Primary Science

A Collection | *Creativity*

The Association for Science Education

From ASE's journal for primary science

FREE to members

Contents

A Collection | Creativity

About this collection

Welcome to this collection of articles from Primary Science (formerly known as Primary Science Review) on the theme of 'creativity'. This is the first of a series of collections based on a different key theme. Collections are freely available to members of ASE.

Why are we doing this? ASE's journal archives contain a wealth of helpful material, often timeless and still relevant today, which many of us may not have seen. We also recognise that it is not always easy to find what you are looking for with so many new teaching resources. We felt that it would be helpful to both point you to the most pertinent articles and provide a collection in one, downloadable, place. The elements in this collection comprise seven of the most informative PS/PSR articles on the subject of creativity, as selected by editor, Tara Lievesley, the Primary Science Editorial Board and ASE Primary Science Education Committee. But, there are more!

The next collection will be on the topic of 'assessment' and will be made available free to members in the spring term of 2016. Our grateful thanks go to Tara and her team for their hard work in selecting and compiling this collection. We hope you enjoy it!

Primary Science

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By becoming a member you can access not only additional Collections that will be of interest, but also recieve all the benefits of membership. Find out more on page 23 and at www.ase.org.uk/membership/membership-category/primary/

ASE editorial contact ***Jane Hanrott***

The Association for Science Education

A couple of years ago an eminent member of the science education community sat down and showed me an article from one of the very first *Primary Science Reviews* (as it was called then). On reading it, they asked what sprang to mind: honestly, the article was as true then as it is today. On looking back through past copies of *Primary Science*, we realised that there were many other excellent resources and articles that those who had just entered their teaching profession would not have seen, which are as relevant now as they were when written, over 25 years ago in some cases. There are obviously many things in education that don't change over time.

On investigating this further, it became apparent that some were unaware of resources (the Science Year ASE CD ROMS from 2000 were a case in point), and articles, as they were 'too young'! So the 'Bundles', or 'Collections' were born. A neat, attractive and simple way to provide past articles to ASE members that can give ideas and insight, from teachers and researchers possibly less constrained by National Curricula than many of us feel today.

For this set, we have focused on 'Creativity' as, along with 'Assessment' (another 'Collection'), this is often the main topic of conversation when talking to colleagues. It perhaps comes back to recognising what 'Creativity' is, and isn't (not just about being cross-curricular, although this can be creative, but you can be just as creative within a single subject).

'*Historically, creativity has been seen as a tortured and mystical process, the province of geniuses, artists and eccentrics*' (Education Scotland). In reality, it is about looking at the same things in a different way; being extraordinary is only looking at the 'ordinary' in an 'extra' special way. The original NACCCE definition, whilst being of 'an age', still holds true: '*An imaginative activity fashioned so as to produce outcomes that are both original and of value*'. The articles we have collected for you not only help to show how to put it into practice, but also some ideas of how to approach the same things differently, and provide a purposeful context to learning.

Education Scotland: (http://www.educationscotland.gov.uk/learningandteaching/approaches/creativity/about/index.asp)

NACCCE: http://sirkenrobinson.com/pdf/allourfutures.pdf

Peter Ovens

(Issue 81, January 2004)

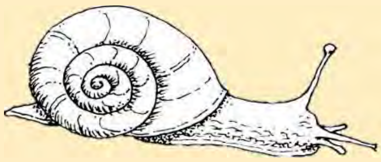
SUGGESTS HOW CREATIVITY IN SCIENCE LEARNING AND TEACHING CAN PROVIDE BOTH *EXCELLENCE* AND *ENJOYMENT*

A 'SANE' WAY TO ENCOURAGE CREATIVITY

We notice children's creativity in their lively talk, practical ingenuity, funny or surprising ideas, or their new or clever ways of applying their knowledge. When the connections they make between ideas seem to come from them as individuals, there is a sense of authenticity. Understanding learning from a constructivist perspective emphasises the creativity of learning. Learners build new experiences into personal knowledge by deconstructing relevant bits of existing actions and understanding while constructing links with fresh ideas and new ways of doing things. Ultimately, only learners them- selves can do this by their own efforts.

Starting points for this process are practical experiences which arouse curiosity and raise questions. For example, a group of year 1 (5–6 year-old) children who looked at and talked about some garden snails, gave a delightful personal response, showing sensitivity to feelings and relationships

The questions they asked (see panel) were elicited by Faye Bartram, a student teacher at Nottingham Trent University. Can creativity and authenticity be recognised in the thinking that appears to be behind these questions? Some of these questions could be a basis for practical scientific enquiry, while others suggest learning of personal, social and emotional kinds. Some questionsare about *similarities* between snails and human beings, such as eating and sleeping preferences, whereas a fascination with slow speed of movement and with anatomical features such as antennae and shells are about *differences.* But even these are expressed from a human perspective, '*Why don't they have legs?*'; '*How fast can they run?*'



Children's questions about garden snails

Dief

- How fast can a snail go?
- Do snails play?
- What do they eat?

Anil

- Why do snails have a shell?
- Do they have any friends?
- Why do they go slow?
- What do they have to move with?
- What do they eat? What do they sleep on?

Naomi

- How fast do the snails run?
- Have they got any friends?
- Do they have a family?

Adam

- Can we set up a race track for the snails?
- How fast does the fastest snail go?
- How do they move?

Hannah

- What do they sleep on?
- What do they see from?
- Why do they have patterns [on the shell]?
- How do they move?
- Do they have friends?
- How fast do they go?
- Do they have sex?

Olivia

- Why do they have sticks with bumps on? [antennae]
- How fast do they go?
- Why don't they have legs?
- How do they move?
- Why do they have shells?
- hat do they eat?
- What do they live on?
- Do they have friends?
- Do they have cousins?
- How do they talk?
- What do they like?

This tendency towards anthropomorphism was noted by Paul Waring-Thomas (2001) when his class (aged 7-8) were learning aboutguinea pigs. Although the bestperson to judge the *authenticity* ofthese questions is the teacher, it seems clear that as authors of these questions the children have created possible links between what they already know and what they would liketo learn next. In responding holistically, they have drawn upon their experiential knowledge and their emotional awareness, as well as their formal conceptual knowledge, to express their curiosity.

Asking Questions

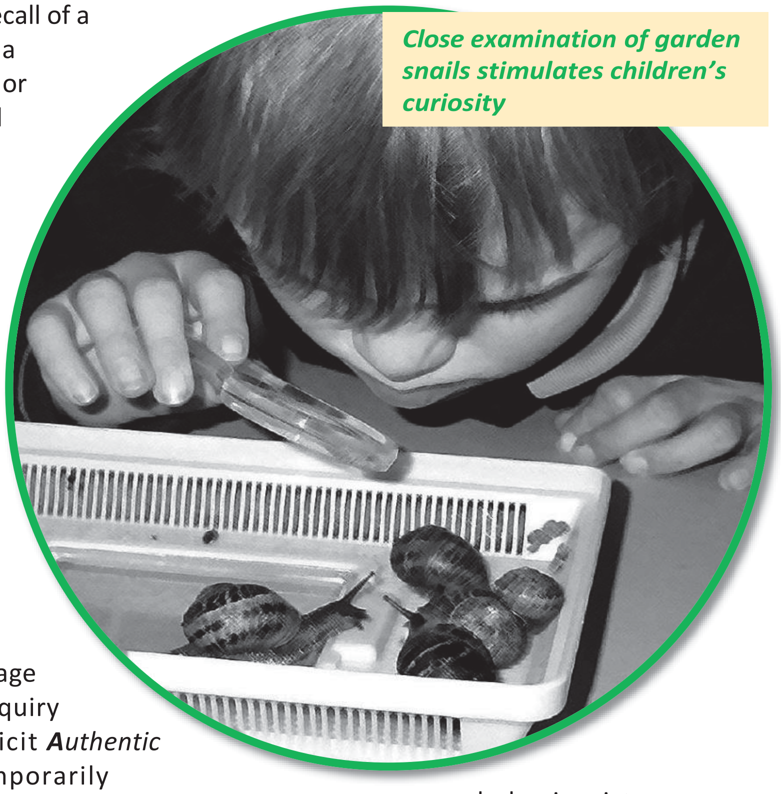
Treating children's questions with the care they deserve, as *emergent objectives,* is considered later. For now, it is worth emphasising that children's questions give a much better basis for constructivist teaching than *eliciting children's concepts*. Beginning a topic by asking children mainly closed questions about their conceptual know-ledge in a context which is neither practical nor enquiring in character is not the ideal constructivist approach. This method tends only to elicit a part of *where the children are*: the science concepts which they '*hold*'. It is unlikely to draw out their interests, curiosity, experiential knowledge and emotional aspects of their awareness. It may prevent learners from having some control over their own learning, which is fundamental both to constructivism and to creativity. It prioritises conceptual knowledge over experiential and personal kinds of knowledge. Worst of all, children's authentic curiosity and independent creative thinking may be killed 'stone-dead' if the teacher sets up the expectation that s/he controls all the right answers on which the children's learning must converge.

