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ABSTRACT

This document discusses the state of science education in primary school before and after the introduction of the National Curriculum in 1989 established science as a core subject. The first half describes research and specific efforts to improve science education in the primary grades. It includes the following sections: (1) "Background to the National Curriculum," which provides a brief overview of past efforts in curriculum reform; (2) "Implementation of the National Curriculum," which discusses strategies used to incorporate science into infant classes; and (3) "Teacher's own scientific understanding," which provides research to support the belief that teacher's subject knowledge plays a major role in effective instruction. The second half of the document encompasses the need for teachers to develop good questions. The discussion includes the following sections: (1) productive questioning in primary science; (2) unproductive and productive questioning; (3) the relationship between the teacher's scientific knowledge questioning style; and (4) suggestions for better classroom practices. (ZWH)

The relationship between teacher's own scientific knowledge and their ability to ask high level cognitive question, in order to teach the National Curriculum for Science.

Virginia Whitby September 1993 Roehampton Institute

Paper prepared for BERA Conference September 1993

Introduction

Science in the primary school has a chequered history despite many different government and educational initiatives over several years. The National Curriculum (1989) finally established science as a core subject to be studied by all pupils between the ages of 5-16. This was indeed a move to be applauded but there have been many concerns and issues raised as a result of such a step.

Background to the National Curriculum

One of the main problems that had prevented science from becoming an accepted part of the primary school curriculum related to teachers lack of scientific knowledge and understanding. Many primary school teachers did not receive any science training during their own initial teacher training. As Black (1980) wrote:

'Many primary teachers probably have a strong aversion to physical sciences, which they last experienced in secondary schools where the didactic and factual approach left them with no experience of the type of work now required'.

One of the main reasons for science initiatives such as the Schools Council Science 5/13 (1971) not being implemented and taken on board in the way that had been anticipated, related to the lack of science training during initial teacher training courses. In 1980 a survey showed that Science 5/13 had only been studied seriously in 30 per cent of schools and was only being used in 22 per cent of schools. It was mainly successful in schools that had been involved in the pilot studies and therefore had received good input from the team.
In 1978 the HMI report noted that science, when it did occur in primary schools was less well matched to the needs and abilities of the pupils than other areas of the curriculum giving cause for concern.

In 1985 the Department of Education and Science produced Science 5/16 a Statement of Policy which detailed the need to provide a broad and balanced science curriculum for all children of compulsory school age. This was an unprecedented step, no curriculum area had ever before received a government statement of policy. This indicated the level of concern at the lack of scientists available in the job market and the need for schools to play an integral part in positively promoting science. The publication of this policy statement was supported by the introduction of government funded Educational Support Grants. These grants ran for a three year period to provide advisory teachers and resources for training teachers in schools. Local Education Authorties were invited to bid for these grants and eventually over a four year period every LEA in England and Wales was awarded a grant. Throughout this period the level of science taking place in primary schools increased in general, but there were still schools who chose not to take part. Such schools still regarded science as a new and unnecessary area of the curriculum. As this initiative was prior to the national curriculum legislation, schools still had the option not take science seriously.

Implementation of the National Curriculum

The national curriculum was introduced to primary schools in September 1989, with key stage 1 children aged 5. Many infant classes traditionally provided a number of activities relating to water play, sand play and other general interest areas that were scientific in their focus. However, these were not necessarily identified as science by the class teachers, although many primary schools did consider they had a responsibility to introduce children to 'nature study', as part of their everyday world and environment. Science, in particular physics and chemistry had a traditional reputation for being concerned with older children, a subject to be introduced at secondary school level.

Many infant schools were well placed to implement the national curriculum as they had taken part in work with advisory teachers funded by the Educational Support Grants during the previous four years. However, as previously stated there were some schools that were ill-equipped to cope as they had never before considered science as part of the primary school curriculum. Now however, there was no further funding for the implementation of the national curriculum, with regard to resources that schools may need to purchase. Nor was there any training for teachers in science, other than on an adhoc local basis. There was no suggestion that a full training programme prior to implementation be put in place, to develop primary school teachers' own scientific understanding with particular reference to the scientific demands of the national curriculum. There were local training sessions to consider implementation of the national curriculum as a whole.

