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Primary Science: are there any reasons to be cheerful?

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ABSTRACT During the last decade, science in the Primary curriculum has been squeezed from different directions. The literacy and numeracy strategies restricted time for science enquiry, and the perceived importance of the science SAT restricted teachers' imaginations and confidence. The end of this SAT was announced shortly after the publication of the Rose review, which had been widely reported as recommending dropping science as a core subject. These events combined to damage the perceived profile of science in primary schools. The coalition government is now promising further curriculum review and an overhaul of primary assessment regimes, alongside stringent financial cuts in local government and higher education. This article reflects on the challenges facing primary science at such a critical juncture and asks: should we be worried about primary science? Are there any reasons to be cheerful?

'It's pretty much all over for science in primary schools' suggests John Stringer in a recent Association for Science Education (ASE) journal (Stringer, 2010). His litany of despair was evidence-based. He cited: the well-publicised removal of science as a core subject in the Rose Review following its systematic squeezing by literacy and numeracy strategies, the withdrawal of the science SAT, the dearth of new materials from publishers, and an acknowledged lack of opportunities for, and participation in, science-focused Continuing Professional Development (CPD)(The Royal Society, 2010, pp. 45-57). Despite the disappearance of the Rose review proposals, those who are handing out P45s to primary science advisors across the country would seem to be in agreement with Stringer's conclusion. Concerns about primary science have been widely aired in scaremongering headlines, reports from esteemed scientific institutions (Royal Society, 2010, pp. 3-10) and the Cambridge Primary Review which opined that 'Science is far too important to both a balanced education and the nation's future to be allowed to decline in this way'(Alexander, 2009, p. 493).

This article responds to these negative reports and asks these questions: should we be worried about primary science and are there any reasons to be cheerful?

To begin I must declare my position. As someone who works within the science education community as a curriculum developer and CPD provider, I acknowledge that I have a vested interest in science remaining a significant part of the primary curriculum. I do not enjoy being told, in schools and the wider community, about the 'downgrading' of primary science. It is distressing to hear of dedicated colleagues who have lost their jobs. I recognise the validity of many of the concerns listed above and I am committed to championing high quality science in primary schools.

The reasons for my personal and professional commitment to primary science are different from those spoken loudest in the science education community. The world of science in schools often appears to be dominated by business, industrial and economic imperatives- the so called 'STEM agenda'. The connection between a scientifically successful population and a successful economy is loudly stated as if it is the only reason for wanting good science teaching and learning in schools and colleges. Nationwide scientific literacy, the ability to understand and engage in debate about contemporary scientific issues, comes a poor second. Much of my work is with the Science Learning Centre (SLC) network, which was tasked by the previous government to improve the quality of science teaching in UK schools with the expectation that better science examination results would lead to a more successful economic future. This expectation is based on persuasive evidence (Roberts, 2002). And the value of primary science to this long-term aim is indicated by research that demonstrates the link between the quality of science that children experience at primary school and later attitudes towards science, specifically subject choices at GCSE (Royal Society, 2006).

I do not underestimate the importance of this argument about creating future scientists; but my own argument in favour of promoting quality science education in primary schools science stems from more immediate observations. Personal experiences in the primary classroom and CPD training room, combined with the testimony of many teachers and children, have persuaded me that there is strong link between high quality teaching and learning in science and an enthusiasm and capacity for learning in general. Science teaching that supports children in expressing and following their own ideas and curiosity, encourages practical involvement with the stuff of the real world, engages children as individuals and in collaboration with others in genuine enquiry and problem solving is motivating and stimulating for teacher and learner alike (Murphy et al, 2005). It is an engaging manipulative and mental activity. Science teaching that convinces children of the robustness and validity of evidence to answer questions, while at the same time encouraging them to value speculation and supposition, forms a vital foundation, not just to further scientific learning, but to learning in all fields (Harlen, 2008) And science need not be taught as a separate discrete subject for these benefits to be apparent. In many European countries science does not form a separate curriculum subject at primary level. Increasingly in England teachers are successfully linking science with other subjects areas, planning for stimulating contexts for science learning that connect with children's wider experiences.

That is my position. I am a supporter of science in primary schools, and I know that at present its future is unsure. As I write the coalition government is promising more curriculum review and an overhauling of primary assessment regimes at the same time as stringent financial cuts in local government and the higher education sector. Teachers, advisory staff and initial teacher education colleagues are working in an atmosphere of uncertainty and for many, insecurity. So to return to my question: are concerns about science in primary schools justified or are there reasons to be cheerful? I offer no definite answers, nor a comprehensive review of all that has happened with science in primary schools in the last 30 years. Rather, I reflect on the challenges and opportunities that I see facing primary science at this time.

