Evaluation of Three Primary Teachers' Approaches to Teaching Scientific Concepts in Persuasive Ways

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Evaluation of Three Primary Teachers' Approaches to Teaching Scientific Concepts in Persuasive ways.

Context and Purpose of Research.

In his often cited work 'The scientific model as a form of speech', Sutton (1996) argues that science lessons tend to over emphasise the role practical work can play in pupils' development of conceptual understanding. Sutton argues that pupils' science learning could be improved by spending more time exploring the established scientific view discursively, rather than pupils trying to construct personal understanding through direct interaction with the phenomena. At the same time he acknowledges the problems involved in teaching pupils abstract ideas which at first seem to have little relevance to how they normally visualise the world. From this perspective he suggests that it is not enough to inform pupils of scientific views but rather to persuade them of their value.

To involve someone else in your science is not just a matter of telling them what you have found; it involves persuading them of the usefulness and validity of the view you adopt, and the relevance of the evidence you present (Sutton, 1996, p146).

Sutton characterises science teachers' normal pedagogical practices as 'oscillating uneasily between persuading and informing' (p 147). He suggests that there is a need to move away from 'telling' or 'informing' to the notion of 'coming to appreciate' someone else's model or 'way of seeing' by trying to look at relevant aspects of the world through their eyes. Sutton stresses that it is only through 'looking at' and 'talking about' the world from scientists' perspectives, will pupils be persuaded of the value of their ideas. His work amounts to a re-description of science learning, which is representative of the shift away from Piagetian constructivism as a theoretical framework for science education. The 'new direction' (Scott, 1998, p46) has its grounding in sociocultural theory and has led to an emphasis on the use of language and context as key pedagogical tools for meaning making.

Purpose of research

Theoretical principles such as Sutton's notion of persuasive discourse do not translate unproblematically into everyday classroom practice (Asoko, 2002). Lijnse (2000) suggests that we have to go back and forth between the specific teaching situation and the theoretical ideas to make effective progress. In this way the existing pedagogical knowledge of experienced teachers, together with the theory, can be used to inform the development of context specific small scale pedagogical models (Lijnse and Klaassen, 2004).

The research set out in this paper seeks to develop context-specific pedagogical knowledge based on the translation of Sutton's ideas into practice by three experienced primary teachers. The intention of the research was to evaluate the teachers' practice and identify successful aspects which could be generalised into a pedagogical model. It was thought that this approach had the potential to develop new pedagogical knowledge with its roots fixed within the contemporary practices of the teachers. From this optimistic starting point, the research set out to appraise the teachers' choice of context and patterns of discourse when trying to persuade their children of the usefulness of the relevant scientific concepts. Outcomes of the study demonstrate how the teachers' choices of learning contexts fail to emphasise the functionality of the target concepts and as a consequence do not provide any significant exemplification of persuasive discourse. To provide a way forward, the outcomes of the case studies were contrasted with an example of more effective practice taken from Feynman (1999). This enabled the development of a provisional pedagogical model which could be used to assist the teachers to improve their practice in ways consistent with Sutton's ideas. The application of this model by the teachers forms a focus for further research.

The research is set out in three parts:

Part 1 provides a theoretical perspective on the nature of persuasive practices.

Part 2 analyses how the teachers interpreted Sutton's ideas and how they put them into practice.

Part 3 uses a case study taken from Feynman (1999) to explore a way forward and to provide a model which could be used to assist teachers to improve their practice.

Theoretical Perspective.

The Discursive Turn in Science Education.

Sutton's article is one of a growing cannon of research literature (see for example Howe, 1996; O'Loughlin, 1992; Scott, 1998; Soloman, 1994) which serve to interpret aspects of discursive or sociocultural psychology as a theory for science education. This 'new direction' has emerged as science educationists have come to view Piagetian constructivism as too conservative to take account of specific economic, social, cultural and historic contexts in which knowledge is constituted (O'Loughlin, 1992). Steering science education in the new direction has involved what Harre and Gillett (1994, p27) have called the 'discursive turn' in cognitive psychology which interprets the driving force for development in terms of social and cultural processes rather than rational internal procedures (Howe, 1996). This move towards situating science teaching and learning within a sociocultural classroom has been greatly influenced by the interpretations of the works of Soviet theorists Vygotky and Bakhtin by prominent scholars such as Wertsch (1991). In his hugely influential work, 'Voices of the Mind', Wertsch sets out a sociocultural account of meaning making which is comprehensive enough to take account of its highly contextualised nature. Wertsch argues that the central link between the thinking of the person and the influence of the contextual setting in which the person acts is the mediational means the person uses to construct meaning. These mediational means can take the form of either technological tools or semiotic systems such as language, mathematics and pictures. From this perspective, scientific models provide people with mediational tools which they can use when interacting with the natural and technological world. Generally, scientific models provide visions of the world that are unperceivable and hence provide unique and privileged insights into how it works. However, as with other types of complex tools, appreciation of their value is dependent on familiarity with the way they function and practice in their use.

Nature of Persuasive Discourse.

Educationalists such as Ogborn et al, (1996); Scott (1998) have analysed aspects of pedagogies that promote appreciative understanding of scientific concepts. This has given rise to new ways of talking about science learning which shift attention away from inductive processes towards the types of social interactions that mediate meaning making. For example, Mortimer and Scott (2003) encourage the science teacher to stage and script teaching and learning performances through which students can be 'introduced to the tools and practices of a school science social language' … and come to 'see how these might be applied to diverse social, technological and environmental contexts' (p16). Other evocative vocabulary which match the 'discursive turn' include the description of scientific models as 'stories' or 'narratives' with 'casts of protagonists' and meaning making as a dialogical process through which the protagonists (i.e., entities or concepts) are talked into existence (Ogborn et al, 1996).

