own training and professional development as the next most important factor in enhancing children's scientific literacy. Some felt that teachers coming out of college lack the skills and knowledge to teach science in an integrated way. The need for greater professional development was, perhaps not surprisingly, also supported by stakeholder conference discussions involving CPD providers.

The third most important factor highlighted during the telephone survey was funding. Teachers felt that more funding would allow them to take children out of the classroom and to use more specialised equipment. Others pointed out the importance of funding to replace consumable items every time practical work is carried out.

A large minority of teachers felt support from a classroom assistant would be the most effective way to improve children's scientific literacy. During focus group discussions, most teachers suggested an assistant to children ratio of 1:15 would be adequate. A smaller proportion of teachers also considered small class sizes to be important in encouraging scientific literacy. Others suggested that having a designated science specialist teacher for every ten schools or so, who could be called upon to help support and develop primary science teaching, would be an advantage.

Several stakeholder groups, including teacher educators, CPD providers and many teachers, felt that giving science teachers greater flexibility, with more time for science and less curriculum content to cover, would be critical to improving children's scientific literacy.

"Do children of ten need to know about anthers and stamens and filaments? It is not relevant to them."

It is noteworthy that while many teachers in the telephone survey highlighted issues relating to the 'here and now', such as funding and in-class support, some of these views changed when given more time to reflect on their science teaching. Effective use of ICT, for example, was identified as higher priority by teachers at the stakeholder conference than those in the telephone survey.

Views on the extent to which encouraging children to question and investigate supports scientific literacy also differed between the survey and other findings. Ranked in only 11th place by teachers during the telephone survey, conference delegates, including groups of teachers, identified this as even more important than relating science to children's everyday lives. It is possible that the latter groups may have been influenced by previous discussions and keynote talks at the conference.

"There should be more stress on the practical side, and more open-ended investigations."

For the most part, all stakeholder groups appeared to hold similar views with regards to engaging young people with science and improving their scientific literacy. An interesting difference was in terms of policy makers, who were alone in highlighting the importance of primary schools working together with secondary schools as a key factor in improving scientific literacy. This perhaps reflects the fact that policy makers may often be well placed to observe how science is taught at both levels.

**3. What are the main issues facing primary science teaching?**

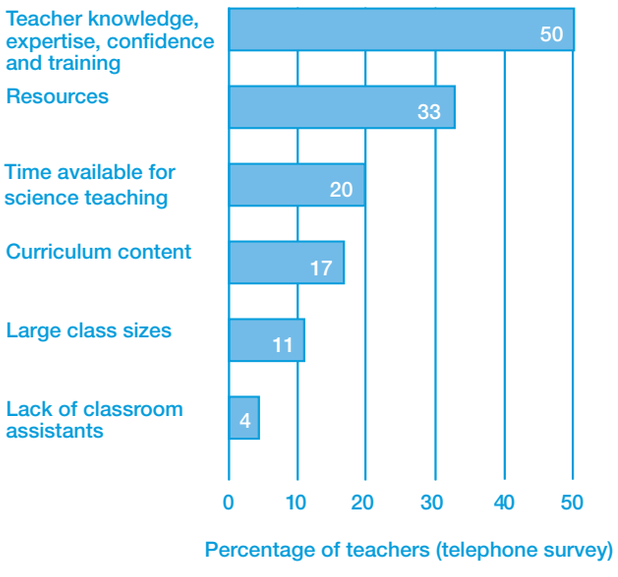
The key finding from this study suggests that primary teachers lack confidence in their science teaching, particularly in relation to carrying out simple science investigations. In an open question, half of all teachers questioned as part of the telephone survey highlighted lack of knowledge, expertise, confidence and training in science as the main issue facing primary teachers in their science teaching (Figure 2).

