AN INVESTIGATION INTO A CONSTRUCTIVIST APPROACH TO RAISING PRIMARY TEACHERS' CONFIDENCE IN TEACHING SCIENCE.

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Abstract

This research has attempted to show that with a programme of continued professional development based on constructivist principles that teacher confidence and subsequently teacher effectiveness can be increased. No attempt has been made to marry the teacher's own professional development and confidence in teaching science using a Vygotskyian approach (Vygotsky, 1978). There is no evidence for this linked with the demonstration of techniques that teachers can use with children even by classroom coaching approaches.

This programme has been based mainly on these research questions:

1. How can the confidence of teachers be analysed and what evidence of increased confidence in this group of teachers can be found?
2. How can a constructivist approach be used to improve teacher effectiveness in teaching science?
3. How can methods of assessment of children's ability be used to assess 'understanding' rather than 'recall' of scientific concepts?
4. What evidence was there that children's and teachers' talk had developed as a result of the intervention?

The programme has developed teacher confidence by raising key scientific concepts and pedagogies through a series of workshops and developing these by using in-class support sessions where particular scientific ideas were appropriately addressed and made accessible to children. The research also demonstrated to teachers, that the ideas children held and were typical, as shown by many other researchers as cited extensively in Driver *et al.* (1994).

Teacher confidence in teaching and developing science was judged by a series of questionnaires based on the ideas of Enochs and Riggs (1990) but covering the main topics in science and scientific enquiry with the questionnaires, containing the same questions, allowing a longitudinal comparison to be made. These were analysed by simple mean values and were displayed using bar graphs. Teacher confidence was also judged by the extent of the effectiveness with which they used the strategies in their own teaching, demonstrating not only a change in teacher practice but also a change in their epistemology, the latter being much more difficult to change. This research has shown a considerable increase in teacher confidence after the second year of support thus agreeing with Hussey *et al.* (1999) that continued professional development takes time, resource investment and a mindset from the teachers. These were analysed by researcher observation, field notes and transcription of conversations. The number of subjects in each of these analyses varied, so they are quoted as percentage values, as are the attainments of children.

Children's attainment has been assessed in their developing skills of communicating scientific ideas more cogently. This has illustrated their developing understanding assessed by observation and differences in attainment for research devised tests and national tests, focussing particularly on the children's ability to apply their scientific ideas to different contexts. All these were compared to published national performance and analysed statistically using *t-tests*.

Finally part of the research was triangulated by use of an independent questioner interviewing the Headteachers from the primary schools. This was to validate, as far as possible, the evidence the researcher made in the observations of the teachers' changing practice and the impact the intervention had on the children.

List of Abbreviations

Abbreviation	Meaning
ASE	Association for Science Education
CLIS	Children's Learning in Science Project
Dcsf	Department for Children, Schools and Families
DES	Department for Education and Science
GCSE	General Certificate of Secondary Education
GEST	Grants for Education Support and Training
HE	Higher Education
HMI	Her Majesty's Inspector
ITT	Initial Teacher Training
INSET	In-Service Education and Training
LA	Local Authority
LEA	Local Education Authority
NCTAF	National Commission on Teaching and America's Future
NFER	National Foundation for Educational Research
NVR	Non Verbal Reasoning
PSTS	Primary Schools Teachers and Science
PGCE	Post Graduate Certificate in Education
Ofsted	Office for Standards in Education
QCA	Qualifications and Curriculum Authority
QTS	Qualified Teacher Status
SAT	Standard Attainment Tests
SSCR	Secondary Science Curriculum Review
STEBI	Science Teacher's Efficacy and Belief Instrument
TTA	Teacher Training Agency

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1. Preliminary Discussion

1.1 Introduction

The basic principles for this research coincide with my own philosophy of science education. This is an approach based on what helps children learn. There are two main precepts:

- Enjoyment and challenge within science activities
- Building on what the children already know or can do

When I was teaching, I supported the children to enhance their skills, I monitored their skills and knowledge by designed outcomes and the children's success was evidenced in the conclusions they came to and the quality of the evidence they presented in order to support their arguments. It is this philosophy which has driven the aims and methodology in this research.

This chapter will consider the impact of the National Curriculum on learning by children and the epistemology of teachers. This leads on to the need for continued professional development and the philosophy surrounding how this will be delivered. This method of delivery and the surrounding principles will also link to the way in which children learn and develop their scientific expertise.

1.2 The research questions

Following initial readings and the pilot study considering the structure of the research the following research questions were thought to be the most important:

1. How was the confidence of teachers analysed and was there evidence of increased confidence in this group of teachers?
2. How was a constructivist approach used to improve teacher effectiveness in teaching science?
3. How were the various methods of assessment of children's ability used to assess 'understanding' rather than 'recall' of scientific concepts?
4. Was there evidence that children's and teacher's talk had developed as a result of the intervention?

1.3 Impact of the National Curriculum

Education policy, driven by government officials, is mainly conceived by those who have managed to succeed with the traditional education system. Those people who are clever and do not fit in to the rigidity of the school system, or do not see the importance of exams, will not achieve in the traditional sense (or become entrepreneurs!) - so the traditional system prevails. The policy passed down to schools by government puts many of them under pressure to produce high attainment in nationally set examinations. The early National Curriculum for Science emphasised a very prescriptive content for science for the primary curriculum, as well as the investigative nature of science. I found, however, that children could recite correct answers within their classroom science. For example the water cycle, addressed throughout the National Curriculum - when aspects of the water cycle were presented in new 'everyday' contexts, it became evident the children could not apply their knowledge to this different activity. In the constructivist epistemology, which I had unknowingly used, they had not 'reconstructed' the knowledge. The increased scientific knowledge of teachers, alongside their own experiences of science education, led to a practice seen in many science classrooms of science providing the 'right answer'. A quote I often heard from teachers was "What is the right answer then"? or "Have I got it right"? They were exhibiting in their practice a more behaviourist epistemology. Science education was not simply about giving them the 'right answer' because the 'right answer' in science develops and changes. The science experience produces a framework which allows for better and more fruitful explanations than previously held concepts. The evidence produces a more coherent idea that is simpler to understand and more powerful in its ability to explain natural phenomena. Thus, initially, the National Curriculum was a performance driven science curriculum placing the emphasis on correct knowledge rather than interpretation, there was a greater emphasis later, on scientific enquiry. However a good thing was the raising of the profile of science in the curriculum, but this led to greater need for continuing professional development.

1.4 Importance of Continued Professional Development

As a result of the imposition of the National Curriculum in schools, many primary teachers, without a sound knowledge base, were in an invidious position and obviously needed support and continuing professional development. In the early stages of the introduction of the National Curriculum much of the training and research concentrated on the writing of science policies and setting up schemes of work and improving the knowledge base of primary teachers. Much of the funding from Grants for Education Support and Training (GEST) and courses provided by Local Education Authorities (LEAs) and organisations such as the Association for Science Education (ASE) was directed towards one or more of these purposes.

This research has been founded on a constructivist philosophy, so has provided an emphasis based on evidence gathered from investigative activities rather than providing the teachers with the 'right answer' and this had a profound effect on how the after school workshops were constructed. These after-school workshops consisted of three main themes, an input session from a provider on the key concepts of the science (appendix 1), a discussion section for the teachers and a 'hands-on' session where the teachers tried out some of the activities suggested and gave scientific explanations. Scientific knowledge and understanding of facts was seen to be important but this was used to interpret the evidence, so scientific ideas could be communicated effectively.

The philosophy and methodology of the workshops needed careful consideration because of three main constraints:

- The variation of teacher knowledge, experience and expertise (their personal constructs);
- The need to deal with pedagogic and scientific knowledge and
- The time allowed and commitment for the staff to attend.

I had a strong feeling with respect to the In Service Education and Training (INSET) that it might provoke an opinion from the teachers rather akin to, "That is all very well in this situation, but that won't work with our children", (a comment given at an ASE presentation). This was a major issue here, because the town in which the research was being carried out had many areas of social deprivation and I had a suspicion that teachers would be reluctant to try strategies where they would release some control, giving the children more freedom of thought to suggest their own ideas. Hence the approach of working with the teachers' own children in an environment with which the children were familiar, to demonstrate the strength of the ideas and the activities and approach I was proposing. The provider needed to speak from a position of strength and commitment and has to either make the teacher's job easier or empower them to do it better. In a way it has to be plausible, intelligible and fruitful! This is a quote from Posner *et al.* (1982) referring to developing children's scientific understanding, but the idea can equally be applied to a change in teacher's practice. It was intentional, in the workshops, to refer constantly to 'what primary children think, can your children do this? You will find that...', because these things would happen in their schools, which lent credibility to the workshop content and strategies.

