Title: Thinking, Doing, Talking Science

Strapline: Helen Wilson, Bridget Holligan and Pam Hanley share outcomes from their project which encourages childen's learning and engagement with science through simple and effective activities

Key words: higher order thinking, attainment, attitudes

An excellent question for teachers is 'What is education for?' This big question lies at the very heart of our profession and is worth taking time to ponder. What is your answer? 'To help children learn to love learning' is one of our favourite answers and what an immense privilege it is to do that.

Teaching is really hard work and it has become such a results-driven profession that sometimes it is difficult to see how we can help our pupils to 'love learning'. Is it possible to teach primary science in a way that the teacher enjoys more, the pupils enjoy more, and attainment increases? Well, yes: this was the outcome for the first trial of the Thinking, Doing, Talking Science (TDTS) project, funded by the Education Endowment Foundation (https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/thinking-doing-talking-science/). This surely is a win, win, win scenario.

Oxford Brookes University and Science Oxford carried out the TDTS project and the Institute for Effective Education at the University of York was appointed as the independent evaluator. It involved two teachers from each of 42 primary schools in Oxfordshire, including all teachers of Year 5 pupils. In a randomised controlled trial, half the schools were allocated to the intervention group and half to the control. The teachers in the intervention group received training in 2013-14 and the impact on their pupils was measured and compared with the pupils in the control group.

All the Year 5 pupils (more than 1,200) in both the intervention and control schools took a science test at the beginning and end of that academic year, and also completed a survey of their attitudes to science at the end of the year. The control schools received the training in 2014–15, after all the comparisons had been made.

The results showed that the pupils in the intervention group made about three months more progress in science attainment compared with pupils who were taught as usual. The children were also more enthusiastic about the subject and their teachers reported that they enjoyed teaching it more – thus the win, win, win scenario.

Insert Wilson Figure 1 : *A summary of the overview and ethos of the project*:

The joy of science is that it is all about thinking and questioning. The famous scientist, William Lawrence Bragg said: 'The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them' (cited in Mackay 1977). Thus, higher order thinking is at the heart of the diagram, surrounded by ways of encouraging that thinking through talking about and doing science.

Do you ever feel that there is so much work to be done, that there is no time to think? This can certainly be an issue for us as adults, but it can also be true for children in school. How can we carve out time for them to think? Is it worth it? The TDTS ethos is to 'squeeze the thinking from the normal curriculum' so that the pupils engage in deep learning and the project results show that this is well worthwhile.

Talking

The Bright Ideas Time is a dedicated discussion slot to be included in each science lesson. It need only take 5 or 10 minutes, so it is not overly time consuming. A number of prompts was devised to facilitate this discussion, including the Odd One Out and the Big Question.

The Odd One Out

The pupils select the odd one out from three (or four) objects, such as chocolate, water and paper, and explain their reasoning. There is no single correct answer, meaning that pupils are encouraged to think deeply and creatively, and the level of their thinking is demonstrated in their justifications for their choice. It is also an inclusive strategy, enabling each pupil to access the discussion at their own level. We recommend starting with the Odd One Out if the pupils have not previously experienced the Bright Ideas Time – teachers find that pupils engage with it very quickly.

The Bright Ideas Time can take place at the beginning of a lesson, or at any point within it and is an excellent tool for ongoing formative assessment. It should be linked to the theme of the remaining lesson. Many teachers find the Odd One Out useful as an elicitation activity at the start of a topic to uncover what the pupils already know and understand. Some use the same Odd One Out at the beginning and end of a topic to provide evidence of progression. It needs to be verbal though, so evidencing requires a Teaching Assistant to note pupils' responses.

The Big Question

Science is all about stepping back and questioning the seemingly obvious. The big questions 'lurk' in the curriculum and it is such a shame to miss out on the opportunity of posing them. An example of a Big Question is 'How do you know that the Earth is a sphere?' Pupils are not allowed to use pictures from space as an answer, because these could be fake! Examples of pupils' responses are:

'If it's flat, when you make the foundations for a temple why doesn't it go through?'

'Why doesn't water fall off the edge if the Earth is flat?'

And we have been astounded by answers such as:

'Because gravity comes from the centre of the earth, because a sphere is the smallest shape you can make from the centre, it would most likely be pulled up into a sphere.'

This response from a 10 year-old is totally correct and shows an amazing ability to think. There is considerable debate as to the different definitions of higher order thinking. After considering many of these, Lewis and Smith (1993) concluded that 'it occurs when a person takes new information and information stored in memory and interrelates and/or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations' (p.136). This is precisely what this pupil did to reach his answer and, as Wegerif (2010) pointed out, 'Excellent creative thinking is much easier to recognise when you see it than it is to define or explain' (p.4).

