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Teaching ideas and Evidence in Science: Case studies of classroom practice

Keith S. Taber, with Tom de Trafford, Martin Koch, Tamsin Lowe, Susan Millins and Teresa Quail.

The trainee teachers involved in the Cambridge project were asked to think about the teaching of ideas and evidence in science during their work on professional placement. They were invited to apply their understanding of this area of teaching whilst they worked in partner schools, supported by experienced mentors and other science teachers. Five of the (then) trainee teachers made presentations to audiences of experienced teachers – shearing their experiences of starting to find ways to teach about *ideas and evidence in science*.

Outlines of the five case studies are reproduced here (and in more detail in other files on the CDROM). There are not presented as exemplars to be followed, but rather they are designed to show how new teachers (with appropriate support from more experienced colleagues in their schools) were able to incorporate *teaching about ideas and evidence in science* into their classroom work.

Perhaps some experienced teachers, those with particular strengths in teaching about ideas and evidence, may find little that is new or innovative in these cases. However, they do demonstrate that

- teaching about ideas and evidence in science need not be the preserve of the most experienced, accomplished science teachers;
- teaching about aspects of ideas and evidence in science does not mean moving outside the normal curriculum, but can be incorporated in existing schemes of work.

These case studies show what able and enthusiastic, although very inexperienced, trainee teachers were able to achieve within the constraints of a professional teaching placement.

Teaching Electricity at Y7 – Tom de Trafford

Tom de Trafford was training as a secondary science teacher with a physics specialism. He undertook his project work whilst on professional placement at Fearnhill School in Letchworth. He was supported by Jon Dunning (mentor, and Head of Faculty) and Linsey Cushion (Mentor and Class Teacher).

Tom worked with a Y7 group (nominally a 'middle' set) studying electricity. Tom's project examined how *practical work* and the *use of models and analogies* influenced the way pupils construct their own understanding of the concepts that they are studying. He looked at how the use of physical evidence is combined with external ideas to give the pupils the basis to form their own personal models of science.

Tom's taught the group over a sequence of 9 lessons that introduced a range of concepts and practical skills. The pupils modelled the electrical circuits they studied through their practical work in terms of a range of analogies, metaphors and mental images. In particular Tom had pupils try to think about the electrical circuits from an electron's perspective.

He found pupils remembered these ideas, and were able to apply these simple models to typical electricity questions. The used such ideas as a lamp having "one battery to itself" being brighter than when two lamps were powered by (or 'sharing') the same battery. They talked of resistance in terms of electrons 'bumping' into things, or having to 'squeeze' through wires, and considered how 'tired' electrons would be in different circuits!

As Tom comments "This model involves personalising the electrons and then focusing on the experience they (i.e. the electrons) have in completing the circuit."

Pupils considered batteries to be like pumps and to act as the 'source' for an electrical circuit.

Personification is a very common mode of thinking in both science itself and among science classes. Scientists have sometimes developed their ideas by thinking of entities such as electrons as if they were human. Of course, it is important to realise that such thinking can also, often, lead us astray. Any kind of model is a simplification, and all analogies are imperfect comparisons, so we have to teach pupils to use these 'thinking aids' carefully, and to remind themselves that they are only ways to help us think about the science.

Tom was aware of this, and of the danger of some of the ideas pupils used channelling their thinking in unintended directions,

> Most of these ideas [pupils used] allow for the concept of the electrons loosing energy or having to do some work in moving through the resistance. … one however shows the danger of students thinking about a substance called electricity, which somehow goes into the bulb. This model is likely to lead to problems and is unlikely to be much help with answering even the simple questions a year seven student will encounter.

It has been suggested that learners' use of personification can be of two types (Taber & Watts, 1996). Metaphoric use allows pupils to get a 'mental foothold' on an abstract concept – it provides a 'way in' to thinking about a new scientific idea. However, the use of such language can become habitual, and may then stand in the way of developing deeper understanding. As Tom points out,

> "the use of carefully constructed analogies is a powerful tool in developing understanding, but it is critical to asses the understanding and be careful to avoid developing any new misconceptions."

The teacher's role then is to fist provide a way of anchoring new concepts on what pupils find familiar, but then - once pupils are confident that they can make some sense of the new ideas - to help them progress on towards the more scientific language and thinking. Judging when pupils are ready to make such transitions is of course a key part of the science teacher's professional skill.