A lack of science expertise which in turn produced a lack of confidence and had restricted progress in Key Stage 2, despite the increased knowledge base, "Teachers' knowledge of science has improved considerably over the last few years", (Ofsted, 1999; 2004). This research has shown, from the case studies, that there was still a tendency to restrict children's questioning by giving stock answers, which end the questioning rather than provoking deeper thought. Harlen and Holroyd (1997) found that even though knowledge was increasing, this in itself was not a complete answer, the teachers needed support in devising and planning investigative work. This can be attributed to a lack of confidence in the primary teachers which may prevent them exposing possible weaknesses in themselves. Also primary teachers, through lack of knowledge, can give what is to them and the children, a satisfactory explanation, but it may be based on incorrect science, for example incorrect drawing of a particle diagram for liquids (also incorrect in the textbook they were using) and incorrect interpretation of forces operating when an object was travelling at a constant speed.

National data about the science qualifications of primary teachers has found that only 14% of primary teachers had some formal qualification in science, including O-level, GCSE or A-level, with the number having taken science as a main subject in a first or higher degree was even smaller being only 2%. Still Ofsted has found that most primary science is taught by class teachers with few science qualifications or none at all (House of Lords report, 2000). The small sample of teachers in this study mirrored these figures as 12% had a science qualification and only one teacher in 87 sampled had studied a science based subject to degree level.

Despite primary teachers' continuing lack of confidence in their own subject knowledge, Ofsted findings have shown that "science in the primary school is one of the major successes of the National Curriculum" (House of Commons report, 1995), they refer to curriculum and lesson structure and organisation and knowledge from experience of teaching and from national tests. This has been in part by raising the profile of science in the primary school curriculum, yet primary colleagues were expected to bring the children to a level of expertise that might be held by secondary teachers in their specialism. This meant that there was an obvious area for development to help primary teachers in devising strategies for conceptual development aligned to challenging teaching approaches, but paying cognisance to the professional qualifications of teachers, which tended not to be scientific qualifications.

Following initial observations of science lessons, science specific issues within this intervention were seen to be:

- teachers needed to be familiar with children's ideas about science topics. If the teachers were to intervene and children make progress, they had to be comfortable with the notion that these children's ideas were typical of a larger population. This was found from the pilot studies;

- teachers needed to be aware of the additive nature of scientific ideas;
- teachers needed to develop the skills for addressing the understanding of science and not simply 'doing' science (Hodson, 2006). 'Doing' science here refers to that practice of the children following the mechanics of an investigation, but without using the investigation to develop scientific thinking and
- raising the subject expertise of primary teachers by addressing key scientific concepts. They cannot be specialist scientists having a wide knowledge, but they are capable of assimilating some key concepts.

These were allied to the raising of teacher subject expertise; I could not, nor could they, be expected to raise their subject expertise to that of a secondary teacher holding a science degree. However they were adults and they could apply some key concepts in promoting children's learning. The full list of key scientific concepts is given in appendix 1.

1.5 Importance of children's scientific development

The development of children scientifically was fundamental to this research and this had to be demonstrated in two ways, in assessment of attainment for example in tests, comparing these with national Facility Values (which are the average attainment of a large sample of pupils nationally for national tests) and assessment of understanding in less formal activities in the classroom. The former was necessary to demonstrate improvement in national tests (an important issue with many school leaders) and the latter to demonstrate increased confidence and scientific communication, achieved by using interactive work to assess the level of difficulty that children had or appeared to have in different areas of the curriculum. This had to be achieved working with the curriculum materials used by the primary schools and with devising new teaching ideas where there were perceived difficulties for the children. Several sources of research (Driver *et al.*, 1994; Summers and Kruger, 1994, 1991-1995 in their series of publications) have shown that many children hold certain ideas about certain scientific topics, which were not completely in line with the accepted scientific view. The teachers had to exploit the work covered in order to bring out fully the children's understanding. A quote from one primary teacher was *"it is knowing what question to ask next that is important"*. In order to achieve this, knowledge of science was not the only requirement for primary teachers - the range of pedagogic techniques was equally valuable.

1.6 Methodology

Following the perceived needs of teachers and my initial observations of the science work in the primary schools, the methodology centred on the main themes of:

- Interviews with Headteachers, science coordinators and teachers to elicit information about policies and practices within the various schools, to determine some key issues;

- INSET training sessions through workshops to raise the key concepts, provide discussion between peers and provide examples of activities the teachers could use;
- Work with teachers with their own classes to demonstrate and promote the effectiveness of strategies used in order to raise children's confidence and attainment in assessment tasks and in communicating their own ideas;
- Work with children in the primary schools both to develop and assess their capabilities in science;
- Assessment of developing children's attainment, both in class and in National Tests and
- Triangulation interviews with Headteachers to assess the validity of the evidence about teachers' increased confidence and the children's increased confidence to express their ideas scientifically.

Following initial thoughts the plan for the research was according to Figure 1.1

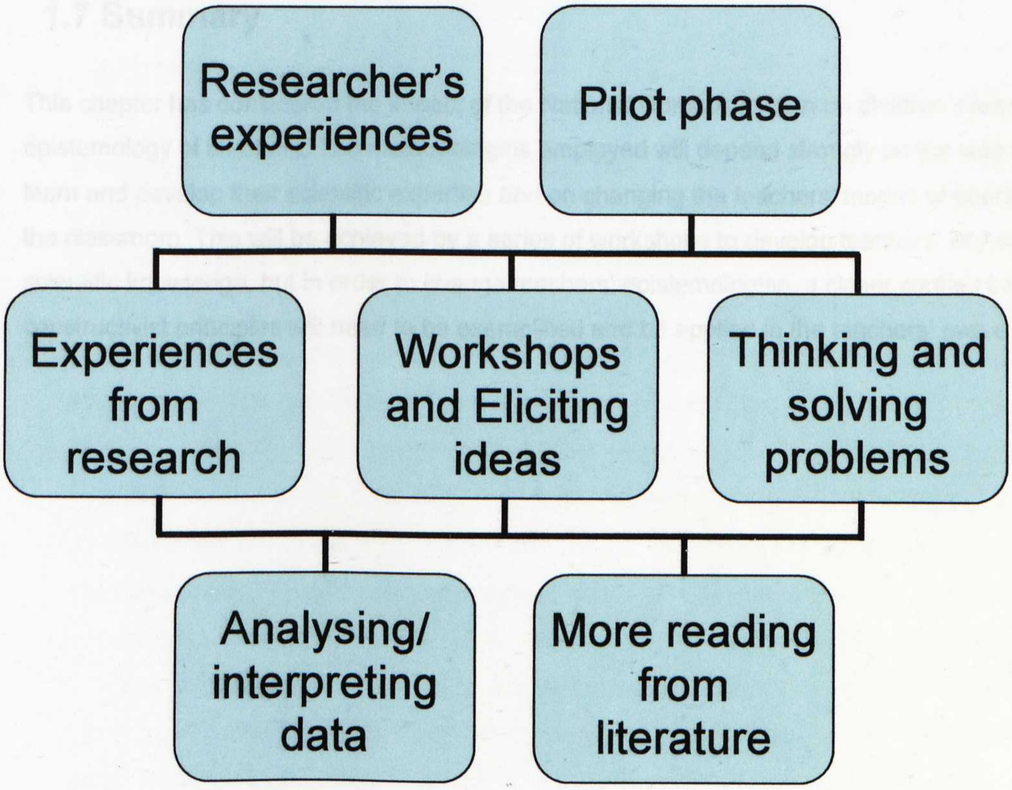

Figure 1.1 Developing phases of research

The methods were in line with the university's ethical requirements and permission to work with children and teachers was granted by the university.