Paul Waring-Thomas's (2001) action research (see also Ovens, 2000) was about *negotiating* with children on how to turn their authentic questions into plans for their own scientific enquiry. Through small-group discussionand using a planning frame, Paul challenged and extended their ideas. Control over the content of the lesson shuttled back and forth between the children and between them and Paul. Forexample, negotiation about the initial question '*Does a guinea pig preferhardorsoftsurfaces?*' revealed that some children felt sure that the answer would be a soft surface, and therefore a more authentic question was '*Does it prefer ordinary material or the towelling which it is used to?*' Further discussion brought in a child's awareness of animals' sense of smell, and a yet finer discrimination: '*Does it prefer its own towel, or a fresh one?*'

Creativity is also evident in children'sexplanations of their findings.The question '*How far away can guinea pigs smell food?*' led to a conclusion that broccoli, their favourite vegetable, could be detected 50cm away. However, the less clear results from tests just before lunchtime, were said to be caused by the smell of food from the school kitchens! Here, interpreting findings critically is part of their creativity. '*Which is the fastest guinea pig?*' led to a plan for a 'race track' bounded by two walls of cubes and with a carrot at the specially made 'finishing line'. A fascinating, unexpected but important piece of learning emerged from children's disappointment when the guinea pigs refused to run down the race track, and ignored the little toys offered to them to play with. There was a growing realisation that their (tacit) anthropomorphic assumptions about the guinea pigs were mistaken: as one child said '*They're not like us!*'

Encouraging children to be creative in science

Creativity is obviously more likely in situations which are open to a range of outcomes. If a single, fixed outcome is expected, a child's creative response may simply be excluded. Children who are not always determined to please the teacher, but who like to please themselves (in a positive sense of persevering with their own interests and meeting their own tacit 'standards' of achievement) may show creative responses which seem to challenge the teacher's plan. Low achievers in numeracy and/or literacy may also be surprisingly creative in contexts like the ones described above. So the first point to make about teaching for creativity is that it must have sufficient openness to give *authentic opportunities* for children to be curious and to think independently. We must be open to what may *emerge* in children's responses to each situation. No teacher can predict with precision what *these* children who take *this* opportunity will say or do *now*. The appearance of creativity cannot be controlled. It cannot be elicited on demand, like the recall of a correct answer to a closed question. Nor can it be predicted accurately across situations. So lessons cannot be planned in very great detail beforehand, like set practical tasks. We cannot teach creativity by transmitting it or telling learners how to be creative.



Close examination of garden snails stimulates children's curiosity

Our role is to ***S****timulate* (encourage and challenge enquiry thinking), and elicit ***A****uthentic curiosity*. We temporarily relinquish some control over content while focusing on the children's constructive learning processes. Then our task is ***N****egotiation* through discussion: of ideas, of purposes, of methods and of meanings. In planning teaching for creativity, detailed and specific objectives must be ***E****mergent*, not pre-specified. This is a ***SANE*** approach. It was the presence of these qualities in Paul's teaching which enabled the emergent learning: '*They're not like us*'.

Before the advent of the original National Curriculum in England and Wales and state sanctioning of planning by objectives, good curriculum planning in schools used a mixture of two approaches. As well as having behaviourist objectives, which listed specific items to be taught in a transmissive way, a good teaching plan contained a degree of openness in content and flexibility of time, to allow response to children's creativity. Of course, we use behaviourist approaches to *train* children, to control their behaviour, demanding a fixed response to our stimuli. And as Nick Selley (Selley, 1999) has pointed out, behaviourist approaches have an important place in learning what he calls *prescribed* or *closed* knowledge, such as knowing facts, spellings and simple skills. He contrasts this with *open*, or *personal knowledge*, which he says should be learned in constructivist ways. Open knowledge includes creative abilities to understand and explain, predict, apply knowledge, choose or devise an enquiry method and evaluate one's own knowledge. Currently, recommended approaches to planning and teaching are dominated by pre-specified objectives for both closed and open knowledge. This is more consistent with behaviourist assumptions than constructivist ones. A dogmatic use of pre-specified objectives in planning stifles creativity for teacher and learners.

Planning teaching with *emergent* objectives

In the context of the National Curriculum, a creative lesson plan would include broad, enquiry-related aims about children questioning and enquiring, and knowledge aims which link with the relevant part of knowledge. Anticipation of a range

Finding out just how snails move

of possible lines of enquiry would enable relevant learning resources to be prepared. But it is only during the session, when the exact lines of enquiry are negotiated with the children, and when specific aspects of enquiry and appropriate parts of knowledge are incorporated into the jointly planned investigations, that the *precise objectives will emerge*, differentially and accurately related to '*where the children are*'.

For me, the real justification for asking the children to do this is not because it will lead to achievement of objectives, however desirable, but because looking at interesting things, and thinking creatively and talking intelligently about them is *educationally worthwhile in itself*. Emphasising the intrinsic value of learning, learning for its own sake, seems like a 'blasphemy' against the 'fundamentalist' movement which the objectives model has become!

There is a sense in which a teacher and the children must dare to step into the unknown, since success depends on mutual trust and confidence in finding out what is not known exactly beforehand. When those children wanted to find out about snails in those particular ways, Faye, their student teacher, was finding out about their emergent thinking, in order to challenge and improve it. In this kind of open situation, where children construct their own responses, not limited to pre-specified objectives, the teacher temporarily relinquishes control over content, to find out what the children know now and want to know next. Control is then temporarily taken back when the teacher evaluates the children's ideas and negotiates what is to be done next by appropriate groups of children. Then the children resume control as they investigate, but with the teacher's emergent objectives built in.

By ***S****timulating* their ***A****uthentic curiosity* and through ***N****egotiation*, ***E****mergent objectives* for their learning can be identified and taught with creativity and enjoyment. Those children who were fascinated with a snail's slow movement could make closer observations of how snails move over transparent plastic surfaces, using hand lenses. The teacher could elicit descriptive talk, enrich their language and ask them for drawing and/or writing. For children who are reliably using language such as *fast*, *slow*, *faster than*, there could be investigative attempts to measure just how slow is meant by slow and there could be negotiation of further questions, such as '*Do they move faster or slower over some surfaces than others or in response to different stimuli?*'

This links with several attainment targets in the science National Curriculum. It may be difficult to find observational evidence of snails having friends, but what they eat, what they 'sleep' on and what they 'like' are all practically investigable. Questions about their reproduction and shells may be dealt with using books and other sources of indirect evidence and through discussion. Different emergent objectives will relate to different groups of learners and are achieved in different ways.

Yet more objectives might emerge from the teacher's observations of children who do not use a hand lens skilfully enough to observe the snails closely, or who do not understand how to measure length accurately enough to compare the speed of the snails reliably. When the children's purposes are to describe carefully how snails move, or to measure just how slowly they move, training them to use a lens or a ruler, *in the context of their purpose*, enables them to apply a new skill immediately and meaningfully. In such situations, it is right to *train* the children what to do or to know, when and where they need it, with specific objectives playing their part as valuable slaves to the learning process, not as tyrannical dictators.

I hope that these examples suggest that creativity need not seem mysterious or difficult, particularly when a *SANE* approach helps to make learning and teaching have both *excellence* and *enjoyment*

Acknowledgements

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CREATIVITY FOR A PURPOSE

Figure 1: Objects frozen in a block of ice can provide stimulating starting points

(Issue 119, Sept 2011)

Hellen Ward shares her ideas of what creative science education is about

Creativity in primary science is even more important now than when it was first raised with the report 'All Our Futures: Creativity, Culture and Education' (NACCCE, 1999). Their definition of creativity: '*Imaginative activity fashioned so as to produce outcomes that are both original and of value*', is just as valid today as it was then.

Education should focus on the needs of the learner, promoting their enjoyment of science and developing their expertise, rather than only thinking of the future needs of society and/or future scientists. It is however too simplistic to ignore the bigger picture and the role primary science plays in ensuring a scientifically literate population, encouraging more scientists whilst providing personal enjoyment for the pupils. It should focus on the nature of science; how scientists work and how children perceive this, linking it to their work in school.

All these requirements will only be met if the science taught has a creative element.

How to increase creativity in the classroom

Creativity needs to involve both the teacher and the pupils. Exciting, creative, practical opportunities provided by the teacher will increase motivation and enjoyment of pupils. However creativity is most effective when it also enables learners to be involved (HMI, 2003). There is a distinction between 'creative teaching' and 'creativity of pupils' and some of the most 'entertaining science shows' do not enable the learners to be more than passive observers. In order to increase creativity of pupils, enabling them to see how scientists might 'think' in real life, some simple practical steps need to be taken.

Context

Identify a context that is realistic, everyday or meaningful. Whilst it is vital to tell children what they will learn, the focus on writing the learning intention has become all encompassing. Instead, try starting the day with 'Ice Sculptures'; blocks of ice which contain objects from whichever aspects of science being covering, e.g. parts of plants, different materials, electrical components; the choice is yours. Provide magnifying glasses and torches and ask learners to identify all the contents and raise their own questions about what they observe. Children will be fascinated; the way the objects can be seen or obscured, the way some leaves are clearly changed by freezing but others are not (Image 1). Some of the most interesting and thought provoking questions can arise from close observations of the flowering parts of plants imprisoned in a block of ice.

The unexpected

Creativity comes from creative starting points, particularly those which have an outcome which is not as the children expected. If growing plants always takes place by starting with seeds and watching what happens in different conditions, there is little opportunity to be creative. However if a bean is germinated in a plastic cylinder or a small transparent sandwich bag, they will see that roots grow first. They can order or sequence the cylinders or bags depending on their own criteria and, if you are really 'sneaky', and wish to promote thinking, give them one that does not do what is expected! For example, I had a bean that was growing 'happily', but then it fell over and started to grow 'down' instead of up. It proved to be a good stimulus for discussion as the children wondered about why it happened, how they could do it themselves.

The most important thing was not to tell them 'why' straight away. By letting them develop their own ideas and then try them out to, they could see for themselves if they are correct. This led to ideas and questions about all types of seeds and how they grow.