Tom reported that,

> "the work carried out for this project has allowed me to look far more at the way in which a pupil is interpreting their science lessons and not just at what they are being told. In asking pupils 'why?' they have given a specific answer to a question, it is possible to learn a huge amount about the way in which they learn and the range of misconceptions they have picked up in the process."

Tom found the approach of allowing pupils to develop their own mental models was helpful for both pupils and teacher:

> "it is useful to give them a chance to tell you more about their understanding of a phenomenon than they can be answering a simple closed question. Allowing pupils to develop their ideas and describe them is useful both for them in formulating these ideas, and for the teacher in understanding [their thinking about a topic]"

So Tom found focussing on the modelling process very helpful in his teaching. In an important way his science teaching was authentic, reflect the way scientists develop models to understand and explain phenomena. Making the modelling process explicit should help his pupils both understand the science, and the nature of science.

A fuller report of Tom's work, and the questionnaire he used with his class, is included on the CDROM.

Teaching the Solar System at Y7 – Tamsin Lowe

Tamsin Lowe was training as a secondary science teacher with a biology specialism. She undertook work while on professional placement at King Edward VII School, King's Lynn. She worked with a mixed-ability Y7, supported by Stephanie Wells (mentor) and Greg Reid (class teacher). The class were learning about aspects of the solar system. She used this context to develop pupils' understanding of scientific models.

A curriculum model represents *target* knowledge and understanding, and the teacher has the role of transforming such a curriculum model into something suitable for their particular class. Tamsin's approach exemplifies this well.

Tamsin started by producing a 'pupil-friendly' curriculum model, aimed at Year 7 pupils ('what is science all about?' - see Box 1). She then probed prior understanding of the nature of science. Tamsin produced a pupil-friendly version of the type of questionnaire that the trainees had previously used to interview pupils (see *Exploring the Curriculum Model for teaching about the Nature of Science*, also included on the CDROM) but more suitable for eliciting written reponses. Tamsin found that the pupils' understanding of the scientific model was particularly out of line with the target knowledge she had identified. She therefore decided to focus her teaching on this aspect of 'ideas and evidence'.

Over two 70 minutes lessons, Tamsin set out to teach about models in science through the context of the topic of the solar system (National Curriculum for Science, KS3, Sc4, objectives 4a-c, DfEE & QCA, 1999).

Prior to the first lesson, Tamsin gave the pupils a worksheet to probe their prior knowledge about the solar system, and this showed that most of the group had a good understanding of the topics taught at KS2. She used the first lesson to consolidate learning for weaker pupils, and to apply teaching about scientific models to concepts with which most of the pupils were confident.

What is Science All About?

Theory
A theory is a way of explaining the relationship between different things, using scientific information that we already have. A useful theory must allow us to make predictions that we can then test.
Scientific theories should be as simple as possible.
No matter how much evidence supports a theory, scientists always realise that other experiments/observations later on might mean that the theory needs to be improved or changed completely.

Observation
An observation is what scientists see, hear, smell, touch or taste when they are looking for evidence. Sometimes, this involves observing nature eg. just watching what happens, and making notes or taking measurements. Sometimes this means taking down the results of an experiment.

Experiment
An experiment is when the scientist sets up the conditions for an observation. This often gives much better evidence than you get from just observing (watching) nature, because you can control the variables and make it a fair test.
Before scientists can carry out an experiment to see if there is a relationship between two or more variables, they must already have an idea of what the relationship might be. An idea that has not yet been tested is called a hypothesis (an intelligent guess).

Evidence
The evidence that scientists need to back-up their theories is simply the results of their observations or experiments. Very often, the evidence that scientists get from their investigations suggests that the original theory was wrong. The theory then needs to be improved, or changed completely.

Model
Nature is extremely complicated. Scientists create models to help them understand difficult ideas. A model is simpler that the real thing, but shows how some part of it works. Models can be physical (scale models), mathematical (equations), graphical (drawings, graphs, flow-charts), or even an analogy (saying how something is like something else). Because the model is much simpler than the real thing we have to remember that what we learn from the model may not always give us good information about the real thing.