1.7 Summary

This chapter has considered the impact of the National Curriculum both on children's learning and the epistemology of teachers. The methodologies employed will depend strongly on the way children learn and develop their scientific expertise and on changing the teachers' modes of operation within the classroom. This will be achieved by a series of workshops to develop teachers' key concepts of scientific knowledge, but in order to change teachers' epistemologies, a closer contact based on constructivist principles will need to be exemplified and be applied in the teachers' own classrooms.

2. Theories of learning

2.1 Introduction

Learning is a complex process with many different facets and many psychologists have contributed to our understanding of how to make learning more effective. There are different theoretical bases of how learning takes place and these could be placed on a spectrum of learning styles. Here, behaviourism is compared with constructivism with the advantages and disadvantages of these two contrasting epistemologies highlighted. Behaviourism with its transmissive approach where knowledge is considered as a commodity transferred from the teacher to the learner, promotes a restrictive style of teaching with an emphasis on truths. Positivity is observable, which fits in with the scientific viewpoint, but does not take into account that the scientific viewpoint is subject to change. Constructivism expects us to reflect on our own experiences and learning involves adjusting our mental models to accommodate these new experiences (Von Glasersfeld, 1989). What a teacher believes about how learning takes place, whether knowingly or unknowingly, will influence how they operate within the classroom. Constructivism in its various representations emphasises the importance of the learner being an integral part of the learning process. The development of constructivist theories from radical, social and interactive constructivism is discussed. Comparing radical and social constructivism, where radical constructivism considers the learner as an individual who knows or understands, and social constructivism where a consensus view of scientific knowledge is highlighted. Interactive constructivism allows for the conflicting views between radical and social constructivism.

How to translate the learning theories into classroom practice is discussed. The existing teacher epistemology has a profound effect on teacher practice, for instance a teacher may be reluctant to let go of some measure of control in that they don't want to teach them something that is wrong, yet if we are to change teacher strategies intuitively, constructivist approaches must be used. Teachers who need to develop new skills and adopt a new approach must take account of how children learn as well as what they learn, yet most INSET is behaviourist in nature and ignores the former aspect. The views of Vygotsky (1978), that learning takes place more effectively if there is a dialogue between the teacher (expert) and the learner will become an important feature of this research.

Children's scientific ideas have been highlighted by many researchers and these are well documented, as well as children holding onto these original conceptions despite teaching. Hence demonstrating, using practical examples and using evidence, provides a different emphasis on teaching science that the teachers have not been used to. The importance of dialogue in learning in what has been termed a Non Threatening Learning Environment (NTLE), written work using the sequence of think → talk → write and the importance of language and the emphasis that the teacher places on the children communicating their own ideas scientifically, are all considered to be important features of learning.

2.2 Impact of learning theories

Different learning theories related to science should, and indeed have, influenced both research and classroom practice. This discussion explores Behaviourist and Constructivist epistemologies and the effect these are likely to have both on teachers and learners. The results of research findings have profound implications for changing practice in providers of teacher professional development. A lot of teacher INSET is modelled more on a behaviourist philosophy whereby the provider will model the new skill and the learner will assimilate these behaviours, especially if the provider has desirable qualities such as credibility or position. Behaviourist theory treats the learner as a black box who processes knowledge and it stresses the absolute and permanent character of knowledge. The Modernist rise of experimental sciences led to a view of knowledge which is still explicitly or implicitly held by many people today, that is viewing knowledge as a set of facts, reinforced by the observation of external data, through our senses. Here knowledge itself is absolute but limited by our observations of reality, even though these become more and more precise as experiences accrue.

If the teacher is to develop a new epistemology, then a more constructivist approach may be needed so that the teacher can adjust their mental model to accommodate these changes. Teachers' views, whether overt or covert, about what teaching is, how we come to know, or how children learn make up our own 'philosophies' which are reflected in and guide our practice. Teachers may not actively think about their epistemological stance in their day to day work but undoubtedly this will have an impact on the way they teach and will lead to the assumption that their preferred practice will produce effective learning by the learner. As Ernest (1998) argues, all practice and theories of learning and teaching rest on an epistemology, whether articulated or not. These epistemological beliefs about knowledge and how we come to know are not only long standing, having their roots in the work of Plato, Socrates and Aristotle, but they are also fundamental.

2.2.1 Behaviourism

Behaviourism is at one end of the epistemological spectrum, it was developed during the 1950s, most notably by Skinner (1953) and began to exert an influence on educational thinking. Behavioural psychology limits its focus to observable behaviour and not to underlying phenomena, such as understanding, reasoning and thinking (Good and Brophy,1990). Behaviour changes as a result of conditioning, that is the children's efforts to accumulate knowledge of the natural world and on the teachers' efforts to transmit that knowledge. According to Fosnot (1996), a Behaviourist approach would involve breaking down the subject area into simple parts and then building these parts hierarchically into a more complex whole. This is indeed a facet of supportive teaching, but it does not take heed of any creativity on the part of the learner. Learning is viewed as conditioning and it is dependent on the knowledge of the teacher. One consequence of adopting this philosophy is that learning can be limited by the experiences of the teacher in a particular area of study. In addition, this view of learning links with an 'objectivist' view of knowledge: that is the existence of a body of knowledge which is transmitted by the teacher to the learner and it assumes that the learner replicates its structure and thinking. What constitutes valid knowledge is publically observable, and as such, behaviourists believe that the concept of mental states can be discarded (Freiberg, 1999).The role of education here is to interpret natural phenomena and the role of the educator is to interpret these events for the learner, so they too can reproduce them for others. This theory adopts 'memetics' where the truth, namely, the 'meme' can be passed on through social interaction and is therefore maintained, a stance which still dominates much, if not most, of science teaching. If the teacher perceives knowledge as a commodity that is typically transferred, or transmitted from one person to another, then what happens in the classroom will reflect this belief. In cases where teachers see themselves as transmitters of knowledge and the children as receivers, Jonassen (1991) describes how the objectivist epistemology translates this into an approach to teaching and learning. Classes are usually driven by 'teacher-talk' and depend heavily on written resources for the structure of the course. There is the idea that there is a fixed world of knowledge that the student must come to know. Information is divided into parts and built into a whole concept. Teachers serve as 'pipelines' and seek to transfer their thoughts and meanings to the passive student. There is little room for student-initiated questions, independent thought, or interaction between students. "The goal of the learner is to regurgitate the accepted explanation or methodology expostulated by the teacher" (p.3).

2.2.2 Constructivism - Recognising the importance of the learner

Rote learning confers some advantages when simple recall is required, but this does little to address faulty conceptions, which may be one reason why these conceptions persist (Novak, 2002). Later theories of learning recognise the importance of the mind in making sense of the material with which it is presented and here the emphasis is on the relativity, or situation-dependence of knowledge. It has a continuous development or evolution, likened to Newton's often quoted "standing on the shoulders of giants". According to Bruner (1996), learning is an active process in which learners construct new ideas, or concepts based upon their current and past knowledge. The learner selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so and conceptual understanding must be a fundamental part of that learning (Skamp, 2004). The cognitive structure (that is schema, mental models) provides meaning and organisation to experiences and allows the individual to go beyond the information given. Students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills (Chiapetta and Koballa, 2002; Mariano *et al.*, 2001). Constructivist learning requires teachers to consider that each learner will construct knowledge differently and that these differences stem from the various ways that individuals acquire, select, interpret and organize information (Adams, 2006). Thus constructivism, which is at the opposite end of the epistemological continuum to behaviourism adopts a completely anti-positivist approach, arguing that knowledge and reality do not have an objective, or absolute value or, at the very least, that we have no way of knowing this reality. Von Glasersfeld (1995) indicates in relation to the concept of reality, that 'It is made up of the network of things and relationships that we rely on in our living, and on which, we believe, others rely on too' (p.7). The knower interprets and constructs a reality based on experiences and interactions with their environment. Rather than thinking of truth in terms of a match to reality, von Glasersfeld focuses instead on the notion of viability where 'To the constructivist, concepts, models, theories, and so on are viable if they prove adequate in the contexts in which they were created' (p.7).

A constructivist's concepts of 'real' and 'reality' are specific to the learning theories. The world is the way it is and that which is considered 'real' learning is making as much sense of observed phenomena as possible and in as many circumstances as possible. To constructivists this is 'the reality'. Although constructivism is well established as a learning theory it continues to attract research attention (Bransford *et al.*, 2004; Lawson, 2002; Miller *et al.*, 2000).