Alien Adventures

It is also possible to provide more structured challenges. Approaching lessons in a more creative way can lead to more creative activity from the children. A brightly painted box, for example, can excite the imagination of most learners (Image 2). The box came with a 'letter' from a friendly Alien, with questions about the topic being covered (see letter). These boxes and letters have been used in a range of ways, by different teachers. In some cases the teacher was the controller of the box, the teacher had the letter, read it to the children and then took out objects from the box and taught a science lesson. Another teacher, who was not as confident with science, sat the children on the carpet and asked the children '*What is in the box?*' After they had thought about it and responded, the box was opened and further questions posed by the teacher: '*Why is it here?*' and '*What shall we do with it?*' A great deal of speaking and listening emerged along with knowledge that the children already had. This teacher then asked one of the children to read the letter and after it was read asked them how they should carry out the request. The children spilt into groups and took a question each, they decided what equipment they would need and also how they would feedback their results.

Both groups enjoyed the lessons, in spite of realising the letters weren't from a real alien. The most creative out puts came from the second classroom: here the children made great progress as a whole afternoon was devoted to finding out and sharing their knowledge. The teacher

A brightly decorated box can capture the imagination, by wondering what is in it, by holding something unusual or from an unusual person'

Dear Earth Children

I am interested in how the plants on your planet work. Someone said they get food from the ground through their roots. Is this right? Are minerals, water and carbon dioxide food?

What do all the plants on your planet start as? Do they have a life cycle like animals? If so, it would be helpful if you could draw and label the life cycle of some of the common ones for me.

Other things that interest me are what plants need in order to grow and what the word 'germination' means. Where doe the plant make its own food? Are there types of plants that you eat and can you name them and tell me which parts of these plants you eat?

Plants have some long scientific terms for their parts and I am confused about what these words mean. Could you explain in easy words what a stigma, a stamen, a filament, an anther, an ovary and a carpel are? Do all plants have these parts and what are they for? What do the terms dispersal, pollination and seed production mean? Is there a reason why plants are brightly coloured? Is this so they can be sold and put in houses or are there other reasons?

I would like to make some new plants that would grow in the very hot, dry climate on my planet. Can you suggest some ideas for new and interesting plants? I will need to know their life cycles and what they need to be able to live so I can create them.

I am also interested in the different ways in which seeds can be sent away from the parent plant. But why don't plants grow under the parent plant? Animals look after their young; do plants not need to do this too? Could you please send me the information using photographs, models, posters and diagrams.? A simple dictionary of plant words would also be very useful.

With thanks, Parmenides

provided opportunities to try out new things and there was an atmosphere that promoted investigations which were open-ended: the very nature of science.

Imagineering

The American science association promote something called Imagineering (McCormack, 2009). It is also something seen in Sweden (Persson, 2009a). The idea is that a stimulus is provided to promote the children's interest e.g. a magic trick, and then they have to decide how it happened, drawing and explaining what they think happened and why. One example is the 'Magic Cauldron'. A range of liquids e.g. water with different food dye colours added and plastic spiders (and other 'witches brew' type ingredients!) are added to a plastic cauldron by the children according to a 'magic recipe', which the teacher has. When all has been added, the cauldron is turned upside down over a child's head and nothing comes out. Obviously there is a 'wow' factor here, as the children are amazed and intrigued by the unexpected. They are then asked to explain what they have seen – liquids etc going in, but then nothing coming out. The ideas created not only explain the level of thinking of the children, but also allow the children can come up with new ideas or link existing information and knowledge they have: working more like real scientists.

Allowing children to try out these ideas will give them control, provide a creative learning opportunity and encourage their own ideas and solutions in solving the problem. Alternatively you could just tell the children that there is already a powder in the pot (a polymer like instant snow, or the gel/crystals you add to hanging baskets) that swells when liquid is added, so that the liquids become 'jelly' so that when the pot is turned upside down the 'liquid' stays at the bottom and will not fall out. Obviously this means as the teacher, you would have to have set this up before-hand.

Coloured sweets in water –a simple investigation that stimulates children's questions'

How to be Creative

Creativity is an approach that needs you to plan and use subject knowledge, but the skill is using these to promote learners' thinking. After a decade of 'Knowledge Pushing' to enable learners to do well in National Tests, it takes some time to readjust to the 'real' role of primary science education. The approach is not difficult, start with something of interest, for example a plastic Petri dish with 5 different coloured skittles (other sweets are available and yes they do work! And a saucer will replace a Petri dish!). Add water and watch what happens (Image 3). Then it is over to the learners to ask questions – '*What will happen if the water is hot?*', '*Will other type of sweets work'* or even, '*If I freeze it will the colours and patterns stay?*' This last question was asked by an 11 year old child with challenging behaviour. In this lesson he was fascinated. He went with his LSA (Learning Support Assistant) to the school freezer to test his idea. It wasn't successful, as the colours all mixed in the time it took to freeze, but that just got him thinking harder and more engaged in science. All the children understood the science: they talked about it at home and they brought in different sweets to try out in the next afternoons science lesson.

Setting small challenges can allow you to see how creative children can be. Giving them an ice cube on Friday afternoon and asking them to identify the best way of keeping it solid until Monday, can be very thought provoking. (A school who undertook this had made spare cubes for Monday morning for teaching assistants to work with children who had not been encouraged at home.) The winning idea arrived in a plastic yogurt pot surrounded by frozen peas, covered with cotton wool. This is an example of creative teaching, providing opportunities that will promote science in real life and include parents and carers in education.

The point of primary science education should be to promote creative responses about the world around children. These aims can be met if the focus is on the learner! It is important to remember that teaching is *not* the same as learning, just because they are often linked by 'and' when we talk about them. In the current time, when the pressure on teachers are greater than ever, it is not enough to raise children's interest in science it is also vital to keep that interest alive! (Persson H, 2009b).

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ELIZABETH BRITEN USES A SCHOOL GARDEN AS A RESEARCH STATION TO HELP CHILDREN CARRY OUT THOUGHT EXPERIMENTS ABOUT PLANTS

SOWING the seeds of creativity

(Issue 91 January 1991)

The exciting world of plants may be something of a mystery to many children, and the often-dry content of a curriculum taught indoors inhibits real understanding of many complex biological processes. Moving outdoors opens up an unexplored world and presents rich opportunities for imaginative learning. The Life processes and living things part of the National Curriculum for England can be taught in a creative way through cultivation of a small plot of land within the school grounds, to engender a love of the living world outdoors.

The value of outdoor learning

The Qualifications and Curriculum Authority analysis of the 2004 key stage 2 National Curriculum tests (taken at age 11 in England) concluded that to help improve future performance pupils need opportunities to: '*learn the functions of the reproductive parts of the flower and the role of these in the life cycle of the plant*' (QCA, 2004).

Similar conclusions regarding reproduction and plant life cycles were also drawn following the 2003 analysis and as far back as 1998. Through getting involved in the real process of growing plants from seed to fruit and onwards, the cyclical nature of life is revealed to children and explored in situ: the thrill of getting dirty and the excitement of 'hands-on' learning inspires a keenness to learn. Investigative work outdoors provides a meaningful context for the development of a wide range of enquiry skills; children can observe, record, plan and carry out enquiries where the purpose is clearly evident. Important bio-logical concepts are developed, with renewed understanding being brought to previously abstract ideas.

Clear links can and should be drawn to citizenship with its emphasis on responsibility. Appreciating the fundamental role of plants within our delicate ecosystem is vital for children of today, born into a world environment suffering from human abuse. They need to understand the issues and ultimately make informed choices. This process can start on a small scale within the school grounds. Letting the children have ownership of the garden and responsibility for its welfare provides a vehicle for the promotion of many personal and social skills.

The creative garden

There is a justified drive within education to approach the curriculum in a creative manner, spurred on by recent government initiatives and teachers dulled by the rigid implementation of successive 'strategies'. Yet creative teaching is not necessarily instinctive. Creativity is not a natural process of the brain. The latter has a preference for 'in the box' thinking, with new experiences fitting into previously recognised compartments. Creative thinking, however, is concerned with new ideas and new ways of looking at things: *Creativity involves 'thought experiments'. You cannot tell in advance how the experiment is going to turn out. But you want to be able to carry out the experiment*. (de Bono, 2000)

Although the creative solving of dilemmas within a school garden may be on a small ecological scale, the fight for survival and continuity of the species may be just as real for the plants themselves and for the small scientists caring for them.

Into the garden

The garden (or 'research station', as it may be called) can be used for a multitude of creative learning experiences that develop essential enquiry skills and build scientific understanding whilst promoting important life skills. The garden need not be large: 3 m by 2 m would be a good starting point, with additions being made later if necessary. Ideally it should receive a good deal of sun, with an area of paving or grass around the site where the children can sit. Any decent soil could be used, although the addition of sterile composed manure from the local garden centre would be highly advantageous!

Choosing the plants

An enormous range of plants is readily available but a few points should be considered before final choices are made. The plants should require the minimum of fuss and yet represent the diversity of species that exists. The Phormium for example is a red plant!

Examples that have appealing scent and texture are wonderful for partially sighted children. Fast-growing colourful plants are a must for the younger age range. The inclusion of species that illustrate their many uses to humans is valuable. Plants should be chosen that will flower, fruit and set seed at points within the school year. Finally, be aware of avoiding plants that contain sap that may irritate the skin, e.g. Euphorbia, or that produce poisonous fruits, e.g. Laburnum. (See the ASE publication Be safe! (ASE, 2011) for further information on suitable plants and those to avoid.) Box 1 gives some suggestions.

Using the garden

The following collection of ideas suggests some ways in which 'thought experiments' can be employed whilst addressing areas of the science National Curriculum.

Key stage 1 (ages 5–7)

- **Seeds**. Discuss what a seed is and what happens when it is planted in the ground. Plant a range of different seeds, predicting what will happen. Record what happens with the aid of drawings. Pick the seeds from the garden plants and keep to replant the following year. Cut open the fruits from the garden (berries, beans and pods) to reveal the new seeds.