Box 1: A pupil friendly Nature of Science (Tamsin Lowe)

A key aspect of Tamsin's work was that she made the nature of model and modelling explicit in her teaching:

> I began the first lesson by defining what a scientific model is, and then used a series of 'models' relating to the concept of day and night. For each model, I asked pupils to explain (either verbally or in writing) 1) what the model was, 2) what it showed, 3) what its limitations were and 4) how it could be improved to make it more realistic. I then asked pupils to come up with their own models to explain why we get different seasons, and to assess the strengths and weaknesses of the suggest models. I also asked if they could improve a suggested model to make it more realistic.

Tamsin continued this approach into her second lesson,

> During lesson 2, I combined teaching about why we have different seasons with reinforcing learning about scientific models. I showed pupils two models to explain why we get different seasons and asked them to compare how good the two models were.

One important feature of the approach was to look at the limitations of models, and to allow pupils to realise that al models break down at some point:

> This teaching was intended to familiarise pupils with the concept of a scientific model, and to enable them to critically evaluate models that are commonly used, as well as suggesting and critically evaluating their own models, Pupils were also encouraged to suggest improvements to existing models, and explain why it is necessary to use models which are not perfect reflections of the systems they are designed to explain.

One of the limitations of this particular case was that the time available for working on the topic did not allow the ideas to be carefully introduced, and then reinforced over time so that learning can become consolidated. This is important in an area (like models) where many pupil already have quite fixed understandings of what the term means. KS3 pupils will often limit the meaning of models to physical replicas,

> The pupils found it very difficult during lesson one to overcome their misapprehension that a model is a physical scale-version of a physical object or set of objects. For example, when asked 'What is the model?' after considering the first model of day and night shown during the first lesson, the majority of pupils answered that it was a plastic globe. After talking about different types of model however, most pupils refined their understanding.

This is illustrated by the written work of one of the middle-ability pupils in the group. After the first lesson this pupil described the model to demonstrate day and night as "a syther [sphere] made from plastic, its called a globe in a dark room with a light shinning on it". The globe was seen as the model, which was then placed in a room and illuminated. Although the globe was meant to stand for the earth, it was only one component of the teaching model. Two days later when describing the modelling of the seasons, the same pupil wrote,

> "The model was a dark room, with a light bulb and a plastic globe. We placed the light bulb onto a flat surface, then we rotated the globe around the bulb and spinned it around too."

The 'solar system' topic provides a very good context for explicitly exploring the nature of models and modelling in science – but it would be very important for a teacher taking this approach to follow up on the key ideas about models in a variety of other contexts in subsequent topics if new understanding is to become robust. Notwithstanding this caveat, Tamsin's class came to hear and use the term 'model' extensively in these science lessons, so it was well on the way to becoming part of their scientific vocabulary. Moreover, their understanding of what is meant by a model in science progressed.

Tasmsin had been alerted to the likely limitations in pupils' appreciation of the nature of scientific models through interviewing KS3 pupils about key terms (see *Exploring the Curriculum Model for teaching about the Nature of Science*, also included on the CDROM), but she was still surprised by how pupils' preconceived ideas about *what a model is* were so resistant to change. Through her teaching, though, many of the class were able "to accept a model even though it has obvious limitations since often, the more realistic a model becomes, the more complicated it is to understand".

In terms of her own professional development, Tamsin reported that,

> "The teaching also allowed me to develop my own model of how the nature of Science should be taught to KS3 pupils [in order to meet] part of the Sc1 objectives."

The most important conclusion Tamsin drew from this aspect of her professional placements was that "pupils of all abilities are able to learn and understand about the nature of a scientific model, in their first year of KS3".

A fuller report of Tamsin's work, including her prior knowledge probes and outlines of the two lessons, is included on the CDROM.

Teaching Light at Y8 – Susan Millins

Susan Millins was training as a teacher at KS2 and KS3, as a science specialist. The work discussed here was undertaken whilst she was on professional placement at College Heath Middle School, Mildenhall. She worked with a Y8 group, and was supported by Alan Roberts (Head of Science). She focused on *extension work* for a small group of more able pupils in the mixed ability group.

Susan set the group a task to identify which fast food outlet were diluting drinks – requiring the pupils to apply the conceptual knowledge they had been taught in an unfamiliar practical context. Susan aimed to give these pupils more autonomy (something recommended in providing provision for the more able in science) and asked them to design, carry out, and develop, an appropriate practical way of comparing different strengths of drinks using colorimetric analysis (incorporating the use of ICT in the form of a datalogger). This was an activity that Susan felt required pupils to extend their thinking beyond the QCA scheme of work and allowed them to apply and further the knowledge they should already have acquired.