By the time I began teaching in 1986, it was accepted that there were good reasons based on argument, experience and research evidence, for claiming that science education at the primary level had a crucial role to play in preparing children for their future lives (Harlen, 2008). However science was then still new to most primary teachers at all career stages. As the National Curriculum took root many local authorities appointed science subject advisors and ran highly rated 20-day CPD courses to train new subject leaders. Recognition quickly grew that a nature table in the corner and some occasional poetry about pollution were no longer sufficient. The 17 attainment targets, detailing the scientific knowledge and skills that every 11-year-old should learn, embodied a curricular revolution. The introduction of the formal science SAT as an accountability measure was another clear indicator that science was a subject that counted in primary schools. Progress was fast, and despite on-going concerns about teacher subject knowledge, an over-emphasis on SAT preparation, and the dangers of dry, didactic teaching that was fact rather that enquiry driven, science in primary schools was generally agreed to be a success (Parliamentary Office of Science and Technology, 2003). This is now evident in both policy and practice. Science is recognised as an entitlement for all primary school children. There was nothing in any political party's 2010 manifesto to refute this. Science also forms a compulsory part of all initial primary teacher education. The importance of science in primary schools is now widely recognised in schools, and not just by enthusiasts.

> Of course there are still teachers who drag their feet on the way to the science cupboard, but the ranks of the converted are much larger than when I first became involved with the Association for Science Education 20 years ago. Many more teachers, for whom science will never be their first love, appreciate its unique contribution to primary education and teach it conscientiously.
> (Turner, 2010)

As enthusiasts, of course, it is easy to over simplify. There are still traditionalist secondary science teachers who claim that all primary science does is fill children's heads with conceptual inaccuracies and wild ideas that 'science is fun', or even more dangerously, that science is something to talk about. Primary to secondary transition remains a tricky issue, with many secondary schools unwilling to acknowledge children's prior experiences. Classrooms where science is a 'copy-from-the-board' or 'complete-a-worksheet' experience rather than a practical or discursive one, are thankfully rare but not unknown. Unfortunately some schools rely on expensive, commercial, after-school science clubs to engage their children in practical science activities. Resources and courses that guarantee to put the 'wow factor' into science are regularly promoted by commercial and other organisations, implying that science itself is intrinsically dull unless there is an explosion to observe. Some schools assert that they are working in a cross-curricular way, planning to include science in catch-all topics such as 'chocolate' and 'houses and homes', but then failing to recognise the need to plan for progression in scientific skills and understanding.

These are flaws; but they are small parts of a bigger picture which also includes some excellent practice underpinned by a significant body of research. Wynne Harlen has identified the key areas of such research that have influenced the teaching of science in primary schools. These are: finding out about children's own ideas, advancing their ideas, developing enquiry skills and formative assessment (Harlen, 2010). My own experience, working with teachers in and out of schools, supports Harlen's summary, though like her, I recognise that the teachers may not realise that the approaches and strategies they use originated in research. For example, the impact of the outcomes of the Science Processes and Concept Exploration (SPACE) research project which took place in the 1990s (SPACE, 1990-1998), systematically recording children's ideas about, for example, what makes things move, grow, melt, dissolve, can be seen in lessons where children's own ideas are taken seriously. It is now widely accepted that children have already formed quite firm ideas about phenomena in the world around them before they encounter them at school; and that these ideas often conflict with the accepted scientific view. This understanding has led to the promotion of a more constructivist approach to science teaching in some primary schools, emphasising the importance of teachers firstly gaining access to children's thinking and then supporting a reorganisation of their ideas to accommodate more accepted explanations. Practical work has been seen as central to this 'active learning'.

This constructivist, hands-on approach has not been without its detractors. Critics have argued that primary teachers lack the personal scientific understanding and pedagogic skills required to identify a multiplicity of alternative frameworks and prior knowledge, then to support their conversion through classroom activity into accepted scientific ideas. Too often children have no input in planning the practical activities in which they engage and spend little or no time interpreting their findings. 'Hands-on' does not necessarily mean the 'minds- on' approach required to enable the children to make sense of a concept by relating it to their own experience (Keogh & Naylor, 1996).

Much of the focus of primary science CPD and classroom resource development in the last decade or so has been on addressing these concerns and developing teacher confidence in building on children's own ideas. For example *Concept Cartoons in Science Education* (Naylor & Keogh, 1999), which are widely used in initial teacher training and at all levels of school science education, present a scientific problem in a familiar setting. They propose various predictions and explanations, representing commonly held scientific misconceptions, and so can stimulate argument and practical experimentation.