Both Sutton (1996) and Soloman (1994) argue for a description of science learning which is indicative of the discursive turn. Soloman suggests that constructivism, in the sense it has been used in science education, has always skirted around the actual learning of an established body of knowledge and hence has not come to terms with how students learn the language of science.

What constructivism has not described is the process of learning as arrival on a foreign shore, or as struggling with conversation in an unknown language (Soloman, 1994, p16).

Soloman's redescription of science as an alien cultural implies that learners cannot engage meaningfully in science activity until they have learnt its language. This seems to be stating the obvious, but of course learning language is not the same as learning words. A word becomes part of a learner's language when he populates it with his own intent and adapts to his own purpose (Wertsch,1991). To appropriate a new scientific word, a learner must use his own language as a mediational tool to create an internal representation or mental model of the new word. This involves providing the space within classroom conversation for learners to interpret in their own words the key ideas being taught by the teacher. This view is consistent with Bakhin's notion of the 'internally persuasive word' which is 'half ours and half someone else's' (cited in Wertsch, 1991, p.79). From this perspective the persuasive power of an argument or point of view does not reside in the speaker's words but in the counter or answering words that they provoke in the listener. In this way meaning making is multivoiced in that it requires at least the interaction of two voices – the voice of the speaker and the interruptive voice of the listener (Mortimer, 1998). It is through the generation of counter words that the listener gains access to existing mental representations (mental models) from which shared meaning of the taught concept can be fashioned.

Persuasive Discourse Mediates the Modelling Game.

From a sociocultural perspective, conceptual learning can be seen as a semantic process through which learners gain access to existing mental models which they can use to construct shared representations of a target concept. Learning science can therefore be visualised as a 'modelling game' (Greca and Moreira, 2000) in which the teacher's role is to assist the learner to choose the most powerful counter words with which to fashion a functional model of the taught concept. Functionality is the key quality which commits learners to a particular mental representation.

The main role of a mental model is to allow its builder to explain and make predictions about the physical system represented by it. It has to be functional to the person who constructs it. (Greca and Moreira, 2000, p3)

Of course, learners' mental representations of particular concepts do not necessarily have to be scientifically accurate to be personally useful (Borges and Gilbert, 1999; Norman, 1983). This is why, misconceptions are so often very difficult to address. Therefore, key to the success of the modelling game is the commitment to help learners produce mental models of target concepts which are both personally functional and scientifically valid. Greca and Morera (2000) describe the modelling game as an enrichment process of previous models rather than involving complete restructuring. It is not necessary that these scientifically enriched models replace existing ones, only that the learner is persuaded of the usefulness of the scientific model in specific contexts (Driver et al, 1994). The modelling game therefore necessarily involves two distinct stages. The first is what Sutton (1996) calls the'redescribing' stage. This requires teachers to help pupils to use their existing mental models to interpret and create a meaningful internal representation of the target concept. Sutton suggests this involves 'talking around the topic until shared meanings are developed' (p147). From a mental modelling perspective, talking around the topic provokes the generation and externalisation of a 'tool kit' of counterwords with which teachers can help pupils fashion their own personal interpretation of model. In the second stage pupils need to learn to appreciate the utility of their new model. To commit to the model, pupils need to be able to use it productively for the purpose(s) for which it was created. Here we arrive at arguably science education biggest challenge and its most enduring dilemma. Ever since the introduction of the comprehensive school system in the 1960's, schools have failed to develop a consensus about the purpose of science education (Jenkins,1997; Millar and Osborne, 1998). A clear view on what science learning should enable pupils to do is crucial to the success of the modelling game, and conceivably one of the reasons that it is not played consistently well in science classrooms.

Research Methodology

The starting point for the research was a meeting with three primary teachers in which we discussed Sutton's article (1996) about the need to persuade children of the value of the concepts that we teach them. All the teachers were science coordinators in their schools and taught children of ages 10-11. The teachers are referred to in the paper as Pam, Cathy and Brenda.

During the meeting the teachers shared their beliefs about effective science teaching and discussed ways in which children could be persuaded of the value of scientific ideas. As a result of the discussion the teachers were asked to describe their understanding of the nature of a persuasive learning setting and to construct a pedagogical model to guide their lesson planning. Having agreed a framework, the teachers were asked to plan their lessons independently. They were expected to continue with their normal curriculum but to adapt their teaching style to accommodate the agreed teaching model. The researcher was present throughout the meeting to answer questions relating to the theory and to help the teachers to generalise their ideas into a pedagogical model.

Data collection and analysis focussed on the teachers' choice of context and patterns of discourse in what they considered to be a persuasive lesson. Each teacher provided written plans of their lesson and video or audio recorded their interactions with a focus group of children. In each case, the children were already used to staff videoing their activities and therefore it was decided that in house recording would have least influence on the nature of data collected. This method helped to maintain the integrity of the teaching and learning setting, but gave the researcher less control over the data collection process.

Analytical Framework.

Transcriptions of the video and audio tapes were produced and analysed to identify, in light of sociocultural theory, interactions which could be described as persuasive. The basic unit of analysis was taken to be an exchange, which is defined as a set of utterances which serve to complete a topic of conversation (Sizmur and Osborne, 1997). The analysis of the classroom exchanges follows Scott's (1998) characterisation of authoritative and dialogic functions of discourse. In brief, Scott describes authoritative discourse as being univocal and with fixed intent. It is a mode of discourse used for transmitting information, which does not encourage the sharing and exploration of ideas. Dialogic discourse is situated on the other end of the discursive spectrum. Dialogic practices encourage learners to generate internally persuasive words in response to the ideas being taught. In a dialogic exchange the teacher helps the learner to access meaningful answering words and use them as tools to interpret and make sense of the scientific view. An exchange would therefore consist of a pattern of authoritative and dialogic utterances, the balance depending on the purpose and topic of conversation. If the purpose of a conversation is to persuade children of the merit of a scientific view, then it needs to be set in a context which serves to emphasize the functionality of the view presented and also helps to resolve ambiguities with regard to the meaning of the scientific language (Millar, 1996). This is consistent with sociocultural theory which interprets the modelling game as a process of dialectical interaction between the pupils acting with modelling tools, the activity and the context in which the activity takes place (O'Loughlin, 1992). The context in which science learning is set has the power to shape both the nature of the pupils's activity and the choice of modelling tools for the relevant task (Lave, 1988). As the case studies exemplify, the choice of context is crucial to the development of persuasive pedagogical practices.