This type of investigation is familiar from the assessed practical work undertaken for Sc1. In this case Susan wanted pupils to have the opportunity to use data-logging with the colorimeter, and so directed them to predict how colour would be influenced by dilution:

> "If the squash is stronger the light reading will be lower because less light will come through. Because it will be harder for the light to filter through dark liquids"

> "I think there won't be as much light if the squash is stronger than if it were thicker because it will be thicker and won't pass through so easily. The light will be absorbed more if it's stronger"

The practical work gave pupils the opportunity to test their predictions, and see if they could collect *evidence* to support their *ideas*.

Had Susan had more time for this activity, she could have taken advantage of the more open-ended nature of the brief, by also allowing pupils to follow up their own alternative suggestion for investigating the squashes,

> "Do an acid test to see how much citric acid each one contains to give the sharp tangy flavour. The one closest to being an alkali or being neutral is the weakest and

> the one closest to acid is the strongest. The one closest to alkali is the one cheating their customers"

This is a very creditable suggestion, drawing upon science knowledge. Of course, citric acid is not a strong acid, and other ingredients in the squashes could well negate any difference in concentration of the acid, so it is quite possible this would give a different result to the colorimetric tests. That could have led into a more rigorous consideration of the nature of measurement, and the status of evidence in science – but perhaps Susan was wise not to introduce such potential complications at this stage!

Susan reported that pupils enjoyed the opportunity to work at their own pace and being chosen for this activity. They were also pleased with the opportunity to use the computer to produce graphs and collect data.

In terms of her own professional development, Susan reported that

> "participation in this project allowed me to focus in on a group of more able pupils and learn more about strategies to extend gifted and talented pupils".

She concluded that the type of practical extension activity employed produce a range of benefits, i.e.

- it extends and challenges more able within class
- it consolidates learning about concepts in the topic of light
- it encourages thinking and investigative skills
- it requires pupils to apply theoretical knowledge to a practical task
- it is synoptic: drawing together information from across the entire topic
- and it gives pupils more autonomy and ownership of their own learning

Whilst this last point is of particular significance when working with the most able, it is also a key aim for much current innovation in Education (e.g. Arnot et al, 2004).

A fuller report of Susan's work, including the brief for the activity, is included on the CDROM.

Teaching Forces at Y8 – Martin Koch

Martin Koch was training as a secondary science teacher with a physics specialism. The work described here was undertaken while he was on professional placement at Deacon's School, Peterborough, working with a Y8 class. He was supported by Richard Worsey (mentor), Gareth Burley (class teacher) and Zulfikar Sayeed (school Gifted and Talented Coordinator).

Martin focussed on tasks designed to develop 'higher level' thinking skills, including modified CASE (*Cognitive Acceleration through Science Education* – Adey & Shayer, 1994) tasks. The topics were related to 'forces' – i.e. moments and pressure.

His aim was to engage more able pupils in challenging thinking, e.g. by letting them apply previous knowledge in a different context. Two tasks involved the introduction to new topics (moments, pressure), and an investigation based around the practical application of a principle (moments). Instead of presenting the pupils with facts (rote learning), they had to develop their own ideas and find laws. Daily life experience had to be related to the new science concepts, and formulating their findings mathematically provided an extra step of abstraction. Martin was guided by the notions of higher level thinking skills in terms of 'Bloom's taxonomy' (Anderson & Krathwohl, 2001).

Martin reports that this in this Y8 top set the pupils *did* demonstrate higher level thinking skills, and that they reported that – once they had gained confidence that they could deal with the new type of demand - they liked their thinking to be challenged.

Martin concluded that the pupils were not used to higher level thinking tasks. He found that initially they showed some resistance, but that once they realised that they were capable of success on the tasks, they gained confidence. In terms of his own professional development Martin found it

> "helpful to gain experience with higher level thinking skills exercises and pupils' responses to it. It increased my awareness of gauging the challenge at the right level."

A key feature of Martin's approach was the use of pupil predictions, that could then be tested out. The well-known POE (predict-observe-explain) teaching approach is a useful way to get pupils to think about ideas and evidence in science. Asking pupils to make predictions can be a very valuable starting point, especially with less able or younger pupils, Most pupils are able to make predictions that can be tested, *even when they are unable to verbalise their thinking* (which may often be tacit).