2.2.3 Views within Constructivism: Radical Constructivism versus Social Constructivism

Even within constructivism there is a spectrum of views represented at one end by von Glasersfeld who typically holds the views of a Radical Constructivist and there are other similar ideas such as Individual or Cognitive constructivism (Duffy and Cunningham, 1996). These views of constructivism are concerned with how the learner as an individual understands things. This will be impacted upon by learning styles and conceptual developmental stages. Here learning and making sense rests entirely with the individual. Under cognitive, individual and radical constructivism each of us generates our own rules and mental models, which we use to make sense of our experiences. Learning, therefore, is simply the process of adjusting our mental models to accommodate new experiences and the consequence is that there can be many different interpretations of events. Constructivism changes the concept of knowledge, instead of knowledge being a 'representation' of what exists. Knowledge becomes a mapping of what, in the light of human experience, turns out to be feasible.

At the opposite end of the constructivist spectrum, social constructivism which assumes that new meaning about natural phenomena arises to a large extent out of a dialogue, a social interaction often between a 'novice' and an 'expert,' that is the learner and the teacher. This is rooted in Vygotsky's (1978) ideas that learning will take place better, or more effectively, with the help of an expert other, provided the learner is in the 'Zone of Proximal Development'. Here the Zone of

Proximal Development is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers (Vygotsky, 1978:86). What children can do with the assistance of others is even more indicative of their mental development than what they can do alone (Vygotsky, 1978:85). This aligns with so called 'Socratic Learning' where the teacher and learner engage in an active dialogue to arrive at an agreed reality.

Heylighen (1993) summarises this view of Social Constructivism seeing "consensus between different subjects as the ultimate criterion to judge knowledge. 'Truth' or 'reality' will be accorded only to those constructions on which most people of a social group agree" (p.2). In a science education context this will be the scientists' consensus, giving the 'accepted scientific explanation'.

If learning necessarily includes the social interaction with others this is obviously fundamentally important to education practice. The teacher in generating, or modifying, the cognitive constructions of a student and introducing the notion of social interaction, raises a problem for individual constructivists. If what a cognising subject knows is only what that subject has constructed and this may be completely different from what someone else perceives, there is no requirement for a consensus view. Conversely, in a social dialogue, ideas develop and it may be that one idea does not explain all phenomena, whereas another one does. These two ideas can then be posited against one another, to develop learning in one and strengthen understanding in the other.

The notion of knowledge being simply something that fits with one's own understanding, or a particular scientific community's view, does not sit comfortably with the nature of science. Reality must go further, it must also sit with the 'real world', it must be verified by experiment and by peer groups. Science educators need to anchor their claims to the context of the nature of science, science teaching and learning, and formal and informal learning environments. Learning is contextual: we do not learn isolated facts and theories in abstract and separate from the rest of our experiences. We link new ideas and concepts in conjunction with what else we know, including emotional factors.

2.2.4 Interactive Constructivism

Further developments of social constructivism which address this issue have been made by Reich (1998) and by Shymansky *et al.* (1997), who each use the term Interactive Constructivism. This interpretation of constructivism recognises that contemporary science is based on a hybrid worldview of knowing that stresses the importance of interactions with the physical world and the sociocultural context in which interpretations of these experiences reflect the lived experiences and cultural beliefs of the knowers (Prawat and Floden, 1994). It is evidence from nature and canonical science that supports, or rejects the interpretations, not sociodemocratic consensus (Prawat and Floden, 1994; Fosnot, 1996). The pedagogical structure for learning in an Interactive Constructive model is shared by the learner and the teacher. The basic constructivist assumptions about the role of prior knowledge, the plausibility of alternative ideas, and the resiliency of these ideas are preserved in an Interactive Constructivist perspective.

An Interactive Constructivist perspective also assumes an epistemological and ontological view of science that recognises the limitations of people and procedures in attaining an accurate interpretation of the real world, and that stresses evaluation of all knowledge claims. This evaluation requires that explanations and interpretations are judged against the available data and canonical theories using evidence from nature and a scientific perspective warrants to justify claims about reality (Kuhn, 1993; Hofer and Pintrich, 1997). The locus of mental activity and construction of understanding in Interactive Constructivism involves both a private and public component, unlike social constructivism which defines understanding as group consensus building, or radical constructivism which defines understanding as a uniquely individual decision (Hennessey, 1994; Prawat and Floden, 1994). An Interactive Constructivist perspective assumes that discourse reveals the variety of alternative interpretations but that consensus need not be reached.

While the Radical, Interactive and Social perspectives of constructivism each have their particular emphases, Ernest (1995) derives a set of theoretical underpinnings common to constructivist ideas:

1. Knowledge as a whole is problematised, not just the learner's subjective knowledge, including mathematical knowledge and logic.
2. Methodological approaches are required to be much more circumspect and reflexive because there is no 'royal road' to truth or near truth.
3. The focus of concern is not just the learner's cognitions, but the learner's cognitions, beliefs, and conceptions of knowledge.
4. The focus of concern with the teacher, and in teacher education, is not just with the teacher's knowledge of subject matter and diagnostic skills, but with the teacher's belief, conceptions, and personal theories about subject matter, teaching, and learning.
5. Although we can tentatively come to know the knowledge of others by interpreting their language and actions through our own conceptual constructs, the others have realities that are independent of ours. Indeed, it is the realities of others along with our own realities that we strive to understand, but we can never take any of these realities as fixed.
6. An awareness of the social construction of knowledge suggests a pedagogical emphasis on discussion, collaboration, negotiation, and shared meanings (p.485).

If teachers adopt a constructivist philosophy and believe that knowledge rather than being transmitted, is re-constructed through a process of assimilating different experiences and making sense of them, then they are more likely to see their role as that of a mentor of individuals who facilitates the sense-making, or re-construction process. This view of learning sees science knowledge as a set of models that attempts to represent the environment and no single model can ever hope to represent all knowledge in that area, so we have multiple models and in teaching we often use the idea of the 'good enough' model. This has in the past often been the accepted scientific viewpoint and, in a behaviourist philosophy, often represented as a 'scientific truth'.

2.3 Translating to classroom practices

The development of these learning theories led to a fresh scrutiny both of what should be taught in school science education and how it should be taught. Surveys from the Assessment of Performance unit (DES 1981, 1982a, 1982b) showed that many children found difficulty in understanding certain key scientific ideas. In addition surveys of teaching methods showed that didactic teaching was the norm in many classrooms (DES, 1979). The Association for Science Education (ASE) initiated the Secondary Science Curriculum Review (SSCR) and the Children's Learning in Science (CLIS) Project. The purpose of these two initiatives was to develop revised teaching strategies firmly grounded in what children thought and the current theories of developments in cognition.

Many studies were carried out which explored the nature of children's ideas about natural phenomena and the emphasis of the research at this time was based upon interviewing children, either individually, or in small groups and eliciting the ideas they used to explain natural phenomena. The research shows that some of the ideas that these children hold are typical of those of philosophers of previous times who wrote about natural phenomena. Different authors researched children's ideas in particular topics, thus contributing to the general body of knowledge, for example, Osborne (1981) on children's ideas about electric current; Guesne (1984) on the nature of light and how we see; Erikson (1979), on children's conceptions of heat and temperature; and Novick and Nussbaum (1981) on the particulate nature of matter. Driver *et al.* (1985), collected together and summarised these ideas, and proposed a model of learning that children will incorporate their new experiences into an existing 'scheme'. This coherence of ideas was not the view of children's thinking held by Osborne and Bell (1983), who in their studies found that children will often contextualise their ideas and be content with simple pragmatic explanations, other researchers have spoken of fragments of knowledge, with little or no coherence. The scientist's view however would emphasise the importance of a coherent theory.