Research Outcomes.

All three teachers interpreted Sutton's ideas from a techno-utilitarian perspective. For them a useful scientific view would be one that would help inform an everyday activity. For example, thermal insulation is a useful concept because it helps us understand how to keep things warm and could be applied to a wide range of everyday situations. They agreed that useful scientific ideas should present children with tools for problem-solving and decision making. The teachers were also unanimous that empirical evidence was crucial in persuading children of the validity of a scientific idea. Scientific enquiry was considered to be an important part of the persuasion process, and Brenda and Cathy very firmly believed that children were more likely to value the scientific view if they discovered it for themselves.

The teachers were less certain about their role in the persuasion process. There was consensus that they needed to listen to the children's ideas and to present the scientific view as an alternative (potentially more powerful) way of thinking about an event or issue. However, they could not agree on when, within a problem-solving context, the scientific ideas should be presented. Pam thought the key ideas should be taught in advance and the problem-solving activity should be used as an application of the ideas. Brenda and Cathy thought that the problem-solving activity should come first and the scientific ideas introduced after the children had been given the opportunity to discover a solution for themselves. Both approaches were considered to provide opportunities to demonstrate the value of the scientific ideas.

What the teachers had not considered was how the scientific ideas would be presented and how the children would learn to use them as cognitive tools. The nature of the teachers' discussion implied that they thought children learned through either being 'given the ideas' or by 'discovering ideas for themselves'. Intuitively, the teachers viewed active learning as a hands-on activity and there was no evidence that they considered how they would manage the children's mental activity. It is fair to conclude that the teachers viewed explaining as univocal and synonymous with telling; in contrast, active learning involved some form of practical work.

Based on the initial discussion, the teachers agreed on the following framework for planning a persuasive lesson.

1. Choose a science-related practical problem.
2. Construct a list of scientific ideas which could be used to help solve the problem.
3. Provide opportunities for children to evaluate the usefulness of the scientific ideas against their own ideas, when trying to solve the problem.
4. Having solved the problem, children would make a display of the ideas they found to be most useful.

The framework seemed to hold some potential for organising a learning setting which provides children with opportunities to talk about scientific concepts in light of their understanding of everyday reality. The emphasis placed by the teachers on the use of scientific ideas for problem-solving purposes suggests a commitment to developing children's understanding of scientific ideas as tools for thought, rather than just 'things' to think about (Sutton,1996).

The teachers' utilitarian commitment is also shared by educationalists such as Jenkins (1999) who calls for an approach to science education that 'relates in reflexive ways to the concerns, interests and activities of citizens as they go about their everyday business' (p9). This is arguably a different epistemology to the cultural and historic one Sutton had in mind when he described the scientific model as a form of speech. However, it is a view of science reinforced by many contemporary teaching resources including The National Curriculum (DfEE, 1999) programmes of study for primary science. We only have to look at the picture of Tom on page 77 in his reflective coat and the caption '*Tom wears a reflective coat. The car lights shine on his coat and then* *you can see him in the dark'* (p77), to get a flavour of the techno-scientific epistemology that permeates the primary science curriculum in England.

Arguably, a teacher's image of the purpose and nature of science will influence the nature of both their pedagogy and the children's learning (Mathews, 1994). Mathews suggests that, to foster a cultural appreciation of science, 'the teacher needs to have an idea of what science is, needs to have a sense of the essence of science, an image of science that is going to be conveyed to classes and which is going to inform decision making about texts, curriculum, lesson preparation, assessment and other pedagogic matters' (p204). In this study, it was the teachers' techno-utilitarian image of science which dominated their practice and consequences of this on the topics and nature of classroom talk were clearly evident in their classroom practice.

Analysis of the Classroom Practice.

Although the teachers had a common framework on which to base their lessons, the nature of the contexts and discursive interactions were sufficiently different to warrant separate analysis. Issues raised by the case-studies are discussed in the context of contemporary practice in primary science education to enable generalisations to be made.

Pam's Lesson

Context

Pam's lesson required the children to modify the design of a Roman house to make it warmer in winter. This complemented recent work which they had done on the Romans as part of their history curriculum. The nature of the learning setting could be described as cross-curricular in that science, history and technology are conceptually linked. The English Primary National Strategy (DfES, 2004) encourages teachers to make links between curriculum subjects and hence Pam's approach could be considered representative of contemporary practice in this phase.

Having decided on the problem, Pam identified a list of scientific propositions which she thought could inform the children's designs. She identified them as scientific resources and posted them prominently on a display board to make them available to the children.

Pam's Scientific Resources

- Insulators prevent heat passing through them
- Some materials are better insulators than others
- Air is a good insulator
- Materials that trap air have good insulating properties
- Warm air rises

The list of scientific resources represents the conceptual content of Pam's lesson and is consistent with the requirements set out in The National Curriculum (DfEE, 1999) programme of study for primary science. For this age group The National Curriculum states that 'pupils should be taught that some materials are better thermal insulators than others' (p87). There is no reference to an explanatory model which can be used to explain why some materials are better insulators than others. In the absence of an explanatory model, Pam defines thermal insulators as materials which prevent heat passing through them. This is an inaccurate or incomplete proposition as it is only true with regard to heat transfer by conduction. However, the proposition is presented to the children as the key epistemic criterion on which to base their problem-solving.