The value of children encountering scientific ideas and developing an understanding of scientific concepts through practical enquiry is axiomatic. The message is relayed loudly and frequently to primary teachers particularly by the science subject associations and Ofsted (Ofsted, 2005), and has even been endorsed by a government and industry funded 'Getting Practical' strategy (DfE, 2009). What children do when they practically investigate scientific ideas, by asking questions, predicting, planning, collecting data and interpreting what they find, has a direct relationship with how they develop explanations and understanding. The methodology for developing science enquiry skills, identified in the 1998 QCA Scheme of Work for Science and the 2000 reform of the National Curriculum, shows the influence of research carried out in the 1990s. For instance, the 1990 STAR -Science Teaching Action Research (Cavendish et al, 1990) project studied classroom practice in relation to process skills and produced results about young children's competence in these skills that at the time surprised many. In 1998 a team of researchers from AKSIS-Kings College London and the Association for Science Education (Feasey, 2006) looked into how science investigations are carried out in schools and offered suggestions for future development and support which have influenced initial teacher training and primary science CPD, as well as curricula. One of the AKSIS team's observations was that in many primary schools science enquiry meant always 'doing a fair test', but that this type of science investigation was not always well taught or understood. A lot of the work that immediately followed AKSIS focused on developing strategies for teaching fair tests and appeared to lead to improvements in understanding on the part of teachers and children; but also increased the belief that the fair test was the only way to answer questions scientifically. To their credit, the AKSIS team had clearly suggested that a greater range of science investigations could be carried out in primary schools, including classifying and identifying, observing over time, pattern seeking, making things and investigating models. These suggestions have had some take up, and an imminent ASE guide to science enquiry entitled *Its Not Fair – Or Is It?* (ASE, 2011) will reflect current good practice in a wider range of science investigations.

It is therefore widely acknowledged that enquiry based activity in science is a good thing, and most schools' policies and schemes of work reflect this belief. This is a reason to be cheerful, but certainly not complacent. School policies have a habit of being written, filed and forgotten: their impact on, or relationship to, practice is often minimal. Primary teachers can have very different kinds of activities in mind when they refer to science enquiry. Some view science enquiry as 'discovery' learning while others see working systematically as fundamental. Some assume that it's only about practical work while others feel that it should include children learning scientific concepts. The criticism levied at an incomplete or superficial understanding of the value of constructivism in primary science can equally be levied at much classroom activity that purports to be science enquiry. Just because children are using equipment, working in groups, collecting data or completing graphs, it does not automatically mean that they are developing skills in science enquiry. It is the conscious search for and use of evidence, be that from first or second sources, in order to challenge ideas and answer questions that identifies an activity as an educationally valuable science enquiry. My own personal experience is that this is rarely the identified objective of a science lesson.

However, when teachers spend time thinking about what they understand by science enquiry and how their practice can embody this, the results can be very encouraging. For example, this extract from a school policy was written by a group of teachers at a London school, and recommends the following synthesis of pedagogic, curricular and scientific thinking:

All lessons:

- start with a question
- encourage creative thinking
- involve all children using all their senses to investigate real things
- have a context that connects with children's own lives and experiences
- allow pupils to ask their own questions and discover science themselves through practical investigations and research
- emphasise the role of evidence to challenge or prove ideas and answer questions
- include discussion and debate
- make good use of resources that are exciting, high quality and are of a quantity that allow full participation
- take into account pupils' prior knowledge and understanding
- support children communicating their scientific findings and understanding in different ways including talking and writing in different forms using science vocabulary, pictures, graphs and using ICT.
  (William Tyndale Primary School 2010)

Reading this and seeing it brought to life as a planning and evaluation tool has been, for me, an heartening example of the research, policy, practice dynamic. The policy represents principles of procedure (Stenhouse, 1975), based on evidenced good practice and research, which are shared, understood and enacted.

In her list of key areas of research that have influenced primary science teaching Harlen also includes developments in formative assessment. Working inside the Black Box (Black et al, 2002) summarised the implications for secondary science teachers of the review carried out by Paul Black and Dylan Wiliam (Black & Wiliam, 1998) into classroom assessment. The slim publication achieved wide currency in secondary science education and was a foundation stone of the Secondary Science Strategy. This government-funded CPD initiative attempted, with some success, to translate ideas about pupil directed learning, peer and self assessment, feedback and teacher- pupil interactions into classroom strategies for teaching science in KS3.