As a result of these findings many researchers and adults criticised children's ideas because they were not applied consistently in what, to scientists, were collectively similar contexts. As a result of these and many other researches, it has become widely accepted that children develop ideas from their experiences outside of what they are formally taught in the classroom and since each child's experiences are unique, their ideas are personal. These ideas may be linked in ways that appear coherent to them. Much of the research into children's ideas in the topics mentioned above found that children appeared to persist in their own interpretation of phenomena despite science teaching. They often tinker with their ideas to accommodate new experiences while still holding on to their original premise. Science teaching 'gives them the correct answers', so children are often able to give accepted responses in an educational scenario, but they can hold a different view to explain life-world phenomena where they are expressing their own ideas. The approach adopted to address this conflict was rooted in Personal Construct Psychology (Kelly, 1995) and the notion that children must be active in the learning process to integrate the new information (Ausubel, 1968).

Initially, this highly individualistic approach to learning did not seem appropriate to whole class situations in education, and Geelan (1997) highlights the difficulty for teachers measuring the personal constructs of students. However, Driver and Easley (1978) and Pope and Gilbert (1983) attempted to do this both to education in general and science education in particular. In parallel with this was the research of Tasker (1980) and Osborne and Bell (1983) in New Zealand who devised the term 'children's Science' to go alongside various terms being used at the time of 'misconceptions', 'conceptions', 'alternative frameworks', 'interpretive models', 'schemes', 'schemata' and there are others! These terms were used to describe the personal constructs of children.

Pereira (1996) again emphasises schemata, with new knowledge being assimilated into the existing framework. All of these developments led to the rise in popularity of constructivism in science teaching and mirrors the "move away from a positivist view of knowledge" (Chalmers, 1982), with knowledge acquisition being viewed not as discrete items but as a series of structures, and the process of learning involved changing these structures. This active process needs to be taught, for as Lorsbach (1992) suggests, "Students must learn how to learn" and "the responsibility for learning rests with the learner". Harrison and Treagust (1994) echo this statement that "knowledge is not passively received but is actively built by the learner".

If the conceptual structures that children have are going to be changed then certain conditions need to be met. There needs to be dissatisfaction with the existing conception and the new scheme must be "intelligible, plausible and fruitful" (Posner *et al.*, 1982). Geelan (1997) has highlighted the importance of understanding the terms such as prior knowledge, or concepts, elicitation and construction, and stressed its implication for teachers.

Science, as previously stated, is not considered as a set of irrefutable facts, as its ideas, models and theories are continually changing and developing for example, the changing model of the atom. Similarly student personal constructs cannot be defined absolutely and, in fact, as Bannister and Fransella (1977) point out, the teacher, or indeed a researcher cannot be an objective observer, as they are intrinsically part of the interaction whereby new constructs are made. Steier (1995) agrees that this is unavoidable so we must accept that the teacher is part of the whole process. Because understanding as defined by personal constructs is so personal we cannot know exactly how someone else perceives things. Consequently, a written activity, with no dialogue, only tells you what the person recalls, not the processes by which they are making sense of it. However the social environment and the dialogue comprise a fundamental part of developing the new construct.

The development of a constructivist school environment does not depend solely on the teacher understanding the nature of science and nature of constructivism as social conditions must be satisfied and these must be developed to produce the 'constructivist classroom'. There must be good classroom management and Evertson, Emmer and Worsham (2003) suggest these, but there must also be an environment where the children feel comfortable to explore ideas. In order to achieve this there must be a supportive environment where an individual's comments are valued (Claxton, 1984). Lorsbach (1992) and Pereira (1996) have both emphasised the social environment and this is supported by Watts and Bentley (1987) who use the term Non-Threatening Learning Environment. If a constructivist approach is to be adopted and conceptual change is going to take place there will inevitably be challenge to children's existing ideas and this could be very intimidating and may be counter productive. Minstrell (1982) suggests that for conceptual development to take place there needs to be an engaging, free thinking, free speaking, social context; again emphasising the social nature of conceptual development. Similarly Gurney (1989) requires "a safe environment in which students are free to ask questions... to wonder out loud...voice agreements or disagreements....with the expectation that justification will be given". Driver *et al.* (1994) regards the teacher as pivotal in these debates as "intervention and negotiation with an authority figure, usually the teacher, is essential," whereas Lorsbach (1992) seems to recognise peer discussion much more as a means of formulating new constructs. These illustrate the importance now being placed on discussion in the classroom, (Driver, Newton and Osborne, 2000; Norris and Phillips, 2003; Mortimer and Scott, 2003). However Sewell (2002) suggests that many students may be hesitant to share their beliefs regarding new concepts publicly and that a more effective, non-threatening means of accessing prior knowledge is through writing. However experience shows that writing is more difficult conceptually than talking, so the method of communication will have to determined by the teacher.

2.4 Impact on the classroom of a constructivist view of learning

These instances lead to certain issues in implementing a constructivist view of learning, constructivism is concerned with the teacher and researcher considering how the children in a particular group will learn and is a method whereby the children make sense of what they know and do. This is in contrast with behaviourism, which is transferring the truth and is typified with transmissive teaching practices. Here knowledge resides in various resources and is independent of the learner, so science becomes a search for truth. The transmission of knowledge demands that the teachers attempt to cover the content of which they might be aware, but they have not considered necessarily, how to achieve it. Thus the teacher's epistemology will have a strong influence on classroom practice, and more traditional teaching practices may prove difficult to change, this will necessarily take time.

Since science education research is often viewed by teachers and policy makers as having little to do with teaching, far from the intention here since a major aspect was to make the teacher's role more rewarding and the teaching more effective. Thus using the teacher's own class to demonstrate the effectiveness of the strategies was an important strategy. After seeing methods work the teachers are more likely to change their practices as this quote demonstrates: "after seeing the strategies the researcher was using (the intervention), I realised my science teaching before, was rubbish"! (A little bit harsh on this very good teacher, but the quote is valid).

Constructivism as opposed to objectivism states that: knowledge resides with the individual and it is the individual who tries to make sense of what s/he has experienced in the past using the evidence from the activities provided to make the new explanations plausible, intelligible and fruitful (Posner *et al.* 1982). The teacher's role changes to that of a provider of activities which produce evidence, rather than that of being the font of all knowledge, which is a major change of emphasis the teachers have to assimilate. Teachers and researchers often use problem solving as a strategy e.g. where does the ice come from? (Ice appears on the outside of an ice-pop, the children volunteer the reason being 'the freezer, then inside the wrapper' and only when this is disproved by the evidence, will they consider the atmosphere). This is allied to Socratic learning where there is a conflict between the evidence and what they hold to be true (another common example is: force is needed to maintain movement). These ideas are difficult to change, hence the teacher will have to take cognisance of what the children say, because simply telling them the answer will not change the children's ideas, they are still likely believe what they said first. Presenting them with contrary evidence, they are more likely to change their ideas.

They try to make sense of their evidence, experience discussing this with others, others might also constrain thought and the protagonist to justify their beliefs based on the evidence available. Negotiation between children is to be encouraged, theories of peers within the class and the community of scientists identify the scientific truth to the children. This is a social constructivist perspective as described by Driver *et al.* (1994). Science is not solely the search for truth, although much of what constitutes school science is confirming what scientists have found previously, it should constitute more a process that the children undertake, as scientists do, of making sense of their experiences. It should also lead to the scientific truth which is defined here as the 'accepted scientific explanation'. The content should be used as a vehicle for effective scientific communication. The word friction covers a multitude of ideas and its use makes the communication much more efficient (although the teacher has to check understanding before use of the scientific word is allowed. This can be done by use of Basic Interpersonal Communicative Skills (BICS) and developing the Cognitive Academic Language Processes (CALP).

However this dialogue can sometimes lead to construction of meanings contrary to the teachers expectations. The teachers will need to be aware and sympathetic to these interpretations because by doing that will they find out more about how the children are making sense of their experiences. Therefore an important part of a constructivist curriculum should be the negotiation of meaning - because learning takes place within the child's head. Resolving discrepancies between what is 'known' and the evidence found is an important part of learning.

Learning to describe think and explain natural phenomena scientifically can be very difficult so the way in which the teacher develops the scientific story, including the activities which will make this accessible to the children will have a significant impact on learning. The teacher has a critical role here in building motivation and enthusiasm in asking key questions and making comments, thereby moving the scientific story along.