Age, and therefore perhaps time in service, appeared to influence teachers' views on confidence and training: while few teachers (23 per cent) in their 20s felt that lack of science training was an important issue, 50–60 per cent of those in their 30s, 40s, 50s and 60s highlighted it as a major problem. There were no differences, however, between male and female teachers. Question 4 looks at the issue of teacher confidence in more detail.

"Teachers have [a] lack of confidence in teaching due to lack of science knowledge."

The second most important issue recognised by teachers was teaching resources. Teachers of all ages stressed lack of resources as a concern, although fewer older teachers (28 per cent) rated it as a problem than younger teachers (35 per cent). There was also a gender skewing, with more male teachers (37 per cent) than female teachers (25 per cent) recognising it as important. Interestingly, professional development also influenced teachers' views: only 21 per cent of teachers who had experienced professional development in science thought lack of resources was an issue compared with 36 per cent of those who had not received such support.

**Figure 2. Issues of concern in primary science identified by teachers.**




The research also identified lack of time for science as a cause for concern. Some teachers felt that lack of time was caused by a skewed emphasis on other subjects.

> "Another issue is the lack of overall time because of the time spent on maths and literacy."

More female teachers (22 per cent) brought up the issue of lack of time than male teachers (16 per cent). Time concerns also varied with age: while 12 per cent of those in their 20s rated lack of time for science as a problem, 26 per cent did so in the 50–59 group. Some teachers' comments pointed at other compounding issues such as small classroom size and the lack of a dedicated area for practical work, which meant they had to move equipment around.

There was again evidence to suggest that teachers who had undertaken professional development in science were more positive in relation to how much time they had for teaching science (only 18 per cent perceived lack of time as an issue, compared with 22 per cent of teachers who said they had not undertaken professional development in science).

It is noteworthy that the priority issues identified by teachers did not always match those of a mixed stakeholder group comprising teachers, teacher educators, researchers, CPD providers and policy makers. Both groups agreed that the most important issue of concern was teachers' lack of knowledge, expertise, confidence and training in science. Yet they differed in the next most important factor: while teachers identified lack of resources, the mixed stakeholder group highlighted the lack of classroom investigation.

## 4. What affects teachers' confidence to teach science?

Most primary teachers are not science specialists and may feel unsure of their own scientific knowledge and skills. As described in the previous section, half of all teachers questioned highlighted lack of knowledge, expertise, confidence and training in science as the main issue facing primary teachers in their science teaching. Teachers also felt less confident teaching science than English or mathematics, although they were more confident than when teaching history, geography and information technology (Figure 3).

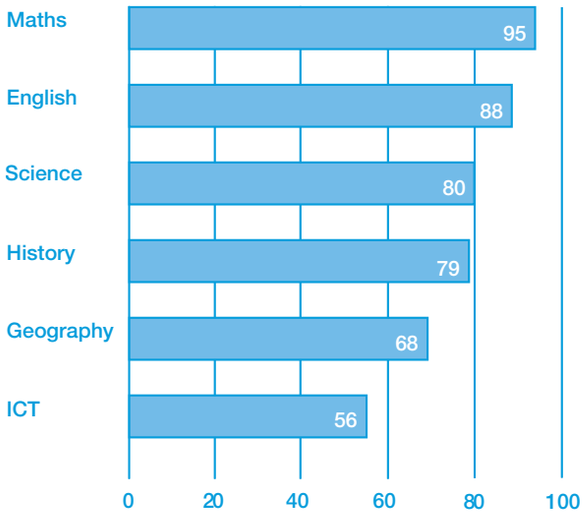
Levels of confidence in specific science teaching skills varied markedly. While 80 per cent of teachers were assertive about showing children how to record data, only 66 per cent felt confident in helping children relate science to their everyday lives (Figure 4). And although strongly confident about their ability to make effective use of questioning, confidence dipped markedly in using ICT for teaching (Figure 5).