Pam's lesson lasted 60 minutes and consisted of three key exchanges. In the first she established a purpose for science learning by telling a story of Roman domestic life and the problems the poorer classes faced to keep warm in the winter. The introductory part of the lesson invites the children to intervene in the lives of these Romans by using scientific ideas to mediate solutions to their problems. Arguably, this strategy holds potential for children to re-express scientific ideas as tools for thought and to use them to mediate their technological activity.

The purpose of the second exchange was to introduce the children to the concept of thermal insulation as the key useful scientific idea. In the third exchange Pam used everyday experiences to exemplify the usefulness and validity of her list of scientific resources.

Patterns of discourse.

Discursive practices throughout Pam's lesson could be best described as deterministic and authoritative. This was perhaps inevitable because, by identifying thermal insulation as the most useful concept, Pam had predetermined the solution to the problem. As evidenced by Episode 1, this provided few opportunities for the children to meaningfully participate in the problem-solving process.

Episode 1

Pam: Poor families couldn't afford to have hypocausts built in that way. So have a look at page 6 in your history books. On the very left-hand-side you can see a townhouse. It's more like an apartment or little block of flats. And here at the top it says where poor families lived and they are the ones we want to try and design a way that would keep the heat from escaping – keep the heat inside the house. Right let's have a look at that first. Why do we think it wouldn't be very warm?

Child: It doesn't have windows.

Pam: It does have windows but it doesn't look as if it has any glass in them. It doesn't look like it – it's just small holes isn't it – in the brick. Possibly they should have shutters in them. The ones down stairs have shutters do they? Some of them do. How else are they designed to keep the heat in? Have a look at it and see if you can think of anything else?

Child: It would be colder up there.

Pam: They are three storeys up – why do you think it would be colder up there?

Child: The higher up the colder it is.

Pam: Right, as you go higher up the air will be colder. Good boy. Anything else? The higher up the colder. Does anyone know a word for keeping heat inside?

Pam's solution to the Roman problem was to fill the wall cavities with an insulating material. Therefore, when Pam asks the children how heat could escape from the house she is looking for an opportunity to introduce the notion of thermal insulation. The child's idea of heat escaping through open windows is an obvious reason why Roman houses may be cold in winter. Instead of using the remark as a catalyst for discussion about how heat travels through convection, Pam side-stepped the child's response by quickly asking an unrelated question. Pam seemed then to reinforce a possible misconception. The response that 'the higher up the colder it is' is a contentious one in this context and one perhaps that could have generated reasoned argument about the validity of this view in light of children's experiences and the scientific model for convection. As Ogborn et al (1996) points out, dealing with the difference in views is what drives classroom explanatory practices and from this perspective Pam seems to have missed an opportunity to scaffold persuasive discourse.

This episode highlights two problems primary science teachers face when teaching science in cross-curricular contexts. The first is the demand placed on their scientific knowledge by the complexity of the learning setting. To respond sensitively to the voices of the children the teacher has to adopt a more conceptually flexible approach than would be required in more narrowly focused scientific contexts (Jenkins, 1999). For many primary teachers, who have limited scientific background to draw on (Murphy and Beggs, 2003; Parker and Heywood, 2000; Parker, 2004), the need for conceptual agility can reveal quite serious weaknesses in their own scientific knowledge. The second problem stems from the nature of contemporary lesson planning which is based on predetermined and conceptually narrow learning objectives. As evidenced by Pam's practice, teachers can be tempted to discount children's responses which divert the conversation away from the key knowledge objectives (Levinson and Turner, 2001). This suggests that narrow, inflexible conceptual learning objectives can prove to be a drawback when trying to maintain meaningful patterns of discourse within cross-curricular contexts.

In the second and third exchange Pam attempted to provide the children with a functional understanding of thermal insulation. The nature of her interactions with the children could be best described as labelling language (Sutton, 1992). The purpose of labelling is to pass on to the children an unambiguous meaning of the label (Sutton, 1992) and hence the nature of the interaction is authoritative. As evidenced by Episode 2 Pam does this in two steps. Firstly, she defines thermal insulation in abstract terms and then she links the definition (label) to familiar objects and events to give it some form of physical reality. With regard to meaning making, her labelling strategy relies on the children's familiarity with the nature and behaviour of the objects chosen by Pam. In effect, she is expecting the children to construct their own mental models of thermal insulation based on their experiences with the objects. Since the children's thinking is not explored, Pam has little control over their meaning making. There is specific evidence that Pam leaves the children unclear about whether the purpose of insulation is to stop 'hot air' escaping as suggested by the child or to stop 'heat' escaping. If she had encouraged the child to externalise his thinking, she could have perhaps took a step towards resolving ambiguities between the scientific concept of heat and the physical entity referred to by the child as hot air. As it was, the children's utterances were never developed and Pam's exposition remained authoritative throughout the exchange. Generally, Pam's exchanges throughout the lesson exemplify Sutton's (1992) view that labelling uses language in ways which discourage interpretative forms of discourse.

Episode 2.

Pam: Does anyone know a word for keeping heat inside?

Silence (No one answers)

Pam then walks to the blackboard and writes the word insulation and asks the children to read it.

Children read the word insulation out loud in unison.

Pam: Has anyone heard that word before – insulation. What do you think it means? If something is being insulated what has been done to it?

Child: Keeping all the hot air in.

Pam: Keeping the heat inside and stops it from leaking out. Another word that goes with that is thermal.