This relinquishing of some control and teachers taking risks balancing coverage with losing control of the flow of lesson which prepare for external demands as well as using unfamiliar processes, may present difficulties for some teachers. Instead of managing to keep children quiet and attentive, the teachers are changing to an epistemology where children are encouraged to talk to one another and discuss the relative merits of one idea over another. Children might have difficulty also changing their expectation of what learning is. They too are used to transmissive methods, they have become to expect control and transmission of knowledge. So as teachers have to change and learn to teach from a constructivist point of view, children must also learn how to learn. This is probably easier the younger children are, however it is important to retain the discursive environment.

The teacher needs to support this gain in confidence, so that the children move from reliance on the teacher having the knowledge to independence where they are examining and making sense of the evidence.

The teaching sequence and concept of learning demand must also be considered. The teacher must consider why one teaching sequence is more engaging with thinking than another and why some teaching sequences are more intellectually satisfying than others. They must identify the scientific knowledge, determine language learning demand considering any scientific vocabulary and determine the appropriate teaching sequence.

2.5 Impact of existing teacher beliefs

A significant feature which affects much of science teaching is that many teachers place importance on the need to ensure that children 'get it right'. Many teachers will have had an unsatisfactory science education themselves and several sources indicate primary teachers' anxiety in teaching science, even using traditional strategies. Many primary teachers lack confidence in relation to science and they tend to teach it dutifully but without much enjoyment (Harlen and Jelly, 1991). Teachers avoid science because the thought of teaching science fills them with anxiety and dread (Rigden, 1999) and many teachers reported that they had only taught science when they have the time. Other research (Taber, 1991) has shown that girls in particular, lose enthusiasm for science and since the majority of primary teachers are women, the problem perpetuates. If the teachers use outmoded curricula and the same strategies that failed to excite them, it is probable that this will result in a cycle of lack of interest in science (Friedman, 1999). Some of this reluctance to teach science may be due to a lack of confidence based in lack of knowledge. Teachers know little about either the content of science, or the way scientific knowledge is acquired. In this sense teachers are failed professionals (Rigden, 1999). Carré (1993) reports that teacher trainees have limited understanding and knowledge necessary to teach science at primary school level and that many have understandings of fundamental science concepts which differ from the accepted scientific view. Typically, Webb (1992) reports that the views of electric current held by Australian and South African primary teachers are very similar to those held by 11 year-old children in New Zealand and Australian primary schools. Jones (1991) found that Australian student primary teachers have similar views to those of primary children. Perhaps these comments are not surprising because the vast majority of primary teachers' science education has generally not progressed beyond secondary school level, therefore the commonly held precepts of children will be maintained into adulthood.

There have been limited in-service opportunities for teachers to implement constructivist approaches and the thinking of teachers which accompanies that change. McNamara (1990) has observed a major and disturbing gap in the literature, namely the failure of researchers to investigate teachers' thought processes. This will affect a primary teacher's classroom practice as described by Hashweh (1996). He describes how teachers' epistemological constructs affect teaching. He identifies what he calls 'empiricist' science teachers and 'constructivist' science teachers. The empiricists are likely to take a positivistic approach to science, stressing its objectivity and the fact that it explains the way things are. Constructivists are more likely to see science itself as a human construction and is subject to revision as new information is gathered. Hashweh has highlighted four different types of teaching strategies:

- the teacher provides an explanation for scientific knowledge;
- the teacher offers examples, analogies, demonstrations and student activities that facilitate acquisition, assimilation and acceptance of a new scientific concept. This method is considered more effective;
- the teacher offers a refutation of a wrong explanation by providing various types of counter evidence, and
- the teacher facilitates Cognitive Restructuring. This is usually attempted through showing how alternative conceptions are not totally wrong, but limited.

Hashweh found that empiricist teachers were much more likely to explain the right answer and to repeat such an explanation. The two groups were similar in their use of convincing arguments, but large differences in practice appeared between the two groups in the use of evidence to refute a conception, or to help restructure it. The constructivists were just as aware that children's answers were wrong, but were more likely to have some understanding of the assumptions underlying the children's ideas and to be able to take action to alter those assumptions. The empiricist teachers emphasised the correct scientific concepts and gave examples that demonstrated the truth of these concepts. The constructivist teachers used appropriately challenging activities to produce further evidence, causing the children to question their beliefs and formulate a new, revised concept. The question for science teachers thus becomes how to provide for individuals' private knowledge construction but at the same time ensuring that this private knowledge relates to the publicly accepted knowledge constructed by scientists. Prior to the introduction of a constructivist approach, science teachers have traditionally designed curricula with activities that have been conducted to focus on the production of correct results, rather than providing maximum opportunity to receive and understand science concepts. The consequence is that science teaching is generally teacher-centred and controlled. Hand and Vance (1995) suggest that there is a reluctance on the teacher's part to relinquish the control of the individual lesson content and this may be due to the pressure of the timetable and examination syllabus (Gabel, 1995). This produces a conflict, since they argue that planning for subsequent activities can only be done after each lesson. There needs to be some flexibility in planning activities but with experience and background knowledge of what ideas children are likely to hold, an overall framework can be devised for a particular lesson, or series of lessons. They need to take cognisance of the idea put forward from the researcher's experience of children this age "you don't know who will say it, or how they will phrase it, but you do know that someone will - they always do". The strategic plan also contains the 'triggers' that will provoke thinking and allow the investigation to move forward, however most authors state that the first lesson, usually elicitation, is crucial since it directs the remainder of the sequence of activities. The importance of curriculum planning based on what children say is emphasised in Driver and Scott (1996).

In adopting facilitative roles science teachers must become flexible in their planning to enable them to change direction in response to student needs, but this has to be within the constraints. The teacher has a framework wherein the desired concepts lie. By defining essential concepts, teachers develop their own conceptual framework and a framework for the unit. Designing an essential concept core is not easy however, and most teachers struggle when they are asked to go beyond a description of content areas (Bowden, 1988). This provides a different type of teacher classroom management, where the teacher plans the essential concepts which underpin the sequence of activities. The teacher must now identify appropriate activities to help the children construct scientific knowledge. The teacher must examine some possible pathways that children may take in constructing their conceptual understanding. Experienced teachers can identify areas within their subject where children 'go wrong'.

2.6 Acquiring new skills

Hand and Vance (1995) state that teachers adopting a constructivist approach will have to develop these new skills. Teachers will have to continually reflect on their own understanding as they are challenged to defend their own ideas and this process can be intellectually stimulating for the teacher. Teachers should identify appropriate activities which will help children construct scientific knowledge, and suggest that these should create conceptual conflict. In addition to creating conflict there is a need to identify activities which will help them in a revised concept, that is to reinforce the new ideas again to make them intelligible, plausible and fruitful. They also discuss the crucial nature of the first lesson which seems to be a widely held view and is supported by the findings in this research. Sprod and Jones (1996) discuss alternative explanations and discuss that children can operate in a number of cognitive modes (Sensori-motor; Ikonic; Concrete Symbolic). Also, they discussed the Zone of Proximal Development, a mode of operation which requires motivated discussion. If the children are not well motivated the conversation is likely to stay within the Zone of Acquired Development where they repeat uncritically the present knowledge at an individual understanding and reinforce it.

How children learn is just as important as the actual knowledge itself and teachers need to understand that unless the knowledgeable teacher intervenes, the children are unlikely to develop a sound knowledge simply through exploratory activities. The teacher's role is to cause the student to reflect on their concepts and defend their stated position (Hand and Vance, 1995). Social construction of knowledge implies group work, which provides a forum for testing, extending and expanding knowledge. Group work has traditionally been confined to practical activities but this should not be so, as the children need to test out understanding of ideas among their peers.

Time spent in preparation where the teacher knows what is likely to happen will help the teacher in having to decide on the next steps in the learning process. It may be that the unexpected comment from the child will fit better into the progression of ideas at a later stage. Driver *et al.* (1994) point out that it is important to at least have an idea of what possible children's ideas might be used in any topic and how to manage the practicalities in a real teaching situation. This is particularly important when the teacher is about to relinquish much of the control that s/he traditionally held. There is obviously a need here to extend the assessment tools available. Assessment tools must allow children to demonstrate their understanding of essential concepts and assessment criteria must be conceptually focused, if they are to require applications to new problems in new situations. Some teachers, initially, have felt overwhelmed by this (Hand *et al.*, 1991).