This is especially useful when predictions are found to be incorrect, as this often acts as additional motivation to make sense of phenomena. By asking pupils to predict answers before carrying out activities, Martin provided pupils with a personal interest in the evidence to be collected, and a strong impetus to explain any aberrant findings.

A fuller report of Martin's work, including the tasks set and examples of pupils' work, is included on the CDROM.

Teaching Electricity at Y9 – Teresa Quail

Teresa Quail was training as a secondary science teacher with a physics specialism. She undertook the work described here while on professional placement at Jack Hunt School, Peterborough. She worked with a Y9 class learning about electricity and was supported by Stuart Kilby (Mentor) and Hannah Perry (Class Teacher).

Teresa's project considered three aspects of the nature of science – empirical work and the use of models and analogies. She considered how teaching strategies (practical work, the use of models and analogies) can help identify and correct pupils' misconceptions (analogous to the way science develops through the interplay of experimental and theoretical work).

In particular, like Tom, Teresa asked pupils to imagine electrical phenomena from the perspective on an electron,

> "The 'imagine you are an electron' written activity focused on what the students understand, the model answer provided an opportunity for the students to evaluate (and modify) their work as well as their level of understanding and how they have constructed their ideas to be analysed."

Asking pupils to transform material presented in class through creative writing makes them actively think about the ideas, especially if they are asked to work key points into their stories,

> "My name is Adina the electron. Me and my friends had a race around the circuit, at half way we were all still together and we all finished the race at the same time. The battery gives us more energy to go all the way round the circuit. The only time we stop is when the batteries [sic] energy is taken away."

> "…I also meet up with my big group of friends called currents…"

Imaginative writing tasks also provide a way for the teacher to see how pupils are conceptualising key ideas, and so diagnose misconceptions:

> "I go around the circuit. I am walking when I stop at the batteries, they give me energy. Then I carry on around the circuit walking then I'm stopped again by a light bulb…"
>
> "…I started flowing through a wire with lots of negative energy, I felt really funny, As I got faster & faster I started to feel hot and tired, I was getting transformed into light + heat energy…I got slower and slower until I hit the end of the battery…"
>
> "I am an electron. I am stored in a battery. When I am needed, my power is turned on and I become negatively charged…If there is a break in the circuit, I stop. However, if the circuit is complete, I flow through the wire and stay charged…"

This approach reflects Martin's (above) in the way pupils produced something (predictions, or a piece of creative writing) reflecting their existing thinking, which *they* then compared to a 'standard' (empirical testing in Martin's project, or in Teresa's case a model answer telling the journey of Eddie the electron),

> "In my description I wrote electrons start from the battery as they get the energy from there but in Eddie's Journey it says electrons usually live in atoms…in metals (which are used in electrical circuits) an electron from each atom is free to move within the metal."

Teresa designed her sequence of lessons with a view to:

- Set more challenging inventive tasks;
- Use plenty of open questions, and set open-ended tasks;
- Provide opportunities that develop thinking skills: observation, exploration, comparison, classification, imagination, prediction, critical thinking, interpretation, summarizing, reflection and evaluation;
- Give the pupils a chance to plan, select, analyse and discuss their own work;
- Use a wider range of curriculum materials from later key stages as an extension to develop deeper understanding.

Teresa reported that she felt the approach taken had benefited all pupils in the topic of electricity. In terms of her own development as a teacher, Teresa found that involvement in the project made her look very closely at what degree of conceptual development can be expected in a few lessons when teaching such an abstract topic. It also made her think abut the nature of the subject matter in considerable depth. In particular she reflected that she would,

> "continue to use the inverted Bloom structure (i.e. focus on 'higher level thinking skills') as I feel that all the pupils benefited at differentiated levels more than a focus on the lower level thinking skills could encourage."

A fuller report of Teresa's work, including an outline of the lesson sequence, is included on the CDROM.

Learning from the Case Studies

The work described here reflects how five trainee teachers chose to approach teaching about the nature of ideas and evidence in science with their KS3 classes. Each of these teachers (trainees then, working as qualified teachers now) found a way to address the 'ideas and evidence' strand of Sc1 within the context of their professional placement school, and their assigned timetable.