Surprisingly, teachers' confidence to tackle certain scientific topics did not always mirror children's experience. Teachers were most comfortable teaching content-driven topics such as the life cycle of a flowering plant, and had less confidence when trying to explain conceptually challenging topics such as sources of energy (Figure 6). In contrast, many children find the complex terminology involved in learning the parts of the flower one of the most difficult tasks they encounter in primary science classes[24].

The most important factor influencing primary teachers' confidence in science teaching was their experience of professional development; those who had carried out CPD in science were more confident in nearly all aspects of science teaching, from developing children's investigative skills, to developing their understanding of topics deemed difficult and addressing how science might affect children's lives.

Teachers who had undertaken professional development in science also felt more confident to decide the skills that would be developed in an activity, assess and set up practical work, explain scientific ideas and ensure all children are engaged in science learning.

**Figure 3. How does primary teacher confidence in science relate to other subjects?**




**24** Murphy C, Beggs J. Children's perceptions of school science. School Science Review 2003; 84(308): 109–116.

School size also had an impact on teacher confidence (with teachers from small schools less confident than those from larger schools), although to a lesser extent than professional development. Gender, age and extra funding for science had little relationship with teacher confidence. There was, however, a strong correlation between confidence in the practical aspects of science teaching and the presence of a classroom assistant.

Teachers also pointed out the need for clear and supportive teaching materials and resources to help them deliver the curriculum.

Despite these difficulties, many comments were upbeat. Teachers pointed out that they could learn alongside the children.

"It's not admitting you're a failure by not knowing all the answers, rather it's encouraging the children to understand that there are ways of finding out the answers."

**Figure 4. Which science skills are primary teachers most confident to develop in their pupils?**

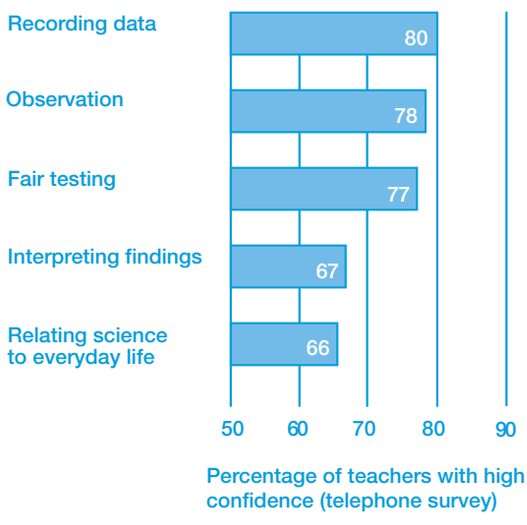


Figure 5. Which science-teaching skills do primary teachers have most confidence in?