Box 1 Some possible plants

Plant	Features	Notes
Allium	Flower heads die back to reveal newly formed seeds within 2–3 wks of flowering.	Flowers May/June. May grow to 1 m. Buy as bulbs to plant in autumn. Collect and plant seeds the following spring, if not already dispersed by the plant.
Apple tree	If flowers are pollinated, fruit containing seeds (pips) produced in autumn.	Deciduous tree. New smaller varieties may be grown in a container. Flowers produced in spring. Flower scent attracts insects for pollination.
Aquilegia	Following flowering and pollination, many seeds are produced. Can be collected and replanted to flower the following year.	Flowers May/June. Perennial. Small to medium height. Dies back in winter. If seed heads left on plant seed dispersal occurs and new plants grow around the old.
Daffodil	Flowers clearly show reproductive organs. Good for close observation,	Plant bulbs in autumn. Spring flowering.
Holly	Holly is an example of a plant that is 'designed' so that male and female reproductive parts are on separate plants.	Evergreen shrub. Insignificant flowers. To get berries on the female plant also need a male plant. The plants produce berries containing seeds. Holly berries are POISONOUS if ingested, so grow a single male plant only e.g. Ilex 'Silver Queen'.
Nigella	After flowering, interesting seeds pods are produced illustrating dispersal mechanism.	Annual. Height 30–60 cm. Plant seeds straight into ground in autumn or spring to flower in summer. Also known as 'Love in the mist'.
Phormium	Red-coloured leaves to illustrate not all plants are green. Some use pigments other than green chlorophyll to	Evergreen perennial that flowers in summer. Height up to 1 m. Plant any time of year.
Runner beans	Illustrates full life cycle that can be observed during school time.	Flowers in early summer with beans being produced from summer into autumn. If beans left on, plant will dry and seeds inside pod can be collected and replanted the following year.
Sunflower	Children's favourite. Fast growing with seed being produced once flowers are fertilised. Great for recording growth.	Summer flowering annual. Plant seeds indoors and observe growth before planting outdoors in garden complete with stake.
Tulip	Male and female reproductive parts can be clearly observed, recorded and compared with other plants.	Flowers April/May. Plant bulbs in November.

- **What is a plant**? Discuss what is living/non-living, and what a plant is (many children have odd ideas about these!). Use pictures to aid the classification task.
- **Sunflower competition**. Plant sunflower seeds and record growth. Plant different varieties of sunflower seeds and compare results. 'Russian Giant' will usually live up to its name, growing up to 3 metres high!

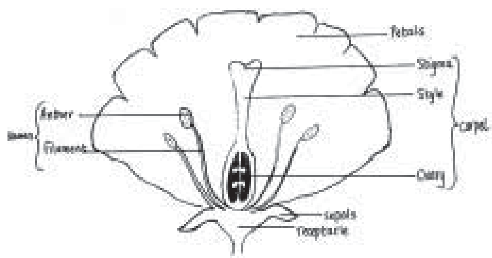
Sunflower: an excellent plant for observing & recording growth

- **Using plants**. Consider ways in which plants are used by humans. Expand with a visit to a local supermarket to look at produce that originates from plants (not only food; what else are plants used for?).
- **Plant shapes and sizes**. Look at the variety of plants growing in the garden and compare their different shapes and sizes, including leaf shapes and types of flower. Encourage the children to think about the 'why?' e.g. Why do the flowers on the apple tree smell sweet? What will happen once the flowers on the bean plant die?

Key stage 2 (ages 7–11)

- **Garden vocabulary.** Discuss definitions of words associated with the garden, e.g. seed, plant, weed, fruit, vegetable. We may think we know what they mean, but do we really? Good one to try in the staffroom!
- **Leaf classification.** Produce a branching key (ICT is an invaluable tool here), using observable features of leaves from plants in the garden. Consideration of how to distinguish between leaves will prove challenging! Adjectives such as rounded, lobed, spiky, saw-toothed edges may help in the process
- **Plant classification.** Extend the leaf classification to consider the range of plants that exists. A simple 4-group system is often helpful, i.e. mosses, ferns, conifers and flowering plants.
- **Life cycles.** Many of the flowers in the garden can be used to observe the male and female reproductive organs and what happens following pollination. Comparisons should be made between different flowers, noting number of stamens, carpels, petals, etc. It would be valuable to record the stages from germination to seed dispersal with the aid of a digital camera.
- **Adaptation.** Consider adaptive features of plants within the garden, e.g. Why does holly have prickles? Why do some plants produce juicy fruits enclosing the seeds where others have dry seed pods?
- **Design a plant.** Children design a new plant complete with adaptations to suit its environment. They could consider pollination and seed dispersal mechanisms (with drawings) or write a short item for a seed catalogue giving instructions for care and maintenance of the plant.
- **Lawn seed trials.** Engage in a series of trials in part of the garden, using lawn seed appropriate for differing situations, e.g. shade, full sun, etc. Small repair packets can be bought to keep the costs low.
- **Using fertiliser.** Extend the usual growth experiments by using differing quantities of fertiliser. Observe the effects and compare with plants not receiving the benefits. Be aware that misconceptions may occur as some fertilisers are termed 'plant food'.

The garden can be used for a multitude of activities. The list is endless, particularly if one starts to consider the wonderful opportunities for cross-curricular work. Perhaps the children could even think of their own creative learning experiences linked to the garden – hand them the National Curriculum and see what happens!



The reproductive parts of a flowering plant

Above all we must ensure that science is exciting, stimulating and taught in such a way that it challenges and inspires children to search for answers. We must capture children's imagination and interest early in their educational career by using contexts that are meaningful and supportive of the learning process: *Informal, non-classroom-based contexts can make an important contribution to learning for pupils studying science. Whether the outcomes are measurable in terms of their contributions to the planned curriculum, or in terms of the development of the individual, their impact is significant and long lasting.* (Braund and Reiss, 2004)

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Kew Gardens' website: http://www.rbgkew.org.uk

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Figure 1 A squishy circuit!

'SQUISHY CIRCUITS' a novel way of teaching electricity – with playdough!

Anne Buckley and **Kim Harvey** *explain how playdough can provide a fun way for children to learn the basics and conduct further enquiries (Issue 135 November 2014)*

The Discovery City Learning Centre is an educational centre in Wirral specialising in technology and science. We have up to four primary school classes visiting every day to undertake workshops that utilise technology in all aspects of the curriculum. We are also fortunate to have a science laboratory that was specifically designed for use by primary school children. Over the last ten years we have used this facility to support many areas of the primary science curriculum, including teaching electricity with 6- and 7-year-olds.

What are 'squishy circuits'?

'Squishy circuits' have been developed by Professor AnnMarie Thomas and her co-workers at the University of St Thomas, Minnesota (see *Websites*). They are simple electrical circuits constructed using a conducting salt dough and an insulating sugar dough, a battery with electrical leads and probes attached, and a component to demonstrate the flow of electricity such as an LED or a 6 V buzzer (Figure 1). The salt dough is significantly more resistive than a metal wire, so low-current LEDs rather than bulbs have to be used. The sugar dough is used to provide an insulating barrier between two blocks of conducting salt dough, so that the children then have to connect the two conducting pieces using the LED.

How do squishy circuits work?

Most commercial and home-made playdoughs are semi-solid ionic materials, that is, material formed between metal atoms that have lost one or more electrons and non-metal atoms that have gained one or more electrons, making them 'charged'. These charged 'atoms' are called

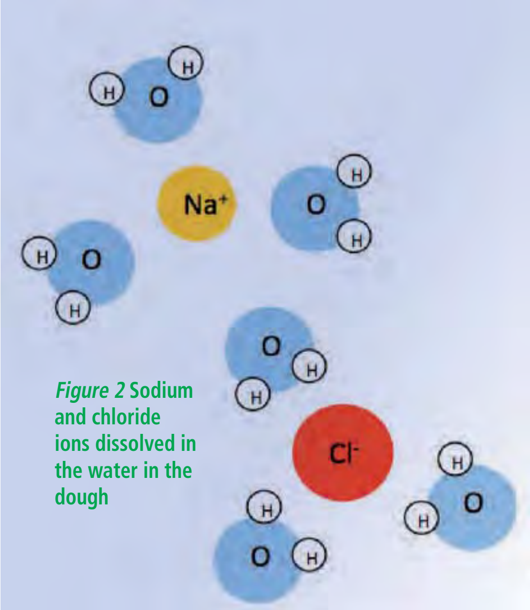


Figure 2 Sodium and chloride ions dissolved in the water in the dough

ions. Salt is an ionic compound consisting of sodium (Na^+) and chloride (Cl^-) ions (Figure 2). The salt dissolved in water within the dough allows the electricity to flow through it because it contains these oppositely charged ions. As mentioned above, the dough is still relatively resistive and so, with a sensible number of batteries, it cannot be used to light filament light bulbs used in conventional school electricity experiments (these typically require 300 mA). However, a range of different-coloured LEDs (light-emitting diodes) are available that can be used under these conditions. Buzzers are also great squishy circuit components, as most need less than 30 mA to operate and add another (noisy) dimension to the circuit!

If you put an LED into some salt dough and stick the two battery leads in it nothing will happen. This is because the electricity goes through the playdough rather than the LED: the dough short-circuits the LED because the electricity would rather flow round the dough than enter the LED (electricity is intrinsically 'lazy' and entering the LED makes it work harder as it has a greater resistance than the dough). To get the LED to light up, the playdough has to be separated into two, with one 'leg' from the LED in each blob of dough, so that it makes a bridge between the dough balls (Figure 3). The electricity is then forced through the LED to complete the circuit. The dough can be separated by air or a small ball of insulating sugar dough. Sugar has to be in the dough because even without salt the dough is slightly conducting. We follow the example of the University of Minnesota group and make our conducting and insulating doughs in different colours.