A good question requires time to think and it is invaluable to use the 'think, pair, share' strategy, especially with Big Questions, i.e. give the pupils a minute to think (without talking), then ask them to share their ideas with a partner, and finally ask some of the pairs to share with everyone. Because the Big Question is a whole class activity, pupils have opportunities to listen to and build upon each other's ideas and reasoning, thus acting as cognitive models for each other (Smart & Marshall, 2013).

The Primary Science Teaching Trust website includes an on-line module that has full details about the Bright Ideas Time, including videos of lessons, teachers' and pupils' comments, and a

downloadable sheet of examples of the different prompts, suitable for different primary age groups and in all the curriculum areas: https://pstt.org.uk/resources/cpd-units/bright-ideas-in-primary-science

These strategies have now also been included in the Explorify materials, produced by the Wellcome Trust: https://explorify.wellcome.ac.uk/. This includes good quality photographs and a range of resources to prompt discussions. There are many other excellent resources, such as the Concept Cartoons by Millgate House Publishers (www.millgatehouse.co.uk).

The Practical Prompt for Thinking

This is another prompt for talking about big ideas. It is a short teacher demonstration, designed to cause wonder and to intrigue. An example is holding a balloon over a person's head, putting a flame to the balloon and watching it burst. This is then repeated but with the balloon partly filled with water. What will happen next? Having created suspense, the 'wow' moment occurs: nothing happens– the balloon remains intact and the person's head remains dry. Why? The pupils are given time to wonder, speculate and to share ideas which might explain why the balloon does not burst.

Bianchi and Murphy (2014) highlight the centrality of wonder in teaching and learning but, as Lynne Bianchi often says, it is important to give time to move from the 'wow' to the 'wonder':

From  to 

Doing Science

Science is a practical subject and every primary science lesson should include the pupils doing some practical work. One of the principles of TDTS that the teachers found very helpful was the concept of 'focused recording'. There is no need for the pupils to record everything they have done in a practical - it is better for them to focus their recording on the learning objective(s). For example, if the learning objective is to develop the skill of drawing conclusions from the results of an investigation, then that is what is recorded. The teacher might scaffold the class by discussing suitable ways of planning and carrying out the investigation, to ensure that pupils obtain results to think about when drawing their conclusions. If it was a problem-solving activity, then labelled photographs justifying the steps taken might be the best method of recording what they have learned.

Refining the recording in this way releases the time for the thinking and doing, and also enables the teacher to assess the pupils' work clearly and sharply against the learning objective. Over time, lessons are planned with learning objectives focused on each of the different practical scientific methods, processes and skills required in the National Curriculum (Department for Education, 2013).

In their study of both primary and secondary schools in England, Abrahams, Reiss and Sharpe (2011) found that practical work can be more 'hands-on' than 'minds-on'. In other words, pupils engage with the materials, but not necessarily with the underlying ideas and concepts. During the CPD for TDTS, the teachers undertook practical investigations for themselves and at the end of each one they were asked 'That was fun, but where was the higher order thinking?'. This encouraged them to reflect in detail on the opportunities for the development of a 'minds-on' approach. They could then plan similar investigations and problem-solving for their pupils (e.g. 'how is pulse rate affected by

exercise?', 'devise an alarm that warns when the hamster cage is opened') and actively encourage the pupils to engage with the underlying ideas and concepts.

Conclusion

Phillip Adey made the telling point that 'what the research shows consistently is that if you face children with intellectual challenges and then help them talk through the problems towards a solution, then you almost literally stretch their minds. They become cleverer'. Presenting challenges and then encouraging the pupils to talk them through is at the heart of the TDTS approach. The pupils' minds were indeed stretched and consequently they attained more highly in a written test. Undoubtedly, the most encouraging outcome for the TDTS team was that the pupils developed more positive attitudes to science. However, the increased attainment is also important because it gives teachers confidence that this way of teaching is not just enjoyable but also deepens pupils' learning.

Helen Wilson is a Principal Lecturer in Primary Science Education at Oxford Brookes University. Email: h.wilson@brookes.ac.uk

Bridget Holligan is the Director of Education and Engagement at Science Oxford. Email: Bridget.Holligan@scienceoxford.com

Pam Hanley is a Senior Research Fellow in the School of Education and Professional Development at the University of Huddersfield. Email: p.hanley@hud.ac.uk

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