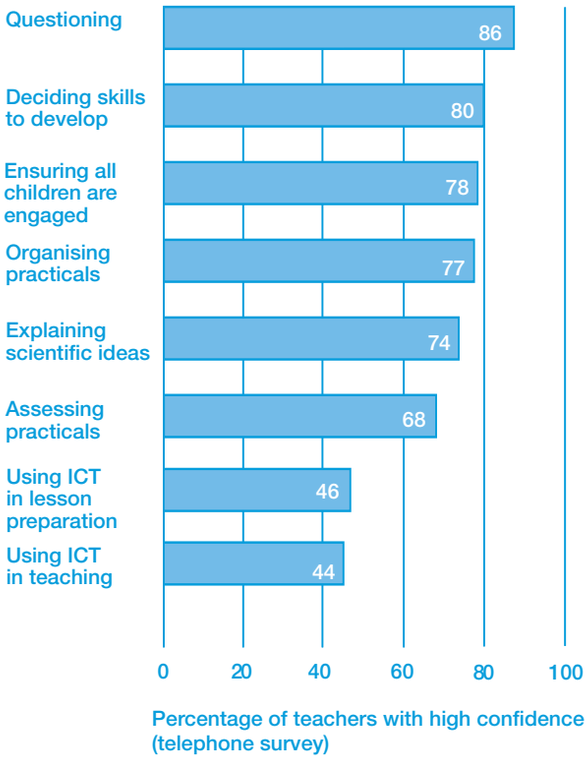
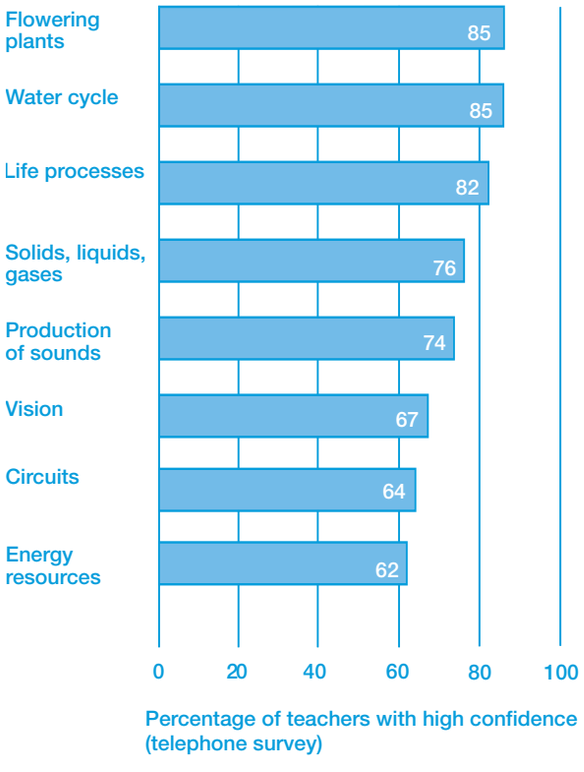



Figure 6. Which science topics do primary teachers have most confidence in?



**5. What formative assessment methods do teachers use?**

Young people often respond positively to constructive feedback that provides them with updates on progress and informs their development. Teachers in this study agreed that both teachers and children find this sort of formative assessment more enjoyable than summative assessment, where the main purpose is to give a quantitative grading.

Most teachers (96 per cent) indicated that they provided feedback with advice for improvement to children during science teaching, and a high proportion (90 per cent) evaluated children's pictures and graphs. Almost 75 per cent of teachers said they used checklists to record their observations of children.

When asked as an open question which other types of assessment methods they used in their science teaching, 30 per cent of teachers responded that they used formal tests, 14 per cent used national tests, 13 per cent used observation, 10 per cent used informal tests and quizzes, and less than 1 per cent indicated that they used mind mapping or investigative work.

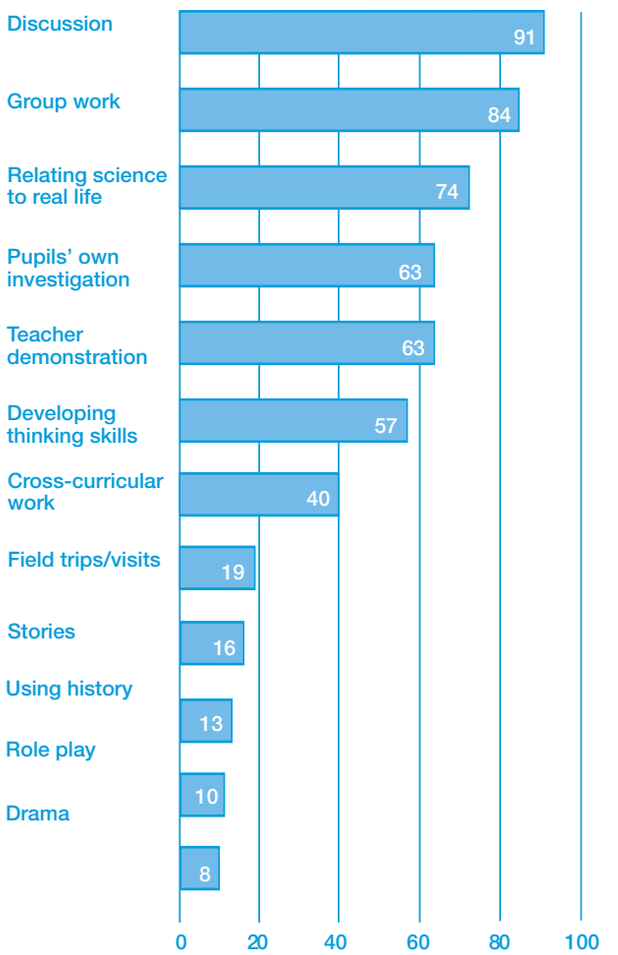
Focus group discussions highlighted interesting differences between teachers of younger and older pupils: while teachers of younger pupils seemed to make more use of checklists and pictures, teachers of older pupils used more oral assessment methods, such as questioning and discussion.