2.7 Language

The use of language is vital to the expression of the new ideas, so there must be a concomitant development of language so that children are able to reflect upon their interpretations (Barnes, 1976). The meaning of the words themselves needs to be agreed, for example, "can you give me an example of force" from the teacher elicits a possible response from the child that "my mum forces me to eat greens".

The teacher should negotiate (Hand and Vance, 1995) children's adoption of scientific language. This is an important role of the teacher since there is a language convention within the scientific (and examination) community. The teacher needs to make the student comfortable and at ease with the new scientific language so that it has a greater chance of being assimilated into children's conceptual framework. The purpose of knowledge in a constructivist environment is to make sense of the child's ideas and observations and the purpose of language is to be able to communicate these ideas coherently to other members of the scientific community be they classmates (at this stage) or qualified scientist to qualified scientist. Ideally the scientific language developed should provide the student with a more effective way of communicating his or her ideas so that it becomes fused with the concept being explained. This language extension appears to benefit children since they feel more involved in the science and can express their ideas more comfortably. New language has to be developed both in terms of vocabulary and syntax, the teacher should negotiate children's adoption of scientific language, the link between student knowledge and scientific knowledge needs to be made by them and thus they need to be given the opportunity to feel comfortable with the new scientific language. A method for assessing scientific communication is provided by Mortimer and Scott (2003). Since many teachers in science lessons do not focus on the language of science, focussing on the way they communicate will help the teacher to find out what the children are thinking and help the children communicate their ideas more effectively becoming scientifically literate (Trefil and O'Brien-Trefil, 2009).

2.8 Training strategies

If children are to change their methods of learning, and if teachers are going to be instrumental in effecting this change in their own classrooms, changing from the traditional position of a transmitter of knowledge to a constructivist or as a facilitator of knowledge construction (Hand and Vance, 1995), then the implications for teacher training are profound. In order to accommodate the revised teaching practice many authors agree that teacher training must by its nature be constructivist, that is, teachers need to assimilate and reconstruct the new pedagogic approach using appropriate experiences. The strategies teachers commonly use should be modified to match the precept that science is a process of discovery, not a collection of terms, or facts supported only by deductive laboratory experiences. Loucks-Horsley *et al.* (1996) set out training criteria to produce effective classroom practices which are summarised below which:

- provide a clear vision of effective classroom techniques, for example, commitment, sensitivity, enquiry-based learning, core concept to construct new understandings and clear outcomes;
- provide teachers with opportunities to develop knowledge and skills and a broadened approach;
- provide good learning opportunities which build on current knowledge skills and attitudes and allow teachers to construct their own knowledge by immersion in the process of collaborative work opportunities;
- strengthen the learning community of science teachers;
- prepare and support teachers to serve in leadership roles;
- provide links to other parts of the educational system, for example, training curriculum frameworks standards and assessment and establishing support and
- provide a system of continual assessment and professional development.

Two aspects of teachers' views need to be considered here:
1. the extent to which these views correspond with the scientific view and
2. the nature of the misunderstandings that teachers may possess.

Shulman (1986, 1987); McDiarmid and Ball (1988) and Jaeger (1991) have all identified that content knowledge by itself is not sufficient. It is necessary to identify appropriate pedagogical knowledge and skills when planning in-service provision. Pope and Denlico (1993), have discussed the 'repertory grid', which is a tool used to explore the teacher's repertoire of constructs in a particular topic. Successful in-service programmes, such as those by Summers and Kruger (1994), have addressed these issues by a variety of strategies such as:

- opportunities to discuss and define necessary criteria for good science teaching;

- encouragement to read and discuss articles;
- exploration of children's understanding over a chosen topic, and
- exploration of the change in pedagogic skills required by the teachers.

The successful training models produced a child-centred curriculum based on the philosophy of constructivism. Teachers were exposed to the learning process, they experienced the kind of intellectual engagement to be encouraged in their own classrooms. Teachers worked either individually, or in small groups, designed their own activities, asked their own questions and constructed their own knowledge. Teachers were unsure of how to respond when finding out that children did not really understand what they had been teaching them. This encouraged them to examine their own conceptions of teaching and become receptive to different pedagogical approaches.

Vance *et al.* (1993, 1995) have found a favourable student response to this teaching practice. They found it applied to low achievers particularly, who normally become demoralised with large amounts of writing. At the opposite end of the ability spectrum, the high achievers who may know the concepts might become peer tutors. This seems to be an under-use (and under development) of the brighter children. High achievers are often a great source of new hypotheses which can be tested by the rest of the group and they can act as a 'language bridge' between the expert and the class. They can articulate their ideas (possibly in part) and the expert and the class can negotiate an acceptable terminology. This type of scientific dialogue produces an improving style of communication for the children experiencing difficulties, while at the same time reinforcing effective communication for those confident children. Also the good ideas (testable hypotheses) are not limited to high achievers as many children with specific and general learning difficulties can suggest ideas and explanations which are worth exploring and are testable.

Teachers who have successfully used constructivist approaches in their classrooms have identified major benefits to students. They were learning how to learn rather than being told what to learn and they were actively practising thinking and use of scientific theories, they were using evidence, and the process of drawing conclusions from evidence (Kuhn and Pearsall, 2000). Teachers report that they were challenged, forced to defend their own ideas and intellectually stimulated by engaging in the reflective process (Hand *et al.*, 1991). The changes to teaching practice such as those suggested by the adoption of a constructivist approach in the classroom will, by necessity, create the need for change in how classrooms are managed. Ward and Peard (1995) highlighted that training for teachers needs to be long-term, that short term training can address scientific fact but, reconstructing knowledge and teacher practices takes longer. The teachers need to be empowered which would be very difficult to achieve in twilight workshops (Bethel *et al.*, 1982; Atwater *et al.*, 1990).

The conflict between professional autonomy and accountability leading to competence based teaching has been explored by Patrick *et al.* (2003). They argue that university staff ensure that students are aware of the importance of understanding theories of learning in their courses. Yet schools often find it difficult to ally these techniques with drives for measurable outcomes. This has led to a tension between university staff who are disappointed when their preservice teachers quickly adopt the field-based practices of their cooperating teachers, abandoning the constructivist and inquiry teaching strategies promoted in their on-campus courses. If students are so easily convinced to accept an educational innovation, they are equally convinced to replace it with another idea. It is essential that the on-campus components of a teacher education programme present an internally consistent rationale for, and expectations of, inquiry science teaching. When a misalignment occurs between the images of science teaching promoted in Faculties of Education and real science teachers (academic scientists) and real professionals (classroom teachers), the views of science educators are quickly discounted for lack of validation by scientists and teachers.

Therefore it becomes abundantly clear that to improve teachers' capacity for teaching science a long-term commitment is required and methodologies such as these should no longer be viewed as an experiment in teaching, but should become systemic. They need to change from an epistemological viewpoint that knowledge is what they are attempting to transfer to one where a way of thinking is what they are attempting to develop.

2.9 Summary

This chapter has highlighted the difference between behaviourist and constructivist teaching and although behaviourist teaching has some merits, it has been considered restrictive in its approach in that it takes no account of the learners needs in understanding the scientific truths it posits. A constructivist approach, however, takes into account the learner and a discussion of a range of constructivist approaches shows that this research has more similarities to an interactive approach which allows a consensus approach to the current scientific explanation based on the available evidence, rather than the radical constructivist approach which states that each individual can have his or her own interpretation of the concept under consideration.

The difficulties with children's frameworks as being somehow 'wrong' (as implied by the term misconception) needs more thought in order to devise a term which describes children's ideas more accurately and is helpful to teachers. As shown by many researchers a re-think of how children are taught is needed. This involves allowing children to explore through dialogue their developing ideas taking more account of the learner's needs in this process.

It has been argued that a constructivist approach is preferable to a behaviourist approach but if a change from behaviourist to constructivist epistemologies is to be achieved, the teachers must re-think their approach to teaching to allow some relinquishment of the tight control that a behaviourist teacher might have and allowing an environment where dialogue and discussion can take place.

Most INSET is behaviourist in nature and this produces a dichotomy. In order to change from a behaviourist to a constructivist epistemology, the training must in itself be constructivist not behaviourist. Existing teacher beliefs can have a strong influence on practice, therefore it is these which must be changed. The importance of changing classroom strategies have been explored in this chapter but how this can be achieved is explored in the next chapter.