She then writes the words thermal insulation on the board.

Pam: It means to keep the heat inside and stop it from escaping. What kind of things can you think of that you would want to keep warm? Anything at all that you would know of that you would want to keep the heat inside and stop it escaping. What do we want to stop heat escaping from on a cold day?

Child: Our rooms

Pam: No – from our bodies. We cover them in clothes. We put more layers as it gets colder don't we. What fabric – what material keeps in most heat? Think about what you wear in winter.

Child: Wool

Pam: Wool – do you think that is a warm winter material? I wonder why that keeps in the heat? I wonder why we use wool? Come back to that later. Right our bodies. We insulate our bodies with clothes. What else do we keep warm? Where would you put tea to keep it warm if you were going on a journey?

Child: In a flask

Pam: In a flask – a thermos flask. Again, 'therm'

Pam points to the word thermal previously written on the board.

Pam: You want to keep it warm. That's going to be insulated – the flask. We have our bodies, we have drinks, what else would be insulated.

As the lesson went on Pam's labelling strategy invoked a wider range of objects which included double glazing and bubble-rap to persuade children that air is a thermal insulator. Intuitively, most children are unlikely to perceive air as a substance which prevents heat passing through it. Experience tells them that heat passes easily through air. Each day they feel the heat from the Sun on their faces as it travels through the air. They also commonly experience heat travelling through air when using a hairdryer or when they sit next to a school radiator. Of course, science has answers to these questions but they are based on powerful explanatory models which are not part of the primary science curriculum. In the absence of their voices we can only wonder how plausible the idea that air is a good insulator seemed to the children.

In conclusion, the persuasive power of Pam's labelling strategy is weak and unlikely to provide the children with a functional mental model of thermal insulation. Through-out the lesson Pam was unable to take advantage of the opportunities the exchanges presented for her to scaffold the way children's voices contribute to the modelling game and hence the learning outcomes were unpredictable.

Cathy's Lesson

Context.

Cathy set her children a task to design a solar-water heater. In contrast to the other teachers, Cathy did not prioritise a list of useful scientific ideas in advance. The recording of her lesson consisted of three types of exchanges. The purpose of the first exchange was to introduce the task to the children in a way which emphasised the importance of science in their everyday lives. The second and third types of exchanges focussed on the usefulness and performance of the children's solar heaters.

Cathy started the lesson by talking about what scientists do, and tried to impress on the children the importance of science in day to day living. However, the language used by Cathy served to confuse scientific activity and its products with those of technology and had the potential to mislead the children. For example, when a child remarked that scientists 'invent everything we need'. Cathy validated the child's view by providing the following response:

'Well done, yes. Scientists are involved in our everyday lives. Whatever you see around you, the things you use everyday, all these things are here because scientists developed ways of making them.'

The belief that scientists make things which improve our lives is a common misconception and many primary teachers tend to treat science and technology as a unified enterprise (Driver et al, 1996; Harlen & Qualter, 2004). The consequences of this naïve understanding of the nature of science can be a conceptually barren approach to science learning as evidenced by Cathy's exchanges during the lesson.

In the main part of the lesson the children explored different ways of using a light bulb to heat a container of water. They were encouraged to think of ways to improve the rate at which the water could be heated. For example, some wrapped their container in fur thinking that it would keep the heat in; others used mirrors or aluminium foil to reflect more light onto the water container. Decision making was based on intuitive understanding of heat and light, and trial and error. Cathy wanted them to discover the solutions for themselves as she considered this to be the most effective way to learn science.

Patterns of discourse.

While the children were working Cathy had two types of exchanges with each group. The purpose of the first exchange was to emphasize the utility of their science learning. The second exchange happened after the children had tested their heaters and it was designed to see how well they worked. As evidenced by Episode 1, these exchanges were more concerned with establishing the usefulness of the artefacts, rather than the value of the conceptual models which underpin the design of solar collectors. Consequently, her questions were not designed to provoke the need for a useful scientific explanation, but to persuade the children that science produces useful artefacts.

Episode 1.

Cathy: Right, so tell me, what you are doing here?

Child 1: We're seeing if the tin foil will reflect the light onto the bottle of water to make it warmer.

Cathy: So what is it you're investigating? What are you trying to make?

Child 1: We're shining the light to make the bottle of water warmer.

Cathy: But what is the purpose of it? How could we use this in everyday life?

Child 1: To warm up drinks like orange and tea and that.

Child 2: If you had a young baby and it was hungry in the night, this is a way you could heat up the milk so you don't have to go down stairs.

Child 3: If you need hot water and you are stranded in the forest and you just had your car and your tent and you have a light, you could plug it into your car and then put a bottle of water over the top of it and it would warm up like that.

The episode illustrates how Cathy's questions served to divert the children's attention away from explaining how their solar heater works to describing its purpose. As we can see, the children readily played the game coming up with some imaginative, if impractical responses. Although the uses the children proposed for their water heaters were unwarranted, they were never challenged by Cathy. In fact, there is no evidence of scientific argumentation being used as a persuasive device in any part of the case study. Referring back to the analogy of strangers arriving on a foreign shore, we must be concerned for the impressions of science Cathy's children developed from this lesson.

Successful completion of the project mainly required the use of technological tools and hence dialogic discourse focused on the performance of products rather than a scientific model. Having completed this project, it is very unlikely that the children would have gained any conceptual insights into the nature of solar energy and the energy transfers involved in solar water heaters. Overall, the learning setting is not only devoid of any conceptual models for children to talk about, but due to the treatment of science and technology as a unified enterprise it also misrepresents the nature and purpose of science.