Pressure to perform well in national tests in England and Northern Ireland also appeared to have a considerable negative influence on the use of formative assessment in the later primary years. Teachers agreed that including science in these tests raised the profile of the subject in school, yet they felt national tests had a negative effect on children's enjoyment.

"…you have to try and bring them up to that standard without teaching them to the test. Unfortunately this is what is happening."

An intriguing relationship was apparent in the findings between teachers' assessment style and whether schools had received extra funding for science; teachers who said their schools had received extra funding for science, i.e. outside core funding, appeared to be more likely to discuss and question, or to use peer assessment as part of their assessment, techniques.

Figure 7. Creative contexts used in science teaching.




**6. How do teachers take science beyond traditional teaching methods?**

**Investigations**

Teachers questioned as part of the study were very positive about the power of open-ended investigations to support children's interest and learning but admitted that the school reality often dampens their enthusiasm. An over-emphasis on curriculum content and pressure to prepare for national tests were felt to reduce opportunities for investigative work and lead to science frequently being taught as a collection of facts.

"I want to teach through investigations – that is how I was taught in my teacher training but it's time…we will set it aside and we will just talk about it or I will do it [as a demonstration] at the front… the time is just not available to do it."

Another issue with real open-ended investigative work was felt by one teacher to be young children's need to be right.

"Children think there should be a right answer…to every scientific experiment."

**Creative contexts**

Children enjoy science more when it is taught creatively, and such contexts can support learning by enabling them to approach science from fresh perspectives. According to a recent evaluation of the Wellcome Trust-funded Pulse programme, an arts and science grants programme for primary and secondary age students, many young people reported increased general knowledge of science issues or concepts as a major outcome of creative projects[25].

"It makes it more human and more thinkable somehow to us…it just makes it feel more real to us." (Secondary school student)

The current study showed that the 'creative context' most frequently used by primary teachers was discussion, followed by group work, and relating science to everyday life. The least used creative contexts were role-play and drama (Figure 7).

**25** Centre for Applied Theatre Research, University of Manchester. Making it Live: An Evaluation of Pulse (phase 1): a Wellcome Trust-funded young persons' performing arts and science initiative. (Not yet published.)

Female teachers tended to use creative contexts such as role-playing and drama in science teaching more often than male teachers. Some teachers did use stories, such as that of Edward Jenner, in their science teaching but mostly with younger age groups. Teachers of older pupils felt they needed to be better supported to use stories effectively in science teaching.

**Thinking skills**

Virtually all science learning and teaching develops children's thinking skills, yet only approximately half (56 per cent) of teachers felt they often encouraged the development of these skills through their science teaching. Few teachers focused on thinking skills in the telephone survey but they were discussed more widely as part of the focus groups.

"…I think it [science] is brilliant for developing thinking skills because I think the science topics help to put the thinking skills in context. I think it is giving the thinking skills relevance."

**Cross-curricular teaching**

Cross-curricular approaches to science teaching can be highly motivational for both teachers and pupils. Of the teachers surveyed in this study, 40 per cent said they often integrated science with other subjects, and 54 per cent did so occasionally.