Teacher's own scientific understanding

There was much evidence from research conducted prior to the implementation of the national curriculum that the level of teachers' own subject knowledge had an effect upon their teaching. Calderhead, Miller, McNamara (1986), conducted a study among PGCE students following primary teacher training courses. The debate centred around teachers' subject matter knowledge relating to the primary school curriculum. The students felt their subject knowledge for the primary school was patchy. While they felt knowledgeable in some areas, they felt quite ignorant and incompetent in others. The students regarded knowledge of a subject area helpful in several respects:

- knowledge of sources of reference material, facts and ideas therefore a help to planning,

- evaluation and direction enabling students to decide what are worthwhile activities and how one might lead to the next,

- as a contribution to diagnosis,

- a fund of knowledge to draw on in response to pupil questions and unexpected classroom events, providing confidence for the teacher,

- enthusiasm - more knowledge therefore more confidence and more enthusiasm.

Calderhead, Miller, McNamara (1986)

Another study conducted by Barnes and Shinn-Taylor (1988), into teacher competency in five primary schools in North-East England highlighted science as a particular area of concern. Science was identified by the majority of teachers themselves as an area of 'low' competence. By the time this study was conducted it had been announced that science was to be one of the three core subjects of the national curriculum. Many of the teachers involved stated that·

"their own backgrounds had not been 'science-orientated' and that they therefore required a great deal of assistance to improve their own confidence".

The teachers went on to identify three main problems for the primary generalist attempting to implement science in the primary classroom:

- lack of appropriate scientific background and personal 'know-how',

- lack of suitable facilities and equipment,

- lack of relevant in-service courses or classroom assistance.

It was clear again that the main obstacles to effective science teaching in the primary school centred around teachers own lack of scientific knowledge and confidence. However, despite both of these studies the government chose not to provide courses for primary teachers prior to the implementation of the national curriculum in September 1989. No research was conducted into the appropriateness of the primary sectors ability to teach the science demanded by the national curriculum.

A further study conducted by Kruger et al (1990), on primary school teachers concepts of energy again highlighted a lack of scientific knowledge. The teachers' responses showed numerous examples of personal conceptions of energy which differed radically from the scientific perspective. The notion of energy is one of the fundamental concepts of science and yet is an elusive idea to pin down, perhaps because of its inherent difficulty. The word 'energy has also aquired a wealth of meanings from social usage, which children (and teachers according to Kruger's research), find difficult to dissociate from the symbolic 'life-world' meaning. They concluded that primary school teachers were ill equipped to teach science since they hold views of scientific concepts which are in conflict with accepted scientific theories.

However, in 1990 the government set up training courses for science co-ordinators in order to develop their scientific understanding and their role for helping the implementation of the science curriculum within their own school. These courses were set up as a response to concerns expressed by many teachers, headteachers and LEA's. The courses are still currently running and are funded for 20-days as Grants for Education, Support and Training (GEST) courses. These courses are usually provided by colleges of higher education and universities. They are highly regarded as helpful and successful in developing primary teachers understanding of science both in general and in relation to the national curriculum, also enhancing teachers own confidence to implement science at whole school level.

The importance of productive questions in primary science

Whilst conducting research in an infant school during the implementation of the national curriculum 1989/1990, I was interested to ascertain whether primary school teachers used high level cognitive questions within their science teaching. The majority of previous research showed that as a general rule teachers did not use high level cognitive questions they tended to use low level recall questions. There has been much debate concerning questioning for the last hundred years:

" Questions are as old as speech itself and the use of questions in teaching is at least as old as classrooms. Studies of questions may be traced from pre-socratic philosophers through till modern times " Brown & Edmonson (1984).

However, with the introduction of the national curriculum questioning had once again been identified as an integral part of the teaching and learning process. The non-statutory guidance for science in the national curriculum (1989) recognised the importance of high level cognitive questioning. In science teaching, questions are often used to enhance understanding, but should be of a form which invite children to express ideas in a way that encourages the development of those ideas.

'Productive' questions are seen as those which stimulate productive scientific activity, whereas, 'unproductive' questions do not lead to scientific activity, but promote the recall of factual knowledge. Jelly also regards 'unproductive' questions as those which a child, either knows the answer to or, if not he obtains the answer from secondary sources:

"Such questions may have a place for encouraging conversation or development of reading skills, but as a starting point for scientific activity they are very limited and unproductive" Jelly (1985).

Jelly (1985), identifies the following as the main features of productive and unproductive questions in relation to primary science:

Unproductive Questions

1) Promote science as information.

2) Answers derived from secondary sources talking/reading.