The impact of the Black Box publications and subsequent research on primary science teaching and learning has been mixed. The all powerful rhetoric of the literacy and numeracy strategies crystallised and simplified Assessment for Learning (AfL) into a set of 'must be followed classroom rules'. Many schools encouraged teachers to apply these rules with a broad brush to all subject areas, without serious consideration of their appropriateness. Ofsted reported in 2002 that some reported improvements in the quality of primary science teaching were due to teachers using techniques learned through the literacy and numeracy strategies (Ofsted, 2004). This appears to me to be a gross over- simplification. Where I have observed literacy strategy techniques transferred wholesale to science, it seems to me that the fundamental point of science enquiry is missed. For example, teachers often insist that children copy into their books intended learning outcomes which dictate and reveal the outcome of investigative activities, allowing children no space to raise and answer questions of their own, and certainly ensuring that any purpose for collecting and analysing evidence is negated. Equally the desire to share success criteria often means that inappropriate emphasis is put on finding a pre-determined correct answer, collecting tidy data or, even worse, presentation skills.

Nevertheless there is considerable growing expertise in primary science which has taken the AFL research and made it work. Guidance for teachers which helps them to plan for activities which are developmental, purposeful, collaborative and discursive has led to some really exciting practice. While most teachers recognise that it is impossible to provide a range of different activities in response to each class member's individual learning need, increasingly teachers are planning for science activities where the sense of purpose for the learner is individualised rather than the activity itself (Naylor et al, 2004). This happens most effectively when teaching is focused on generating conflict or disagreement about ideas between individuals and within the minds of individuals. Strategies that enable teachers and pupils to identify uncertainties and which motivate children to investigate through practical experimentation or interrogating secondary sources are both good assessment and learning opportunities.

Another major recent development regarding assessment in primary science was of course the removal of the Science SAT in 2009, in response to the proposal of the Expert Group on Assessment. The evidence that the 'high stakes' testing of science at the end of Key Stage 2 was having a detrimental effect on the process of teaching and learning in the primary phase, and children's long term attitude to science, was overwhelming. The removal of the SAT, and consequently of the preceding months of revision and repetition (Wellcome Trust, 2010), was welcomed by all sectors of the science education community (SCORE, 2009), but interestingly perhaps not by the majority of children, who although voicing concerns about the impact of the science SAT on them, were unhappy about the government's decision to abandon it (Wellcome Trust, 2010). I share some of the concerns that children expressed, chiefly that science, which most children enjoy, would become less of a priority in schools. When asked for my opinion on the proposed removal of the SAT I faced a real dilemma. If science was removed from the statutory testing regime, would the already damaging domination of numeracy and literacy simply grow even stronger? Would children be denied the chance of engaging regularly with one of the most popular subjects in the primary curriculum? In a climate of cutbacks in CPD expenditure, would the opportunity to work with teachers on improving the quality of science teaching and learning totally disappear?

In the face of this radical change I decided to adopt a positive approach. I knew firsthand the damage that the science SAT had done to science teaching and attitudes to science learning. I had read the cautiously optimistic reports of a change in attitude and practice since the removal of the science SAT in Wales (Collins et al, 2009) And I rejoiced that science attainment data were still to be an accountability measure for schools and that standards would be monitored by analysis of teacher assessment data and sample testing (DfE, 2009). Teachers couldn't abandon science; but they would have to become more skilful and confident at teacher assessment. I recognised that this transition would not be an easy one for many teachers, and the danger that statutory pen and paper tests would be replaced by the equivalent commercially produced ones. However, like the scientific bodies, I hoped that teachers would recognise the challenge that this transition presented and rise to it. I, perhaps naively, dreamed of schools investing in developing teachers' understanding of progression in scientific skills, concepts and understanding, and supporting the planning of purposeful learning opportunities which offered rich evidence of children's understanding and attitudes. I was even open-minded about APP (Assessing Pupil Progress)(DfE, 2009). In unskilled hands this threatens to be an overly complex and paper heavy process. However, I was fortunate enough to spend some time in APP pilot schools in Lincolnshire observing lessons and talking to teachers, and I was impressed. It was inspiring to work with teachers who were thinking of their pupils as scientists rather than as levels, to observe stimulating lessons and to meet children who were independent, confident and motivated. Therefore I was hopeful that the removal of the SAT could provide an opportunity to develop and share good practice in teaching and learning, In many schools this is happening. I am fortunate enough to work with some of them: but ask myself whether their practice is an encouraging trend or an isolated phenomenon?