Brenda's practice

Context

Brenda planned to persuade the children that scientific ideas could be used to make work easier. Her focus activity was a task which required the children to lift a weight of 5N to a height of 1m with the minimum amount of force. Brenda's management of the children's learning in the focus session involved setting the task, giving out a sheet of paper containing a list of useful scientific ideas, and then to let them get on with the task in small groups. At the end of the lesson the children were expected to write up their work using a specified format.

Brenda's List of Useful Scientific ideas.

- Gravity pulls objects to the Earth
- Friction is caused when 2 surfaces rub together
- Friction can be reduced by using lubricants
- The steeper the slope the larger the force of gravity on it
- The flatter the slope the less gravity on it
- When more than one force is acting on an object the greater force will affect it

Brenda's approach depended on the children using the propositions on the useful ideas list to inform the way they set about the task. The first three propositions had been the focus of previous lessons and therefore should have been familiar to the children. The last three propositions were added by Brenda because she thought they would prove useful when planning a solution to the task. This had required Brenda to reinterpret her own understanding of gravity, similarly to the way Pam had to rework her understanding of thermal insulation. The complexity of the situation revealed weaknesses in her subject knowledge. For example, it is not valid to suggest that there is less gravity acting on an object on a flatter slope or more gravity on a steeper slope. The situation is more complex than this and perhaps beyond the scope of the primary curriculum. This is another situation where the teacher's knowledge is severely challenged by the complexity of the chosen context.

Patterns of discourse.

Brenda recorded the exchanges of a group of 5 children who were supervised by a classroom assistant. Brenda was determined not to intervene in the children's group work and her voice wasn't recorded on the tape. The children gave scant regard to the list of scientific ideas and they began to complete the task by exploring different slopes and different surfaces for the ramp. The first exchange contained a range of sensible and potentially productive ideas as evidenced by Episode 1.

Episode 1.

Child 1: I reckon we should get a big piece of card to make a slope and pull the weight up a slope with a newtonmeter on it.

They tried this out and found it took a force of 9N to pull the 500g mass up the slope.

Child 2: We need to make it a slippery surface.

Child 3: Use paper

They tried out the new idea and found it took 3N.

At this point there was what proved to be an untimely intervention by the classroom assistant whose job it was to record the children's exchanges. She suggested that they look around the classroom for other things to help them. As a result they found a magnet that seemed to change their perception of the problem. They quickly abandoned the slippery slope approach and instead decided to focus on ways of using the magnet. Creatively, they managed to use a fork and the magnet to lift the weight without recording any force on the newtonmeter. After a number of trials, they came to conclusion that they could lift the load with a force of between 0-1N. However, two members of the group were uncertain that they had provided a valid solution to the task. An argument then ensued, which continued to the end of the lesson without resolution. What started off as a promising setting for the application of scientific ideas turned into an argument about the nature of the task.

Episode 2.

Child 1: Are you still having a go at that although we have achieved what we wanted?

Child 2: No, but we are going to … it went up to 2

Child 1: This is a science lesson and magnets are to do with science

Child 3: But you were holding the magnet

Child 1: Yeah, but the actual newtonmeter was pulling it up – the fork and the magnet were just giving it support to make less force

Child 2: When I was holding the fork and doing it I got loads of force on it

Child 3: But all the force is suppose to be on the newtonmeter

Child 1: Not necessarily. It did actually go to one

Child 2: How come one minute it's zero and then it's one or two?

Child 1: It just happens.

A critical aspect of the lesson turned out to be the unplanned intervention by the classroom assistant. What was especially interesting was the level of influence that her casual suggestion, 'to find something in the classroom to help', had on the children's perception of the task. Compared with the list of scientific ideas provided by Brenda, the magnet proved to be a far more powerful mediational tool. Perhaps this is not surprising since everyday practical problems are usually solved by finding and using an appropriate technical tool. From this perspective, it could be argued that Brenda's list of useful ideas were in the children's eyes the wrong 'tools' for the job. Similar to the other case studies, Brenda's lesson turned out to be conceptually weak with, again, confusing messages being given to children about the nature of science.

Issues raised by the case-studies.

The research set out to examine three teachers' choice of context and patterns of discourse when trying to persuade children of the value of scientific ideas. The outcomes of the study exemplify how the choice of techno-scientific contexts can militate against the development of persuasive practices in the primary science classroom. In each of the case-studies the chosen contexts facilitated learning settings in which discursive interactions were used mainly to mediate practical tasks rather than conceptual understanding. When concepts were explored, they were presented authoritatively as labels for objects or events. There were few opportunities for children to use their own words to interpret them meaningfully. Generally, the influence of any scientific view on the children's activity and meaning making was weak. Meaning making was mainly of a technological nature with no evidence of discursive interactions which had the potential to promote scientific ways of visualising the world. In conclusion, there was no evidence that the children had successfully participated in the modelling game and hence none of the teachers' pedagogies could be described as persuasive.

Although this is a small study it is important, because it exemplifies the problems primary teachers face when trying to adopt persuasive teaching approaches. The key issue raised by the case-studies concerns the ability of the teachers to develop contexts which serve to emphasise the functionality of a target concept. In each case-study the teachers interpreted the notion of useful scientific knowledge from a practical perspective and hence chose to set the children's learning in techno-scientific contexts. Analysis of the learning settings shows that the activities undertaken by the children provided scant reward for engaging with the target concepts. Generally the case-studies militated against the modelling game by rewarding physical effort, rather than active participation in the discursive exploration of scientific ideas.

Way forward

The case-studies identify a need for clear interpretation and exemplification of persuasive approaches to teaching science which can be successfully applied in the primary classroom. In this part of the paper, I draw on Feynman's (1999) account of his formative science education to exemplify learning contexts which address both the affective and effective dimensions of the modelling game and provide suggestions about how primary teachers could be helped to stage persuasive teaching performances in their classrooms.