Why use squishy circuits?

Squishy circuits provide a fun route for children to learn simple ideas about electrical circuits, such as conductivity, and are a novel way to consolidate learning about electricity:

The activities allowed the children to explore circuits independently. (teacher)

Children have had the opportunity to use their circuit skills creatively and embed their understanding further. (teacher)

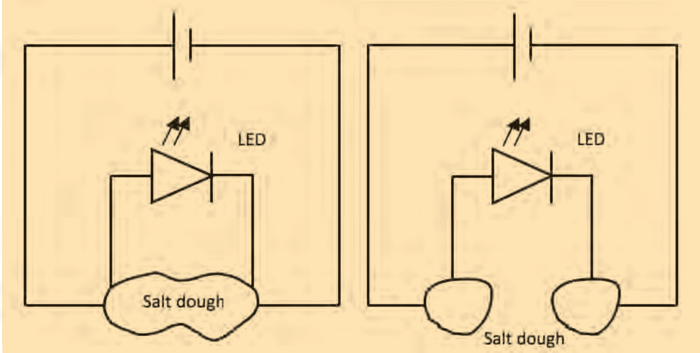
The use of a material they wouldn't normally think of as a conductor immediately grabs the children's attention and starts them asking questions. They have to think carefully about how to get their LED to light up or their buzzer to work and how they can build a particular model and still be able to light the LEDs. This involves examining how the electricity flows through their circuits and why sometimes it does not:

I thought it was really good because I like doing the electricity stuff and making the models. I didn't know you could have electricity in playdough. (child age 7)

My favourite part was using the playdough because the circuit lit up. (child age 6)

This approach provides many opportunities for problem solving and peer discussion.

The properties of the salt and sugar dough give an interesting introduction to conductors and insulators and possibilities for comparing and contrasting. Most of all, this inventive approach encourages the children to be curious and to want to investigate different configurations of the two types of dough and light their LEDs.



Short circuit in squishy circuit; LED does not light up

LED lights up when dough is split

Figure 3 A circuit diagram illustrating how the dough completes a circuit

How do we teach it?

Materials needed for making playdough circuits are listed in Box 1. For the first part of the day we introduce the electricity topic using circuit toys, a giant circuit and simple circuit building using Cambridge Brainbox kits (see *Websites*). This then leads nicely into the idea of conductors and insulators and we discuss the interesting properties of playdough. At this point the children are fascinated to see the playdough '*letting the electricity through it*'. The children start by making a simple squishy circuit using only the conducting salt dough and work out how the dough has to be separated in order to light up the LED. The sugar dough is then introduced as something that can keep the two pieces of salt dough apart because it doesn't conduct electricity. The children then

Box 1 What you will need

- a 9 V battery (although you can use a battery pack of 4 AA batteries)
- battery leads with metal probes attached to each lead (it is not good practice for children to be doing experiments with bare wires!)
- a range of 10 mm LEDs of different colours
- home-made conducting salt dough and insulating sugar dough (coloured differently to salt dough)
- 6 V buzzers
- plastic boards
- playdough cutters
- plastic dough knives

The salt dough and sugar dough are stored in the fridge and can be used many times. The sugar dough can be slightly oily after storage but gentle kneading mixes the oil back into the dough. Eventually the doughs get rather dry or too mixed up and have to be thrown away.

make squishy 'caterpillars' (Figure 4). We often see children experimenting on their own with more than one LED, making series and parallel circuits. Since an LED only allows electricity to flow through it one way, they are continually problem solving to get their LEDs to light up and have to work out where to put the battery leads to get electricity flowing through their circuits.

Once the children have been led through the basics they can then use the dough as a malleable wire that can be moulded into different shapes. We show them some of our squishy creations to give them ideas and then they get on with making their own squishy models. Some children produce a beautiful model out of the salt dough, stick an LED and two leads into it and then put their hand up and say *'It doesn't work'*. We encourage them to work out for themselves what is happening with questions such as:

Is the electricity going through your LED?

Where is the electricity going?

What do you have to do to make the electricity go through your LED?

Most of the time the children manage, without support, to produce some very imaginative squishy circuit models. We have had 'Liverpool Football ground', traffic lights, snowmen, dinosaurs, butterflies and much more (Figure 5).

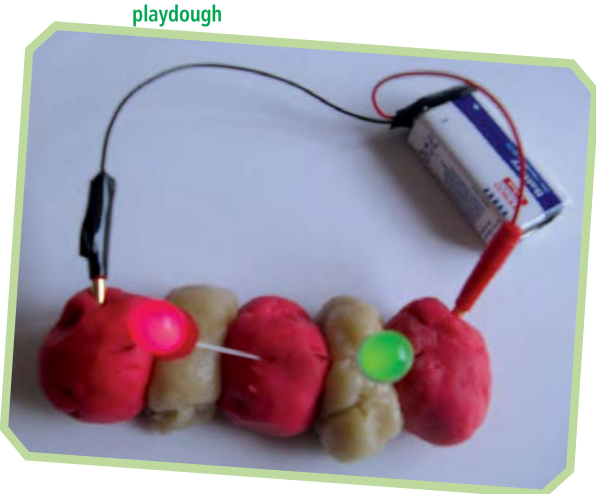


Figure 4 **Making squishy 'caterpillars' with the playdough**

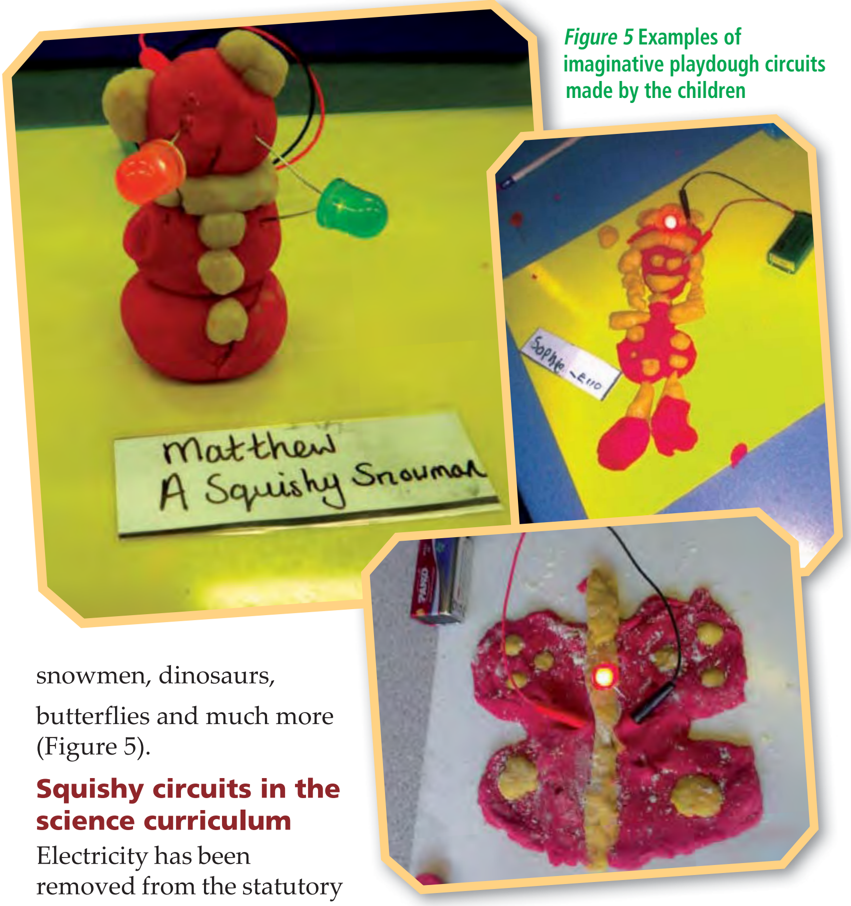


Figure 5 **Examples of imaginative playdough circuits made by the children**

Squishy circuits in the science curriculum

Electricity has been removed from the statutory requirements for year 2 (age 6–7) in England, but it is still in the curriculum and is so in many other countries for primary science. Squishy circuits are a really interesting way of teaching electricity and provide many opportunities for extended investigations, which means you are not limited to using it with 6- and 7- year-olds. For example:

- **Using the dough-making to study materials and irreversible changes.**
- **Making the experiments more quantitative by weighing and measuring different amounts of dough and looking at the brightness of the LEDs in the circuits.**
- **Looking at the effect of salt in the dough on the brightness of the LEDs.**
- **Investigating commercially available doughs.**
- **Challenging the children to make squishy circuit games. One group in Boston has developed** *Rescue Me!*, **a squishy circuits 'operation' type game (see** *Websites*).

This novel way of studying electricity provides numerous opportunities for enquiry and for the children to come up with interesting questions to answer themselves. It is also great fun for the children to use this tactile material that they used in foundation stage to do some serious science!

Next time I teach electricity I will use playdough to reinforce learning or make links to a creative curriculum topic. (teacher)

Websites

Squishy circuits: **http://courseweb.stthomas.edu/apthomas/SquishyCircuits**

http://courseweb.stthomas.edu/apthomas/SquishyCircuits/Publications.htm

http://joshburker.blogspot.com/2012/09/squishy-circuits-operation-game.html

http://fablearn.stanford.edu/fellows/blog/rethinking-squishy-circuits

Cambridge Brain Box Primary Electronics Kit: **www.cambridgebrainbox.com**

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(Issue 123 May 2012)

DRAMATIC SCIENCE AT KEY STAGE 1:

Modelling ideas within an Olympics theme

***Deb McGregor** and **Wendy Precious** share how modelling through drama can engage and activate creative thinking, as well as scientific enquiry skills, in young children*

What is Dramatic Science?