Despite these findings, evidence gathered from the focus group discussions point to the fact that children find it difficult to transfer learning between subjects – even between maths and science. It is possible that the very introduction of subject boundaries, each with their own discrete programmes, has made it more difficult to integrate science across the curriculum. This is particularly likely in England and Wales, where science is taught as a separate subject.

History can bring topics to life and help to fuel children's interest. Half the primary teachers in the survey responded that they occasionally used history in their science teaching, but only 13 per cent used it often.

"My children knew everything about Galileo doing Earth and space - it was amazing, they were just so interested…"

Teachers acknowledged that science history added interest to science teaching, but pointed out that much of the curriculum history did not lend itself to teaching science and that there are few opportunities to bring the two subjects together.

**7. How do teachers deal with gender differences and special educational needs in science?**

Teachers involved in this study did not feel gender was a major issue in teaching primary science. Most (80 per cent) disagreed that girls were less interested than boys in science, although despite this, almost half of the teachers (47 per cent) said they tried hard to get girls more involved in science.

Some teachers pointed out that gender issues surfaced as children grew older. While teachers of younger children commented that girls and boys took to science with equal enthusiasm, some teachers of older children felt girls were more passive and lacked confidence when working in mixed groups. Others disagreed, suggesting that there were no differences and, if any, they were personality driven.

"[In] experiments and stuff, the boys just get stuck in and the girls actually think things through and are organised and a bit scared to…" (Key Stage 2 teacher)

"I don't think they make any differences in Primary One. I think they all just get on." (Key Stage 1 teacher)

Despite the variety of views regarding gender and participation, most teachers agreed that there were no differences between girls' and boys' performance in science tests. This view is supported by the 2004 national test results for England, which showed no difference in levels of achievement by boys and girls in Key Stage 2 science tests[26].

The study did not directly address the question of children with special educational needs, but teachers from special schools were included in the sample. Teachers' experiences confirmed that many children with certain needs, such as Asperger's syndrome, autism and dyslexia, appear to engage well with science, particularly the practical aspects.

"I have a little boy with autism…He will sort of go off and is not paying attention, but anything practical gets his attention straight back. As soon as it is over, that is it, he is gone again."

Teachers were aware, however, that other children with these and other special needs may not be as responsive to science. They also realised that there is a need to balance the needs of one or two children against those of the whole class. Some found the investigative side of science difficult to manage with children with special needs in the class.

The survey of higher education primary science initiatives conducted for this study highlighted a gap in provision regarding projects aimed specifically at science for children with special educational needs.

**26 Department for Education and Skills. National Curriculum Assessments at Key Stage 2 and Key Stage 1 to Key Stage 2 Value Added Measures in England, 2003/2004 (Final). DfES; 2005. www.dfes.gov.uk/rsgateway/DB/SFR/s000581/index.shtml [accessed 30 June 2005].**

**8. What sources of support are available for primary science?**

Many of the teachers involved in this study considered overall funding for science inadequate, especially compared to other subjects. They viewed poor resources and funding as one of the most important issues in primary science, second only to lack of confidence and training. However, there were regional differences in teachers' perceptions, as shown in Figure 8. Teachers from Northern Ireland were the most negative, with only 20 per cent describing resources as good.

Teachers' discussions highlighted disparity not only between funding for science in different schools, but also between science and different subject areas. Extreme examples suggested that one school received only £500 per year for science, compared with £10 000 for English, while another, with 240 pupils, only received £120 for science.

"You have to bid for money and you don't usually get it because it is not in the school development plan; it is not a high priority in the school. So as a science coordinator you have to try and get on the back of other people and get some of their money."

Teachers described the resources available for science teaching – videos, catalogues, books – as good, even 'fabulous'. But unfortunately most of these remain beyond the reach of their allowance. As a result, resources are often 'ancient' and teachers cannot afford to replace them.