In his book, The Pleasure of Finding Things Out, Feynman describes how he was first introduced to the world of science by his father on their many walks together in the local woodland. On their regular walks his father would take great pleasure in tantalising Feynman with questions about the animals and plants which they observed and with challenges to explain reasons for their behaviour. Feynman describes the occasion their conversation focussed on the behaviour of a bird.

During the walks in the woods with my father, I learned a great deal. In the case of the birds, for example: Instead of naming them, my father would say, "Look, notice that bird is always pecking in its feathers. It pecks a lot in its feathers. Why do you think it pecks the feathers?" (1999, p181)

Feynman was encouraged by his father to hypothesise what seemed to him to be a logical reason and his father would help him test if he was right. For example, in this case he hypothesised that the bird was straightening its feathers because it had just landed. They then tested this idea by watching a range of birds land and checked if they pecked at their feathers. When they found that the birds did not necessarily peck their feathers when they first landed they looked for another reason, until it was necessary for his father to provide an explanation about the parasitical relationships supported by birds. The experience was not designed to produce a declarative statement of knowledge about the birds' behaviour but to provide a window through which the theme (big idea) of interdependency could be explored.

…, he went on to say that in the world whenever there is any source of something that could be eaten to make life go, some form of life finds a way to make use of that source; and that each little bit of leftover stuff is eaten by something (p182).

By introducing a new entity (parasites) into the setting his father enabled Feynman to see the same events in a different way. In the beginning Feynman was encouraged to construct a narrative involving events and entities which were familiar to him, when the account proved unreliable there was a need to introduce a new way of seeing the events. In the end he did not discover anything for himself; his pleasure (reward) was derived from being actively involved in the telling of a story which stirred his imagination.

Now the point of this is that the result of observation, even if I were unable to come to an ultimate conclusion, was a wonderful piece of gold, with a marvellous result. It was something marvellous (Feynman, 1999, p182).

The value of Feynman's account of his formative science education is the clear philosophical perspective it could provide for primary science teachers. That is, the purpose of science education is to share with children the amazing visions of the world that science has discovered. If shared through rational and evocative dialogue children can experience the pleasure of learning science which comes from the wonder and awe of finding out that the world is not as we first perceive it to be.

Of course Feynman was reminiscing about an experience which was unique and clearly very special to him. Producing similar intellectual and emotional experiences for a class of primary children may not be so easy. However, the message is very clear about the value of scientific knowledge. The usefulness of science resides in its power to transform the way children see their world. To achieve this, conceptual learning has to be set in contexts which require the need for a scientific explanation. Therefore matching content to context is the first step in developing a persuasive pedagogy. The second is staging the teaching and learning performance in ways which reveal the significance and functionality of the new ideas. The context described by Feynman involves problemizing content, modelling required behaviour and rewarding participation. For example, his father arouses his son's interest in the topic by pointing out a puzzling event. He then guides the way Feynman attempts to construct a valid explanation for what he has observed. This leads to conflict between how Feynman mentally visualises the event and the empirical evidence. This adds tension and an imperative to provide a solution. In effect, the puzzling event pushes the functionality of Feynman's existing conceptual framework to its limit and hence raises his awareness of the need for reconstruction. Cognitive conflict used in this way is a feature of constructivist practices and 'a characteristic of much teaching that would be considered 'good' by expert observers' (Adey and Shayer, 1994, p62). From a sociocultural perspective the puzzling event provides an incentive to engage with new forms of conversation which enabled Feynman to redescribe aspects of nature in scientific ways (Sutton, 1996). Eventually Feynman's active participation in the modelling game is rewarded with the sense of pleasure and satisfaction he gets from resolving the puzzle and being able to see the event in a new and more powerful way. These strategies which Feynman's father assumed without benefit of learning theory are representative of effective discourse based practice identified in range of studies (See for example Asoko, 2002; Lijnse, 2000; Ogborn 1996; Watt, 2002).

The nature of the children's learning in the case studies contrasts with the above account in a number of ways. Firstly, we find that successful resolutions of the problems set in the case studies do not require scientific explanations. In each case the required outcomes can be achieved either through trial and error and/or simple practical testing. This is not to say that the outcomes could not have been influenced by the application of scientific knowledge especially in Pam's and Cathy's lessons where knowledge of heat transfer would have been of value. However, the levels of functional knowledge required were beyond the scope of the course and the expertise of the teachers. This exemplifies the problems primary teachers face when trying to develop persuasive pedagogies in learning environments which are conceptually impoverished. The case studies suggest that primary teachers need help to choose contexts which have the potential to reveal the functionality of the limited conceptual knowledge available to them.

The second issue concerns the need for teachers to model and scaffold ways of talking which help children redescribe their world. In particular, the conversational nature of the talk between Feynman and his father is distinctly missing from the case studies. The scientific knowledge presented in the case studies was delivered to the children in the form of propositions with few opportunties for dialogic meaning making. This contrasts sharply with the nature of the conversation which helped Feynman to construct an explanatory narrative which had the power to influence him both intellectually and emotionally. The staging of the narrative played a key part in persuading Feynman not only of the value of scientific knowledge but also of the pleasure its understanding can provide. This is essentially the divide between the nature of the learning in the case studies and the nature of Feynman's learning. In the case studies the teachers imagined that the sources of pleasure for the children would be the hands-on work; in Feynman's case the rewards were a result of new ways of talking and visualising the world.

The final part of the paper explores possible ways in which the teachers could be helped to develop more persuasive pedagogies by adopting a story telling approach.