Just imagine … the setting: your classroom; the characters: your children; the scene: your children acting out scientific discoveries, such as how Joseph Shivers, the inventor of Lycra, might have tested various materials for their elasticity or tensile strength.

Dramatic Science is an approach to teaching science that purposely places the children in thought-provoking situations where they need to apply their scientific understanding to decide how to act. Teachers can then apply drama techniques to help children develop and communicate their ideas.

For example, if children were asked to '*Step into the magic bowl full of chocolate and mime how you might move*', they would be required to use their imagination and previous learning experiences. They have to think about what the chocolate might be like as a substance and how that might impact on the way they will move. This kind of activity can be fun as well as revealing! The diverse ways in which children enact stepping through or on chocolate conveys how they personally perceive the properties of the matter. Some see it as a solid and walk gingerly on top; others see it as a liquid that they can swim through; some might wade slowly through it; others cheekily break bits off to eat, while some might scoop it up and lick it off their fingers. Communicating ideas by acting and using their bodies to demonstrate what they think is an active and exciting way to learn science.

Observing children learning in the way described above prompted the Dramatic Science project. Eight dramatic strategies (Box 1) were developed and trialled with ten Staffordshire schools.

Figure 1 (left and right) Children modelling how an 'ice' football might change on a hot day

Thematic development using the strategies

These strategies would not work effectively without being applied in context, so various themes were identified within which the strategies were contextualised. For example, one theme is 'sports', given that the Olympics will be held in London in 2012. Within this theme the children are encouraged to think as competitors and consider what special equipment or clothing they might need and how this is related to the materials used to make them. They are asked to consider various materials, including a piece of Lycra and why it is a good material to use for gymnastics or swimming (because it is flexible, light, etc.). *Spontaneous role-play*, encouraged through a market-place activity, means that the children have to think about properties of various fabrics and which sports they may be useful for. They are also engaged in *miming movement* by enacting playing a match in a hot or cold country and how they have to change their actions as the temperature changes (causing for example, the 'ice' football to melt) (Figure 1).

Box 1 The techniques of Dramatic Science

Within the Dramatic Science project the following eight basic teaching strategies have been developed:

- **On the table** – children apply their senses to develop their observational and questioning skills to explore unusual objects.
- **Spontaneous role-play** – in small groups the children are placed in various situations and have to take on varied roles and discuss contrasting views.
- **Hot seating** – someone is placed in an expert role and answers questions devised by the rest of the class.
- **Mind movies** – visual and auditory information is used to convey a different location (or time) in which children have to consider consequences of happenings and events.
- **Miming movement** – miming what it would be like to be a something or have something happening to them.
- **Freeze frame** – in acting out ideas they are asked to stop and explain their enactment and interpretations of it.
- **Modelling** – acting out what an object is or how something works.
- **Acting out mini historical plays** – enacting aspects of scientists' lives, e.g. Alexander Graham Bell as a child helping his father teach hearing-impaired people and eventually designing a telephone.

Scientifc skills developed through the strategies

A number of different investigational skills, some requiring creative thinking, can be developed through this approach, including observing, describing, questioning, speculating, explaining and communicating ideas.

Observational skills

These are developed directly through the *on the table* approach. The teacher guides the children to look in detail at something dramatic with, for example, a digital microscope such as the Easi-Scope. Tiny details not normally noticed by the naked eye become apparent on a large screen. An object such as an ice hockey helmet can be hidden in a bag. The object is slowly revealed and examined, a part at a time, using the microscope to support the development of

Figure 2 (above) Using the digital microscope to closely observe a mystery object

Figure 3 (right) Modelling how to row a boat made of stone

observation skills (Figure 2). The following questions might be asked to stimulate and encourage the development of observational skills:

What does it look like?

What words describe it?

Why do you think it is like that?

What could it be?

What further information might you need?

What is it similar to? Why?

Open and closed questions can be asked by the teacher to focus observations and to encourage the children to speculate about what it might be and to justify their ideas.

Speculating and posing questions

The *hot seating* technique is a great way to support children in formulating questions. The teacher is introduced as an 'expert', such as an athlete preparing for a sporting competition. The scene is set for the children. For example, they may need to find out what kind of clothing has to be packed (in readiness for a competition) for different sports people. As long as an appropriate purpose or context is given to the children they can relatively easily frame their own questions to ask the expert.

Miming movement, *freeze frame* and *modelling* can also promote speculation, prediction and questioning skills, because often the children need to discuss with each other or find out more information before they can enact certain processes. Modelling how to 'row' (Figure 3) and then altering their 'strokes' or 'position' in the boat when told it is made of materials such as stone, chocolate or sponge can illustrate how children perceive the floating (or sinking) properties of different substances. Just imagine how they will change their actions if mimicking the movements of an Olympic oarsman in a melting chocolate boat!

Composing questions also arises through *spontaneous role-play* as well as *hot seating*. The children can be given particular parts to play in different situations. For example, they may have to discuss and decide how they might change their team's playing tactics in football or netball if the ball were made of wood or ice, or indicate how their ice skating changes as the rink melts (Figure 4).

Communicating ideas

Miming movement, *freeze frame* and *modelling* have been particularly useful to clearly convey what the children are thinking as well as helping them communicate their ideas.

Miming playing rounders and then swapping the ball for one made of a different material, such as jelly or rock, pausing mid-action (with a tap on the shoulder) and explaining why their arm is raised high or they are scooping something off the floor, encourages children to think carefully about how they are moving. The force required to hit the ball and anticipation of how far (and in which direction) the fielder has to move, are all ways in which the children can think more creatively to model their ideas.

Thinking creatively about what might happen and what the possibilities are

Mind movies can provide a useful technique to set up scenarios that could be used as starting points to speculate. Theme sounds and/or music are played while the children close their eyes. They are then asked questions about the soundscape that guide them to think about places they are transported to in their mind. They are invited to consider '*What might happen next?*' or '*What might happen if …*'. For example, what would happen if sporting equipment took on different properties at the 'Olympics', if everything became magnetic, sponge-like, or metallic or everything was made of paper? The adoption of mind movies in this instance can really help develop inspired applications of scientific ideas.

Explaining thinking

Through working as an individual, in pairs or small groups, children are asked to discuss and then enact how different forces move things or reshape things or how temperature can cause substances to change. Being able to show through *miming movement* what happens to objects and materials and then answer reflective questions in the *freeze-frame* phase provides a framework for their thinking. This supports the children in explaining how forces and temperature, for example, affect things. The techniques allow teachers (and children) to identify gaps in their understanding. This can often elicit discussion beyond the usual curricular material. For example, miming getting ready to play a sport with clothing made of wood can focus discussion on the change in forces needed to 'squeeze' into an inflexible swimsuit or the effect of gravity can be considered if wearing a swim hat made of stone! There can also be much talk about how 'swimming' may need to change if the costume is made of sponge!

Thinking about scientists' skills

The use of *mini historical plays* provides an ideal opportunity to consider the skills that scientists use and how scientific ideas are developed over time.

The teacher reads a simple story. During the story, members of the group become the characters in the narrative. They can be given props or parts of costume to wear to signify who they are or a simple line to recite. There could be opportunities in the story for the children to enact a scene or they could offer their reflective thoughts on the events of the story. One such story could be that of Joseph Shivers. He had to create a material that was flexible, supportive (for movie stars wishing to appear slender) and could return back to its original size and shape after wearing. He had to consider the different skills his team possessed to ensure that they experimented successfully to produce this special type of fabric. His interest in sport and being a scientist could be prompted by the narrative and enacted by the whole class or in small groups.

Figure 4 Miming how to catch balls made of different materials

Assessment

Formative assessment is continuous. Each time the children are asked to mime, or respond to questions or create questions, their understanding of the science ideas becomes clear from the way they move or the queries they raise. Teachers reported that it became clear whether the children had 'got it' or had little comprehension of something. One teacher reported:

I think the benefits of using the drama – the techniques are easy to use it's a very effective learning tool and I think it's an effective teaching tool because you can see how children are thinking, where they are in their learning. It's really good as an ongoing assessment tool.

It also supported self-assessment of teacher's understanding, illustrated by this comment from a second teacher:

The torch mime made me realise that I didn't fully understand circuits.

Conclusion

This approach has given children opportunities to develop curiosity, open-mindedness, speaking and listening skills as well as supporting higher-order questioning skills. The drama also provides more than just an art form for learning science: it has proffered insights into children's perceptions about scientific ideas and processes. It has enabled teachers to 'see' what children think. Another teacher explained:

It was really great. It 'opened my eyes' to the multiple possibilities for using drama to explain scientific concepts. For the children the overwhelming response was that it had made science more fun. I was amazed by the details they remembered from activities completed months ago.

The teachers involved in the project have recognised how asking children to 'enact' their ideas can illuminate how complete or otherwise their learners' understandings are. This approach, it appears, has unintentionally provided a fun way to formatively assess children's conceptual grasp of science.

Acknowledgements

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Figure 1 A solid fruit pictogram has a low level of abstraction for children

(Issue 124 Sept 2012)

DEVELOPING CREATIVITY AND ABSTRACTION IN REPRESENTING DATA

*There are many ways to represent data. **Andy South** shares some ideas for doing this and shows how they all relate to the use of symbols, size, colour and position*

The world has entered the 'Information Age' with unprecedented access to data and information. The livelihoods and leisure time of adults are increasingly dependent upon their ability to access and interpret information. Graphic designers, IT wizards and scientists are addressing the problem of how to represent data in simple, accessible and visual ways such that it becomes useful information. We now see more data graphics in our newspapers and on television about everything from sport to climate change to election results. Children will need to develop the skills to interpret information presented in a diversity of ways.