The approaches chosen were channelled and constrained by both their personal theories and beliefs about teaching science (hopefully somewhat influenced by Faculty teaching!), and the training context (school, department, timetable, approaches favoured and modelled by mentors and other staff, schemes of work and particular classes). In different schools, with different mentors, classes and topics, the same group of trainees may have worked differently. Had different trainees been placed in the same professional contexts of school, class and topic, they might well also have gone about things differently. This is important, as effective teaching is often about matching between teaching style to the needs of particular pupils, and no resource for teachers (such as this one) will be useful if it is too prescriptive.

It is also important to note than none of the lesson activities reported here are in themselves innovative. Investigations using ICT, creative writing, CASE based activities, applying Bloom's taxonomy, etc., are all part of the science teacher's normal repertoire.

The important point here is that these relatively inexperienced teachers were thinking about how to relate the 'ideas and evidence' strand of Sc1 to the scheme of work, and so integrate learning *about* science with learning some science.

At first sight Martin's contribution may seem to have more to do with the scientific investigation strand of Sc1 than with ideas and evidence. Yet all of classroom practice reported here includes 'practical work' of one kind or another. It is no coincidence that both Tom and Teresa (working with electrical ideas at either end of KS3) decided to use a combination of practical work alongside models, analogies and metaphors. Susan's work had the form of an investigation. There are different types of practical work in science teaching, for different purposes (Kind and Taber, 2005), but whether the practical is an authentic investigation, demonstrating a principle, checking a prediction or measuring the value of some variable, most genuine practical work involves collecting some sort of evidence. The evidence only has meaning in the context of the ideas we use to interrogate it. Thus 'ideas and evidence' is always an *implicit* part of the context for practical work in a school context.

In Tamsin's teaching the practical work involved demonstrating models of how night and day, and the seasons, come about. The connection with the 'ideas and evidence' strand is obvious in this case. The practical work presented as part of the electricity lessons would seem to be standard circuit work – with Tom's Y7 groups finding out the effect of connecting different numbers of lamps and cells (batteries) into circuits. Most science topics, and certainly most practical work, provide ready contexts for teaching and learning about the nature of science – about the role of ideas and evidence in science. Often, however, the lesson *aims* concern concept attainment or fair testing. The nature of science is *implicit* for the teacher – and so often probably *invisible* for the pupil!

What makes these case studies informative in the context of the present resource *is that the trainee teachers were explicit in their thinking and planning about how the lesson episodes would provide contexts for teaching about ideas and evidence in science*. Because of this, the teaching objectives were tied to 'ideas and evidence', and this aspect of the work became visible for the pupils. In particular, the nature and limitations of models presented in class (by teacher or pupils) was made explicit (see Tamsin's case study) so that pupils were able to judge partial models as useful but not absolute.

When we teach that science is a process of developing better matches between our ideas and nature, and so showing that imperfect ideas can still be a useful part of making progress, we in effect give pupils permission to 'be wrong with credit'. We create an environment where playing with ideas – trying them out for fit - is seen as not only acceptable, but a key part of how science works. In this type of learning environment, asking pupils to take some responsibility for their own learning by comparing their own work with model answers can be a useful (and less threatening) way for eliciting, and making pupils aware of, their own misconceptions.

Several of the case studies here placed an emphasis on diagnostic assessment (Taber, 2002) as a way of both teacher and pupil judging where they were, and so informing learning. Both doing science, and learning science, involve constructing mental models to help us understand, and both processes need to be constantly monitored and evaluated to make sure that the scientific knowledge we are building fits with the evidence available. Assessment for learning, with its focus on pupils' active involvement, is something that fits very well with science teaching that reflects the processes of science itself!

Of course pupils need to become familiar with new approaches and demands before they can fully benefit – so Teresa found that some Y9 pupils held onto their misconceptions despite the attempt to get them more involved in analysing their own work, and Martin found that initially Y8 pupils found the demands of higher level tasks testing. It is likely that the successful learning outcomes reported in these cases would not be robust without further reinforcement and consolidation.

In each of the cases, the trainee reported that they themselves had undergone some important professional learning about their own teaching. Moreover, each of these trainees intends to take these approaches forward into their teaching careers, and develop them. In their new schools they will have the luxury - not available to trainees – of working with classes over longer periods of time, and developing new expectations and ways of working with those classes. These new teachers will certainly be explicitly addressing Ideas and Evidence in Science in their teaching, and they have shown us all that such an emphasis can enhance science teaching for our pupils.

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- with Tom de Trafford, Martin Koch, Tamsin Lowe, Susan Millins and Teresa Quail.