Towards the development of theme-specific plots

There is a striking parallel between the way the learning experiences are arranged in Feynman's account and the way events are arranged by authors when writing short stories. When viewed in the light of narrative theory, it can be seen that the events described by Feynman have been arranged by his father to arouse curiosity, create tension and provide satisfaction. His father achieved this by initially choosing a context which was right for the theme and also familiar to Feynman. He then set the scene by exposing the behaviour of the protagonists around which the story would unfold. Next he provided a hook (puzzling event) to stimulate Feynman's interest in the theme and the main protagonists, and a complication to create conflict between what Feynman observed and what he perceived. The conflict reached a climax when Feynman was unable to arrive at a satisfactory solution to the problem. At this point his father helped Feynman resolve the tension with an explanation, which not only changed the way Feynman understood the initial event but also changed the way he perceived the world more generally.

It seems to me appropriate that primary science teachers should draw on established story-telling techniques to create persuasive teaching and learning performances. To help them I propose that aspects of narrative theory could be used to develop concept specific pedagogic structures which I have called theme-specific plots. The need to develop theme-specific plots is consistent with Linjse's (2000) work into the value of establishing didactical structures as the outcome of research on teaching-learning sequences. Lijnse argues that there is a missing level between learning theory and how to apply it to teaching specific content in the classroom.

The missing level is that of describing and understanding what is, or should be, going on in science classrooms in terms of content-specific interactions of teaching-learning processes, and of trying to interpret them in terms of didactical theory (Lijnse and Klaassen, 2004, p538).

Research into the development of theme-specific plots would attempt to bridge this gap by providing concept specific pedagogic structures consistent with relevant aspects of sociocultural theory.

Structure of a theme-specific plot

Part 1: Redescribing phase

The first part of a theme-specific plot could be structured in the four stages that are often used for story writing in schools (Abbs & Richardson, 1990). These four stages would represent the redescribing phase of the modelling game.

a) Exposition – This stage is designed to arouse the children's curiosity in the theme and to provide opportunities for children to talk about the theme from their own perspectives.
b) Complication – This stage creates a theme-based dilemma which requires resolution.

c) Climax – This stage increases the tension and provides the need for an explanation.

d) Resolution – This stage rewards the active participation of the children with new scientific ways of seeing the world.

Part 2: Application Phase

The second part would represent the application stage of the modelling game. This part would be designed to enable the children to apply their new knowledge in another context to help develop an appreciation of its functionality. In this part children use the new knowledge to construct their own explanatory narratives about relevant events or phenomena.

Application of the above pedagogical structure to Pam's case study questions the potential of her chosen learning context to arouse the children's curiosity and to facilitate discussion. Home insulation is arguably an adult theme and young children are unlikely to have much to say about it. As Feynman's account exemplifies, learning contexts which have the potential for the development of persuasive discourse are those which are familiar enough for children to talk about from their own experience, but also produce puzzling situations which scientific ideas can help resolve. From this perspective, I think string vests provide a potentially more productive context in which to teach children about the thermal insulation properties of air.

Example of a theme-specific plot which could be used by Pam to help improve her practice.

Theme: The thermal insulation properties of air.

Title: Why my old string vest is so special.

Exposition

Teacher brings into class an old string vest and develops a narrative about how her parents made her wear a similar one each winter. Children are encouraged to respond to the narrative and to tell their own stories about what they wear to keep to warm in winter.

Complication

Teacher declares that her parents told her that the holes in the vest would keep her warm. This always seemed a bit daft to her! How could the holes keep her warm? What do the children think? She often wondered if she would have been warmer if she had worn a vest without any holes. Children can hypothesise based on their own experiences. What do they know about other materials which keep things warm? How many of them have holes in them? Children work in discussion groups and should be encouraged to provide reasons for their views. Can any of the groups think of any good reasons why a string vest should keep us warm?

Climax

With assistance from the teacher, children design ways of testing whether the holes in materials play a part in keeping things warm. Remember, a string vest is designed to be worn underneath some outer clothing and this must be replicated in the testing. Children report on the things which they have found out and things which still puzzle them.

Resolution.

So can holes keep us warm? Of course the short answer is no. It is not the holes that keep us warm; it is the air inside the holes that traps the heat. Teacher can talk about how the holes help create a layer of hot air around the body. Children can talk about other clothes such as woolly hats or jumpers and why these keep us warm. Resolution depends on the children coming to appreciate the insulation properties of air by talking around the theme. To support their meaning making children can make reference to secondary sources of information and models/pictorial representations provided by the teacher.

Application Phase:

To appreciate the functionality of the key ideas children need to make purposeful use of them in another context. In this case children can explore how different animals keep warm. They can focus on animals with feathers and fur. This can lead them to designing and testing different models and developing explanatory narratives about how particular animals have adapted to the relevant climatic conditions. This provides a window through which to explore the important theme of adaptation.

In conclusion it is envisaged that theme-specific plots could help teachers to:

1. Identify appropriate contexts in which to teach specific concepts.
2. Provide insights into how to stage teaching and learning performances in ways which reveal the significance and functionality of the scientific ideas.
3. Understand how context, ideas, events and discourse can be arranged to evoke emotions such as curiosity, tension and satisfaction.
4. Use scientific enquiry methods, dialogic talk and other modelling tools in ways which serve to emphasise the functionality of target concepts.

When talking about successful story writing, Carver (2005) makes a point about the importance of creating unique ways of describing the world and finding the right context in which to express them.

Some writers have bunch of talent; I don't know any writers who are without it. But a unique and exact way of looking at things, and finding the right context for expressing that way of looking, that's something else (p32).

Primary science teachers face a similar challenge. In order to develop persuasive pedagogies they need to be clear about the unique vision of the world which they want to share and the right context for persuading children of the value of that way of seeing. The research indicates that this is a tall task for many primary teachers and is unlikely to be achieved without the development of concept specific pedagogic structures to help them. I suggest that the notion of theme-specific plots provides a potentially fruitful way forward and an interesting focus for further research.

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