Abstraction

Creating charts and graphs is all about visual abstraction: the process of representing aspects of the data with imagery that can be interpreted by the reader. Children may need help making the link between the 'real' and the image.

This abstraction can be achieved using symbols, size, colour and position. Where the representation is close to what we are representing, abstraction is relatively low; for example, using colours to represent favourite colours or pictures to represent favourite fruit. Abstraction is higher when the size or position of the symbols is used to represent quantities; for example, bars on a chart or points on a graph. These abstractions are not obvious to all children and need to be taught.

Data can be represented using solid objects, paper and computer graphics. To help children develop the skills to understand such abstractions we can challenge them to create and interpret representations in a diversity of ways.

Solid representations

At the lowest level of abstraction, children can use real objects to create a solid pictogram. Because the children are using

Figure 2 A 3D representation could be the next level of abstraction

Figure 3 Using piles of beans to represent bird observations

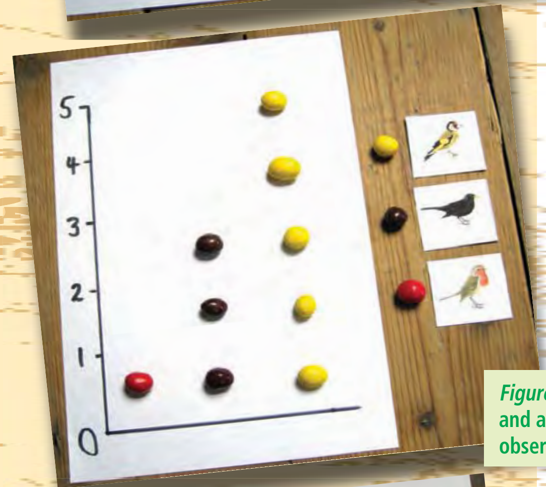


Figure 4 Using coloured sweets and a key in a graph of bird observations

Figure 5 Recording the bird observations as a pictogram

the items themselves to create a chart they can concentrate on the positioning of the objects, which is the abstraction that helps represent the data. You could do this with fruit, different fla oured crisp packets or Smarties. In each case, have a range of items from which children can choose their favourites and use the items themselves to create a pictogram column. You will need enough of each choice for most of the class just in case they all choose the same! Then, after they have chosen, model how they can add their choice to the correct column (Figure 1).

You can increase the abstraction by using different objects to represent the data; for example, record the numbers of different species of bird seen, create axes on a piece of paper, and use pictures of the birds to label columns. The birds aren't 'real', but the children can count out blocks equivalent to the number of each species. Encourage them to position these blocks in the correct columns and they can create a 3D block chart (Figure 2).

If greater numbers of birds were seen you could use smaller objects to represent them, such as beans (Figure 3). Because the beans are placed in piles it is less easy to see exactly how many of each bird they saw. You could ask children how they might want to change this design.

To encourage the use of colour, you could use coloured blocks, counters or even sweets, with different colours representing different species (Figure 4)

In each case, ask the children what the representations show, how they know that and which are their favourites. Encourage them to come up with their own options. Notice how different combinations of symbols, size, positioning and colour help us to identify what the representations show.

Another option is to use the children themselves as the data points. You can create a large pictogram or block chart in which each child stands in a particular column along an *x*-axis. In this case the abstraction is that the children themselves are representing the data by their position. Use a line on the ground in the hall or playground as the *x*-axis and put out labels for categories on pieces of paper along it. This is particularly useful for survey-type investigations, such as favourite animals or birthday months. You could link it into a science investigation, where the children could indicate their prediction beforehand by where they stand, as well as their results afterwards. Take a picture from above and then use it on the whiteboard as a reminder and to compare with more conventional paper charts. In our example of bird observations you could even make bird masks for the children representing the different species seen, thus making the representation less abstract for them.

Paper representations

More conventional paper representations also involve different levels of abstraction. Pictograms are a good first step, being less abstract than bar or block charts (Figure 5).

One way of encouraging children to see how symbols on paper can represent data is to get them to draw around and cut out items to record. I set a year 2 class (ages 6–7) the challenge of discovering what was the most common hand size in the class. The children each cut around and measured an outline of their hand. Then, on a large piece of squared paper with an *x*-axis of numbers in whole centimetres, each child added their hand cut-out to the class pictogram. This provided a good focus for class discussion about what the data showed (which hand sizes were the most common, which were the largest and smallest). By thinking ahead I had asked the boys to cut their hands out in one colour and the girls in another so we could also comment on whether girls or boys had bigger hands (Figure 6).

To make the step from pictograms to bar charts the children were set the task of creating their own bar charts of the class pictogram. Axis templates can help with this abstraction before moving to blank graph paper and giving children the freedom to develop their own creative charts.

Computer representations

Computer representations have the advantage that they can be very quick to create and modify and it is relatively easy to produce very professional looking outputs. The *TES* provides a good collection of activities on data handling (see *Resources*), including tools for creating pictograms of eye colour, snacks and traffic surveys. It divides the resources by age group and includes activities for interpreting graphs as well as creating them. A bar graph generator is provided by Utah State University (see *Resources*). Its strength is that it has few options to set. It allows you to select the number of bars (up to 12) and the height of the *y*-axis (up to 20) and to fill in a label for each column. Bars can be filled by clicking on blocks.

With a few more options, the ITP data handling application (see *Resources*) provides a good introduction to elementary charting. It is easy to input and modify data and plot either a bar or pie chart. It is relatively inflexible in terms of colours and layouts, which for elementary users will be an advantage: not so much to 'play with' and get distracted by (Figure 7)! The ability to switch between bar and pie charts for the same data is a useful feature, as we can ask children about how they know what the pie chart shows and probe for understanding about the role of colour and the size of segments in representing the data.

A further step, with more options, is provided by graphing sites from NCES in the US (see *Resources*). They have a simple (classic) graph generator, where you can choose bar, pie or line charts, that takes you step-by-step through choices, or a more complex version where many options can be set by accessing different tabs (Figure 8).

A new site targeted at adults (chartle.net, see *Resources*) provides even more options, some of which are straightforward enough to be used by older primary children. Similarly, the flexibility of Microsoft *Excel* can make it more difficult for children to get a simple expected result, but once they do it opens up a range of possibilities. The difficulty for the teacher can be in making sure that they have a very straightforward set of instructions to follow that work on the particular version of *Excel* being used, and that they can work out what to do when things go slightly wrong! I found with a class of 7- and 8-year-olds that some children shown how to use *Excel* were very excited to use it on computers at home and bring in their own creations in the following days.

A different way of using size to represent quantities can be demonstrated using *Wordle* (see *Resources*). This is a beautifully simple website that allows you to paste text into a box, and then with one click it will produce a colourful 'word cloud' in which the size of the word is an indication of how frequently it appeared in your text (Figure 9). It is then easy to modify default values specifying fonts, colours and whether common words are ignored. It can be used on fiction texts in literacy lessons and children can produce a visual representation of their own text, explaining how the size of the word relates to how many times they used it. For our example of bird observations, I simply typed each bird name into a word document once for each time it was seen (e.g. blackbird, blackbird, blackbird) and pasted it into the *Wordle* site. You could then ask children to explain how they know that more blackbirds than robins were seen.

All these ideas help children to engage with different ways of displaying scientific information. They encourage children to think about how position, size

Figure 6 A pictogram of children's hands showing the most common size

Figure 7 The ITP data handling application

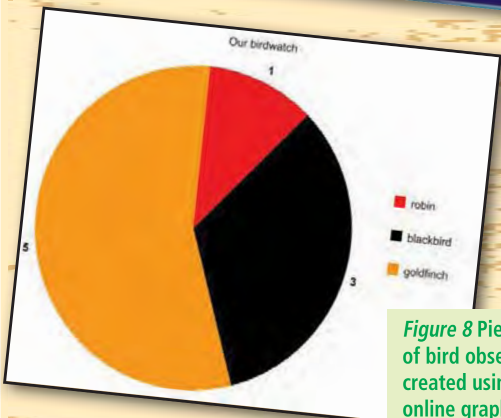
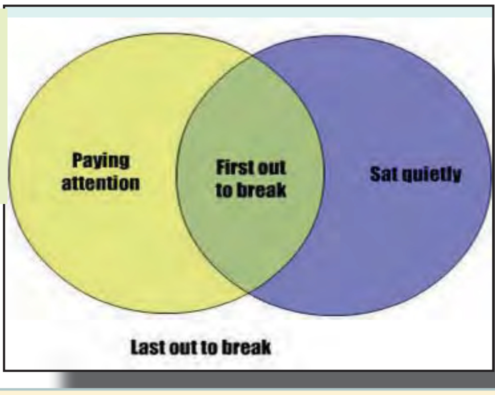


Figure 8 Pie chart of bird observations created using NCES online graph generator

Figure 9 A Wordle 'word cloud' to represent bird observations

Figure 10 Using unusual charts to challenge children's interpretation skills



and colour can be used to represent data. Such skills will be very useful in aiding their presentation and interpretation of scientific and other information, both later in school and outside of it. I would encourage you to challenge your children's creativity in developing ways to display data and then challenge their understanding by asking them to explain what their creations show.

Finally, if you want to make some different charts to challenge their skills of interpretation you could try the *graphjam* website (see *Resources*). Here users create charts (some of wh ich are not suitable for primary child ren) to represent unusual things such as music lyrics. I have used it to create a Venn diagram indicating how children can ensure they are the first out at break time (Figure 10)!