3) Tend to emphasize answering as the achievement of a correct end product (the right answer).

4) Successfully answering is most readily achieved by verbally fluent children who have confidence and facility with words.

Productive Questions

1) Promote science as a way of working.

2) Answers derived from frist-hand experience involving practical action with materials.

3) Encourage awareness that varied answers may each be 'correct' in its own terms learnt in the process of arriving at an answer.

4) Successful answering is achievable by all children.

In my view productive questions are the type we need to encourage in the classroom, but experience and research shows that teachers ask far more unproductive questions than productive ones, and that frequently teachers find the framing of a productive question difficult. Jelly(1985) suggests:

"this is not surprising as most of us acquire our formal education in an environment that tended to require factual answers. However, productive questions are a very powerful tool for the teacher. They have tremendous value in planning science work and are extremely useful in allowing the teacher to make an instant response to something a child says or does. They are also the type of question we want children to develop if we are to encourage them to find their own problems for investigation".

Elstgeest (1985), again within the context of primary science examines different types of productive questions that teachers ask and suggests they fall into the following categories:

a) Attention focussing questions
b) Measuring and counting questions
c) Comparison questions
d) Action questions
e) Problem posing questions

These are the ways teachers ask questions starting with the straight forward 'have you seen' or 'do you notice' progressing to 'can you find a way to?' or 'what happens if' type of question. At the more complex end of the scale children are needing to find a solution to form a simple hypothesis and consequent verification. The non-statutory guidance for science (1989) states:

"Understanding the range of questioning techniques and their use in the classroom will enhance the effectiveness of learning in science. During the planning of a science activity it is important to think about lines of questioning which seem likely to be productive".

Obviously the ideas children have initially may be changed as a result of what they do, what they see and how they interpret what happens. Science for young children concerns basic ideas which can emerge from simple investigations of objects and materials around them. It is important to take account of the way children learn at primary level, where thinking and doing are so closely related:

"Science begins for children when they realize that they can find things out for themselves by their own actions: by sifting through a handful of soil, by blowing bubbles, by putting salt in water" Jelly (1985)

Relationship between teacher's own scientific knowledge and teacher's questioning

When conducting my own research, in order to open up a dialogue with teacher. about questioning, I felt it would be beneficial to provide some material for them to comment on as a starting point. This would hopefully enable them to articulate their ideas and views about questioning and help them to begin to examine the underlying issues.

I provided the teachers with two lists of questions relating to two different topics, water, ourselves. They discussed their views of the questions and were asked to grade them on a 1 - 5 scale. Their discussions were also tape recorded. In analysing their completed questions sheets in relation to the taped discussion, two particular patterns emerged:

1a) Teachers classified questions as 'productive' only if they were seen as appropriate for the age of children they were currently teaching.

1b) Teachers classified all other questions as 'unproductive' ie. inappropriate.

2) Teachers classified questions as 'productive' only where they themselves understood the scientific concepts involved, and could therefore envisage ways of developing these with children.

It was clear from their discussions that the teachers were able to make distinctions between what they regarded as productive and unproductive questions. However, during their discussions it became clear that although they could make that distinction they would not necessarily be able to use productive questions. Evidence was emerging that teachers did not feel they could ask productive questions when they lacked the scientific knowledge. The two questions which promoted most discussion among the teachers both require a knowledge of Archimedes' Principle and relate to the concept of density. One teacher stated:

"I am not sure myself what causes things to float or sink".

Once such open honesty had been voiced, the teachers were all quick to agree that although they regarded the questions as productive, they personally felt unable to use them as they lacked the scientific knowledge and understanding .

Despite a substantial body of evidence to suggest that many primary school teachers lack an understanding of scientific concepts the in-service training is still very limited. How can teachers be expected to ask meaningful and productive questions to develop childrens' thinking when they lack an understanding of the concept themselves? Or perhaps more importantly lack the confidence to tackle science as a major part of the primary school curriculum.

It is clear from several previous research studies that teachers' own knowledge particularly in primary science, has been a major source of concern in the primary school for many years. The notion of the primary school teacher as a generalist is increasingly considered an out dated model. The demands of the national curriculum are increasingly pressing for specialist teaching in the primary sector. There is also a suggestion that an examination is required of:

"that most sacred of primary 'sacred cows' - the class teacher system. Its strengths and weaknesses are being debated; it is no longer a given in the discourse about primary education" OFSTED (1993).