As I write my hopes are subdued. Rumours abound about changes to curriculum and assessment for science. Subject knowledge is apparently the coalition government's holy grail and any weaknesses in science attainment can only be the result of an inadequate transfer of knowledge between teacher and pupil (Gibb, 2010). We are told that ministers don't want to hear about formative assessment strategies in science which inform teachers and pupils alike about progress and next steps. If that is true, then they will not be interested in developing pedagogies building on the research that I have outlined above. With the abolition of QCDA the project to develop a relevant model for sample testing of science attainment has quietly been forgotten. Recent curriculum redesign, which many staff teams have embarked on with enthusiasm and considerable skill, may all be for nothing. It is easy to see why many teachers and senior leaders feel confused about the place and profile of science. It is tempting to share the negativity expressed by colleagues such as Stringer, whom I quoted at the beginning of this piece.

It is, of course, too early to tell what effects the coalition government will have on the primary curriculum. But within political uncertainty, there may be an opportunity for teachers to grab the agenda and decide for themselves how they value, plan and organise for science teaching and learning. Could it be that the momentum that has grown over the last twenty five years for high quality science teaching and learning in primary schools may be too strong to stop?

For example, on the very eve of the 2010 election I was at the Centre of the Cell in Whitechapel, London to celebrate 48 schools' commitment to excellence in science. As participants in the second pilot phase of the Primary Science Quality Mark, the subject leaders in each of the schools focused on evaluating and developing the quality and profile of science teaching and learning in their schools. The impact on the children in their school, on their colleagues and their wider community, and crucially on the subject leaders themselves, as evidence in the evaluation of the first pilot phase, was incredibly positive and will continue to be so (Ponchaud, 2008). One of the participating subject leaders summed it up:

The impact of actions undertaken as part of the PSQM in the last year include:

- an increase in practical science
- more visits, visitors and links with outside organisations
- more opportunities for pupils to experience science outside of lessons
- increased understanding of the teaching and learning of science in the school
- greater awareness of science in the school by governors and parents
- development of the confidence and capacity of the science subject leader
- the more widespread appeal of science.
- a growing confidence among teachers about teaching the subject.

- progress has been made, but this is just the start:
  the year ahead looks very exciting.

In November last year the Wellcome Trust awarded the ASE, in partnership with the SLC network and Barnet LA, £200,000 to support the roll-out of the Primary Science Quality Mark across the UK. This is a meaningful commitment to primary science from the world's leading scientific funder. There are now 43 active PSQM hubs across England, which means that over 230 science subject leaders, supported by local PSQM hub leaders, have embarked on a year- long programme to champion science in their primary schools. Each school has had to commit not only professional time, skill and energy but also cash; though many have been generously supported by their local authority or Specialist Science College. The intention is for up 30% of primary schools to achieve a Primary Science Quality Mark by 2018 and at the moment recruitment figures are looking good.

What excites me most about the Primary Science Quality Mark is that is emphatically not a tick list of criteria to be accomplished in exchange for a certificate. The scheme's processes are designed to ensure that submission should not be a summative description of actions, but a truly evaluative statement of impact of actions on the quality of science across the school. The emphasis is on developing reflective leadership, using Stenhouse's definition of the critical characteristics of 'extended professionalism' (Stenhouse, 1975) as an underpinning methodology:

- the commitment to systematic questioning of one's own teaching as a basis for development
- the commitment and skills to study one's own teaching
- the concern to question and to test theory in practice.

Schools 'chasing awards' is not a reason to be cheerful; but schools seeking out a professional CPD programme to raise the profile of science, participate in a tested model for development and to share and extend good practice, just might be. New Schools' Minister Nick Gibbs has promised that 'we're going to place greater trust in professionals to give teachers more freedom to decide how to teach' (Gibb, 2010). Could it be that the Primary Science Quality Mark is an early example of this policy in practice?

We cannot accurately predict how government education policy will develop, and I recognise that my optimism may be naive. So in conclusion I return to the policy written by teachers at the North London School cited earlier. This exemplifies the possibilities for high quality science teaching and learning when teachers and schools are given the flexibility to be accountable to their own shared principles and values, and when those principles and values are underpinned by research. Primary Science has come a long way in the last twenty years. I am hopeful that in the classrooms of reflective, enthusiastic teachers such a journey will continue.

Note

The 'snowman' illustration is reproduced with the kind permission of Millgate House Publishing Ltd from the book *Concept Cartoons in Science Education* by Brenda Keogh & Stuart Naylor, 1999 (www.millgatehouse.co.uk).

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