Resources

TES Data handling: **www.tes.co.uk/article.aspx?storycode=6073977**

Utah State University entry-level on-line bar graph generator: **nlvm.usu.edu/en/nav/frames_asid_190_g_1_t_1.html**

ITP Data handling: **webarchive.nationalarchives.gov.uk/20110202093118/http:/nationalstrategies.standards.dcsf.gov.uk/node/47751**

NCES graphing: **nces.ed.gov/nceskids/graphing/classic**

nces.ed.gov/nceskids/createagraph/default.aspx

Chartle: **www.chartle.net/create**

Wordle: **www.wordle.net/**

Graphjam: **app.cheezburger.com/FlashBuilder/GraphJam**

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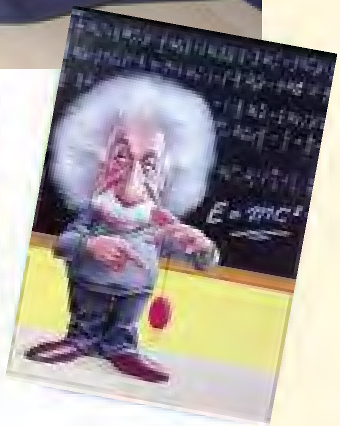
Figure 1 Children absorbed in the 'mixture activity'

STARTING OUT

INSPIRING EINSTEIN MINDS



Jim Beggs, Colette Murphy** and **Karen Kerr

describe a project focused on using creativity to inspire teachers and children

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It is the supreme art of the teacher to awaken joy in creative expression and knowledge. (Albert Einstein)

The project

The New Approaches to Primary Science Teaching and Assessment (NAPSTA) project, funded by the AstraZeneca Science Teaching Trust, was set up to empower teachers and student teachers '*to awaken [children's] joy in creative expression and knowledge*' in their science learning. Our inspiration came from sessions we had attended at various Association for Science Education conferences, when we ourselves were awed by the 'Curious about Science' presentations delivered by Sweden's Hans Persson and by the 'Puppets' workshops of Brenda Keogh and Stuart Naylor. The focus of the project was to use creativity as the key to inspiring science teaching.

We hoped that, through attending a specific series of workshops, teachers would be as inspired as ourselves and use the ideas to awaken and sustain children's interest and engagement in science (Figure 1). This proved to be the case, and in a 'Celebration of Creative Science' event held in Queen's University, teachers, student teachers and children from the

15 participating schools presented and discussed some of their scientific creativity. The teacher educators, advisers, policy-makers and curriculum developers in attendance were delighted with the presentations. They are now going to take forward some of the ideas from this project to inform teaching of 'The World Around Us', the learning area comprising primary science, history and geography in the Northern Ireland Revised Curriculum (CCEA, 2007a).

Fortunately, the revised curriculum promotes creative, thought-provoking and practical science work and the use of assessment for learning (AfL). It also includes cross-curricular skills (e.g. communication, using mathematics, ICT) and the Thinking Skills and Personal Capabilities (TSPC) Framework across various areas of learning, which is summarised in Figure 2.

Why Einstein minds? Perhaps the following quotes will help explain our thinking:

Most of the fundamental ideas of science are essentially simple, and may, as a rule, be expressed in a language comprehensible to everyone. (Albert Einstein)

The whole of science is nothing more than a refinement of everyday thinking. (Albert Einstein)

Figure 2 A summary of the Northern Ireland Revised Curriculum *Thinking Skills and Personal Capabilities Framework* (CCEA, 2007b)

Figure 3 (below) What is causing the coloured water to run clear?

Figure 4 A child's drawing of her ideas on how a wind-up car works

Curious about Science

The 'Curious about Science' presentations we saw from Hans Persson (Stockholm Institute of Education) at an ASE Annual Conference, led to him presenting a series of workshops for our project. His workshop activities were designed to help teachers to:

- encourage children to think and communicate their ideas as a way of introducing science;
- raise questions that lead to investigations;
- show children that we are interested in their ideas;
- be open-minded with no right or wrong answers;
- help make abstract ideas concrete.

He criticised 'traditional' school science by explaining that a lot of it is unfamiliar and separated from the real world. The activities that he demonstrated were in everyday language and used basic equipment. The activities were later carried out by children during science lessons. By far the favourite activity for the children in class was the 'magic' bucket (for this and other activities see Persson, 2006).

The 'magic' bucket

Hans poured coloured water (green followed by red) into the bucket and colourless, transparent liquid came out of the tube at the front! The teachers were invited to draw what they thought was going on inside the bucket to cause this colour change. Back in school the children presented several ideas about what they thought was inside the bucket (Figure 3). One class made 'concept cartoons' to present their ideas.

Many schools carried out their own, novel interpretations of the activities presented in the workshops. For example, a class of 8–9 year-olds was working on the topic of 'toys and materials'. The approach was applied to a wind-up toy, as they were asked to draw what they thought was going on inside it. Figure 4 shows one child's drawing of her ideas. During this topic the children were also involved in activities relevant to the TSPC framework.

The mixture

This activity involved pouring water, cooking oil and syrup into a beaker and predicting what might happen as each liquid was added to the beaker (Figure 1). Children had great fun and voiced highly imaginative ideas to explain why the liquids did not mix, the '*order*' of the liquids in the beaker, and how the liquids '*moved*' to allow another liquid to '*go underneath*'.

The ice balloon

This activity demonstrated how we can encourage children to think creatively. An ice balloon is simply placed on the table. Children start to explore its properties and devise their own experiments:

Usually our science lessons are very structured and you sort of take the children along step by step but we decided, right, we are going to let these use their own creativity. (Y5 (9–10 year-olds) teacher)

Using puppets

As well as encouraging use of creative activities with the children, the project introduced teachers and student teachers to creative ways of delivering science lessons. Among others, the use of puppets to teach science received very positive feedback (Figure 5). Teachers observed that the puppets were an excellent resource for facilitating 'thinking skills'. In particular, they were great for introducing topics in science and during questioning as some puppets were 'forgetful' and needed reminding of things (Figure 6). One teacher said that it was a good idea to get the puppet to ask the first question to encourage the children. Teachers also commented on how effective puppets were with regard to classroom management (e.g. demonstrating 'silly' behaviour) and during circle time.

Assessment for lear ning

Another important aim of the NAPSTA project was to promote assessment for learning (AfL). For example, many classes used the 'two stars and a wish' AfL strategy, which involves children writing about two aspects of their work that they felt were good, and then adding something that they wish they had done better. With respect to peer assessment, each child commented on which piece of work they liked best in the class and why.

Figure 7 shows an excellent example of peer assessment. The children in a class of 5–7 year-olds made a patchwork quilt to show all the different science activities they carried out. The children in the class are holding their quilt up for older children to look at while the child with the microphone explains how he made his section of the quilt. The older children then said what they thought about the quilt. It is also interesting to see (Figure 7) that a puppet also assessed the children's work – another great example of the creative use of puppets in science throughout this project.

The World Around Us

Throughout the various workshops emphasis was placed on the links between history, geography and science. For example, one workshop incorporated lots of stories and 'curiosities' about science in the past, scientists, their work and how things were discovered. Hans talked about a range of topics including accidental discoveries, Greek philosophers, air and the fear of vacuum, magnetism, and Galvani and the jumping frog legs. The participants also took part in a drama to demonstrate how the electric motor works.

One class of 9–10 year-olds addressed science/history/geography links through a topic called 'The Blue Planet'. The children carried out numerous activities including the history of a thermometer, experiments with ice and water balloons, flooding in Bangladesh, and studies of animals that live near and in water. Interviews with children showed how much they valued learning in this cross-curricular way.

Figure 5 A teacher and student teacher learn how to use the puppets at a workshop

Figure 6 A student teacher using the forgetful 'Nana' puppet to teach solids, liquids and gases

Figure 7 Peer assessment in action – a class present their work to older children

Student teachers

Throughout the project teachers and student teachers taught their science lessons together, implementing the ideas from the workshops, with positive results for all student teachers and the children:

The class teacher and I were able to work in partnership to be creative in each lesson and the pupils enjoyed having support and guidance from both teachers. They knew when we were coteaching science that they were able to go to [the teacher] or go to myself for help. (4th year BEd student)

(See Murphy, Beggs, Carlisle and Greenwood (2004) and the azteachscience website (below) for further details on coteaching.)

Reflections

Many teachers commented on the change in their teaching approaches as a result of their involvement in the NAPSTA project. In particular, they talked about a move away from 'traditional' teaching to a shared ownership of lessons:

They [the children] were driving it and they were just really enjoying having that sort of control and we were just really stepping back and maybe just trying to give them little bits of direction but it was really driven by them and they just loved it. (teacher of 6–7 year-olds)

They had ownership of everything and it certainly taught us how to change our minds on teaching science. (teacher of 9–10 year-olds)

As well as talking about the children's enjoyment and the benefits of a shared approach to science, the teachers also talked about their own enjoyment and how it made them think about their science lessons:

We really enjoyed it because it made us think about our approach too. (teacher of 9–10 year-olds)

It was really interesting for us as well. (teacher of 7–8 year-olds)

We end with a final quote from Einstein, which we used to inspire our thinking in this project:

The process of scientific discovery is, in effect, a continual flight from wonder.
(Albert Einstein)

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Persson, H. (2006) *Science plus reactions! Teacher's books years 1–2 (P2–3); years 3–4 (P4–5); years 5–6 (P6–7)*. Oxford: Heinemann.

Websites

Coteaching – A continuing professional development unit:
www.azteachscience.co.uk/resources/cpd/coteaching.aspx

Hans Persson:
www.hanper.se/

Puppets project:
www.puppetsproject.com/meetthepuppets.html

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