McNamara (1991), agrees with the arguments put forward by several previous writers including; Shulman 1986, Grossman et al., 1989, Mcdairmaid et al., 1990, that the following points should be given careful consideration:

- If the aim of teaching is to enhance children's understanding then teachers themselves must have a flexible and sophisticated understanding of subject matter knowledge in order to achieve this purpose in the classroom.

- At the heart of teaching is the notion of forms of representation and to a significant degree teaching entails knowing about and understanding ways of representing and formulating subject matter knowledge so that it can be understood by children. This in turn requires teachers to have a sophisticated understanding of a subject and its interaction with other subjects.

- Teachers subject matter influences the way in which they teach and teachers who know more about a subject will be more interesting and adventurous in the ways in which they teach and more effective. Teachers with only a limited knowledge of a subject may avoid teaching difficult or complex aspects of it and teach in a didactic manner which avoids pupil participation and questioning and fails to draw upon children's experience.

- Knowledge of subject is necessary to enable the teacher to evaluate text books, computer software and other teaching aids and mediums of instruction.

- During their own education student teachers will have acquired knowledge of subjects in both school and during higher education courses. They may therefore have developed attitudes towards the way in which a subject is studied and misunderstandings which need rectifying if they are to teach their subject successfully in school.
McNamara (1991).

Shulman (1986) made an important distinction between two domains of teachers' knowledge, 'subject knowledge' which is knowledge and understanding of the subject itself and 'pedagogic content knowledge' which is knowledge about how to apply the subject when teaching it.

" A number of educationalists have sought to demonstrate that providing students with pedagogic content knowledge gives them the foundation to plan and prepare lessons, access their pupils' knowledge and be better able to match instruction to the needs and abilities of pupils. There are those who go further and claim that teachers' pedagogic content knowledge affects the quality of their teaching" McNamara (1991).

Future approaches to primary science

Two recent documents both highlight issues relating to teachers' knowledge. OFSTED (1993), in identifying factors associated with better classroom practice suggests:

" The improvement of teachers' subject knowledge was widely acknowledged as of central importance if primary schools were to make the looked-for progress with teaching the National Curriculum". OFSTED (1993).

The National Curriculum Council (January 1993), provided advice to the Secretary for Education on the current situation regarding the national curriculum at key stages 1 & 2. They suggest that further guidance and training be provided in subjects which are proving problematic. Science is clearly one of these subjects. They further state that classroom organisation, curriculum planning, and teacher knowledge are not adequate to support the delivery of the national curriculum.

" The introduction of the national curriculum forces a reappraisal of much current primary practice and highlights the importance of adequate teacher training and support to meet the new demands." NCC (1993)

The NCC (1993), suggest that further support and guidance should be provided for existing teachers, whilst a reform of initial teacher training should ensure that new entrants are fully equipped to teach the National curriculum.

There are very clear demands for more support for teachers in order to enhance their delivery of the national curriculum. Research led by Bennett (1993), asked 900 teachers how competent they felt in national curriculum subjects:

"Most felt confident in maths and language, but in other subjects over half felt unsure." TES 30.4.93

Clearly there are many problems for both teachers and those currently involved in Initial Teacher Training. With concern being expressed by many different agencies the issues must be addressed with urgency. Until these issues are addressed there will continue to be a lack of cohesion across schools in the delivery of the national curriculum. Thus defeating the whole point of having a national curriculum.

The Secretary of State for Education has recently (May 1993) released a draft circular which considers new proposals they include:

- Specialist courses for those teaching seven to 11 year olds,

- Improving teachers' knowledge of their subjects,

- Pay particular attention to the core subjects.

What is becoming increasingly apparent is the move towards subject specialism teaching particularly at the top end of key stage 2, years 5 and 6. It is probable that these teachers will predominantly be those following the one year PGCE course, and the primary generalists will be those following the B.Ed./BA. QTS course. The possibility of 'Mums army' working with key stage one children will also have enormous implications for those teaching key stage two children.

There have not as yet been any new announcements in relation to further in-service training for teachers, though the 20-day GEST courses are still running. Many publishers are producing new curriculum materials to support teachers in their classrooms. These are obviously varied and with the recent changes in the National Curriculum documents some relatively recent publications are now outdated. This poses great problems for some schools who made heavy financial investments in these materials as a source of support for their science teaching.

What is clear in order to enhance and develop the standards of science in our society, is that schools require more support in terms of both training for teachers and resourcing science.

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