Interestingly, while teachers identified lack of resources as the second most important issue in primary science, other stakeholder groups rated it only in fifth place.

In terms of other sources of support for primary science, the survey of existing higher education primary initiatives undertaken for this study revealed that most have focused on:

- increasing teacher confidence
- promoting investigation in class
- increasing pupil enjoyment
- improving pupil attainment in science and continuity between primary and secondary schools.

Various approaches have also been adopted, ranging from in-class support, information technology-based support and the use of support materials to out-of-class workshops and production of materials by teachers. The number of initiatives using each of these different approaches is shown in Figure 9.

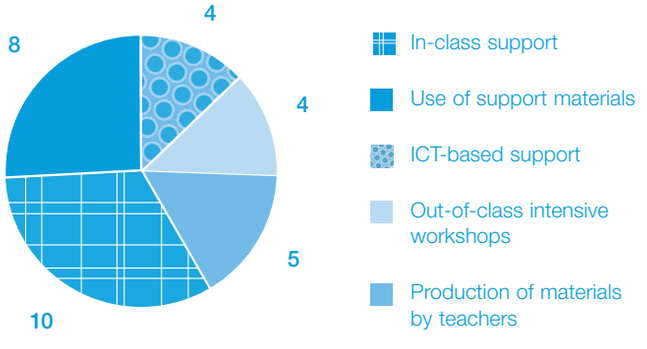
Many of these initiatives have undoubtedly benefited children and teachers in the project schools and often beyond. Even so, most have only reached a small fraction of the UK primary school population. No responses were received from people running projects in Wales and only one from Scotland, although this is not to say that initiatives do not exist in these areas. Parts of north-west and south-west England also appeared to be less well represented.

Much of the valuable work from these projects is also not widely disseminated, particularly to schools that are geographically distant from universities. Some organisations, including the AstraZeneca Science Teaching Trust, have addressed this dissemination issue, at least in part, by creating professional development materials that are freely available online.

**Figure 8. Teachers' perceptions of their school science resources** (telephone survey).

| | Wales | NI | Scotland | England |
|---|---|---|---|---|
| Good | 42.0% | 20.0% | 50.0% | 50.7% |
| OK | 50.0% | 66.0% | 42.0% | 41.3% |
| Poor | 8.0% | 14.0% | 6.0% | 8.0% |

**Figure 9. Different approaches used by higher education primary initiatives** (email survey).



# Research conclusions

**1. A high proportion of primary teachers lack confidence, expertise and training to teach current science curricula effectively;** half of all teachers questioned in the telephone survey felt this was the biggest issue facing primary science. More than half of all teachers surveyed also lacked confidence in using Information and Communications Technology in science teaching.

**2. Good-quality continuing professional development is key to improving primary teacher confidence;** teachers who had carried out continuing professional development in science were more confident in nearly all aspects of science teaching, from developing children's investigative skills, to developing their understanding of 'difficult topics' and making science more relevant to their lives.

**3.** Effective primary science teaching involves children raising questions, wondering and hypothesising about the world, and observing, describing and investigating simple scientific phenomena; nearly a third of all teachers in the study suggested that the best way to help pupils become active and informed citizens is to **make science more relevant to their everyday lives.** All stakeholder groups also felt children's scientific literacy should be supported by providing more opportunities for them to question and investigate.

**4. The use of creative contexts can enable children to look at science from fresh perspectives. These approaches are not widespread in primary school science;** teachers' use of role-play, stories, cross-curricular teaching and real open-ended investigation to support science teaching were all relatively low. Female teachers were more likely than males to use many of these approaches.

**5.** Funding for science varies between regions, and between schools within the same region. Even within the same school, funding for resources may vary widely between core subject areas. **Further research is needed into the variability of funding and into minimum levels of financial support required to provide high-quality science teaching.**

# Notes

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