3. Development of Teachers

3.1 Introduction

This chapter considers learners as adults and the consequent implications for teacher educators or facilitators. Researchers (Salomon, 1996 and Hussey *et al.*, 1999) argue that much of teacher education is too restrictive and removed from the professional and personal differences which provide richness and innovation to the curriculum. This is in direct contrast to the outcomes I am trying to achieve. A transmissive approach from an expert extolling the truths and benefits of what s/he is advocating has to take vastly more notice of the expressed views and needs of the teacher. Teacher reflection and development are considered important goals, yet the lack of continued professional development in non contact time in school often prevents this happening.

The benefits of action research, which is much more long term, are explored. Participant's classrooms are more analytical when reflecting on classroom practice, but within this is the need to reflect with somebody, for example an outside agency, as long as there is professional mutual respect. The importance of this critical thought on the development of action research is stressed, whereby both the researcher and the practitioner constantly review the methods and what they are trying to achieve together. This chapter argues that a pragmatic approach would be an effective method to solving the problem of changing teacher practice. The reflexivity and partnership involved between the researcher and the practitioner is held to be vital in the fruitful analysis of their findings be they quantitative or interpretivist. It is argued that if cooperation and mutual development is going to take place effectively then there must be a move away from the traditional expert-participant style of continued professional development, and the continued professional development must be based on constructivist principles where there is an active cooperation between all the participants and that the teachers become learners themselves and that this type of involvement has to take place over a much longer term. The participants' needs have been ignored in many of present in-service courses and serious consideration is needed for the reasons. Teachers' epistemologies are a key factor in achieving the change from simply a teaching organisation to an education and continued professional development organisation because teachers need to reflect on their practice. Teachers must be more involved and not by-passed in the learning situation. It is argued that there is a need to match the continued professional development to teachers' beliefs, if they are that crucial. Adults as learners are much more motivated, have more life experiences and their maturity is greater and this must match to a learner's individual competence and confidence. The knowledge is situated in their classroom experiences and there is research evidence e.g. from Savery and Duffy (1996) and Hacker and Harris (1998) that a constructivist environment is effective in changing participants' personal epistemologies.

There are three types: andragogy, heutagogy and capability. Andragogy would apply to all adults because they are, to a large extent, autonomous within their classrooms, hence continued professional development providers must take account of andragogy in their practice. Heutagogic learners will change their epistemology, here teachers are looking for a paradigm shift to change practice reflecting on how they have been used to doing things is the past. The greatest change in self-efficacy is seen as learning capability and capable learners will change the way they view learning and teaching completely. There is an argument that capable learners have intrinsic values and we only help them along the way.

If constructivist principles are to be applied to children's learning, it is essential that these are understood by teachers and should be modelled to teachers in their continued professional development. A review of current practice shows that there is a dearth of constructivist approaches. Indeed research findings still show that much of teacher professional development is pedagogical in nature (Rogers *et al.*, 2007), and facilitators' views about the nature and purpose of continued professional development often differ from those of teachers.

3.2 Models of Continued Professional Development

Teacher professional development has taken a variety of forms and venues. Hussey *et al.* (1999) have stated that the challenge for all professionals is to select choices that give the most meaning to professional lives. Salomon (1996) suggested that for a teacher to be an autonomous, confident, widely knowledgeable, professional and a team player, s/he needs in-depth professional training. A recent report of the National Commission on Teaching and America's Future (NCTAF, 1996) reported the critical findings that teacher expertise is one of the most important factors in student learning.

Unsurprisingly, a body of literature has emerged focussing on descriptions of and definitions for 'effective' professional development for teachers (Hustler *et al.,* 2003). Boyle, *et al.* (2004) have identified twelve varieties of continued professional development courses:

- statutory development days: schools closed to children for day, school (whole or department) professional development activities take place;
- workshops: within or without school premises, can be run by LA inspector, consultant or member of school staff, usually focus on a policy, information or subject development issue;
- study groups: teachers engage in regular, structured and collaborative interactions around topics identified by the group;
- mentoring: usually one-to-one induction or ongoing support and advice from senior member of staff to junior or QTS or across peer groups;
- research/enquiry: a local or school-specific research question, within or across schools, teachers take part in same kind of learning as their students, for example action research;
- coaching: one-to-one working with a more experienced teacher;
- networks: linking teachers or groups, either in person or electronically, to explore and discuss topics, share information, address common concerns, etc.; can be formal or informal;
- observation of colleagues: not as formalized as monitoring (structured process) but watching and discussing colleagues' teaching;
- sharing practice: one step on from 'observation', extending to planning and even teaching together;
- drop-in clinics: centres for discussion of professional practice and advice from experienced professionals (LA advisers, consultants);
- courses: (on-site) as distinct from workshops, and
- courses (on-line): electronic downloading or transfer of materials; distance learning.

Although there are these multiple vehicles for teacher professional development, it is still widely accepted that staff learning takes place primarily at a series of workshops, at a conference, or with the help of a long term consultant. It happens either through direct instruction or through the role in involvement in defining and shaping the problems. There are conflicting assumptions about the best way for teachers to learn, but competence and trust are thought to be at the heart of professional development (Cochran-Smith and Lytle, 1990).

If the teacher is the most important learning instrument that a school has to offer its children it is essential that teachers devote at least two to three hours per week to professional development. But it is not simply the time requirement; the devotion to the professional development is a mindset. Hussey *et al.* (1999) have stated that it is not the quantity of time that is important; it is the professional commitment to a regular, consistent, continuous and variable professional development. Although non-contact time is provided this time is rarely spent on teacher professional development. In schools, teachers are rarely expected to, nor are they provided with the time to meet with other teachers, developing curriculum or assessment, and lesson observations that take place are usually focussed on teacher competence and managing current activities, rather than development of new strategies. Initiatives such as restructuring the school day to allow sufficient quality meeting time will probably be necessary if a change of emphasis is to be implemented.

Loucks-Horsley and Masumoto (1999) have stated that professional development consists of four clusters of variables:

- content (what is to be learned- which could be information based or pedagogy based);
- process (how the content is to be learned);
- strategies and structures (how the content is organised for learning), and
- context (conditions under which the content is learned).

In fact Shulman (1986) coined the term pedagogical knowledge rather than content knowledge, thus changing the emphasis to which concepts are most appropriate for students of a particular age, how the students come to understand those concepts, what naive conceptions or misconceptions they are likely to have, and what representations, examples, and experiences help them learn.

Often professional development occurs as short, isolated sessions in which teachers do not have the opportunity to study new ways of learning and teaching the subject matter in depth. The means-ends model of training implicit in the school-based apprenticeship models of Initial Teacher Training in England may reduce the attention paid to critical reflection as a means of learning even further. Day (1999) believes that teacher values which are continually being formulated and refined will be predominantly influenced by information, experience and interaction; adding to these views 'without critical intervention and critical biographical reflection, most teachers fall prey to the influence of the private beliefs and assumptions' (Bullough *et al.*, 1991). In this way teaching comes not to be improved but to be reproduced, or as Britzman, (1991) states 'Practice merely makes practice'. Panasuk and Sullivan (1999) believe that in order to ensure progress, teachers must construct their own professional knowledge and not simply experience an information transmission from in-service specialists. Developing educational programmes based upon constructivist principles can pose problems for many teachers, especially those who work in formal, centrally organised education systems. Learning about new ideas that will affect the content and the processes of teaching are seen as important to the innovator but, ideas that are related to the organisation and context of one's own classroom have a hard time competing with the 'busyness' of the daily routine tasks that must be completed even when teachers are excited about and committed to them. According to Leiberman (1995), the conventional view of staff development as a transferable package of knowledge to be distributed to teachers in bite-sized pieces needs radical rethinking. At present however, as in the 1970s and the 1980s, it remains the case that much research is not only separate from professional practice but has been increasingly captured by its own agenda, divergent from the needs and interests of professional practitioners. Welsh (2002) endorses a framework of collaborative professional development bridging research and policy, at the same time recognising the elements of conflict in teacher development. He suggests that the linking of Universities and Colleges of HE to individuals and schools could integrate both individual professional and school development providing a strategy that enables teachers to initiate and sustain change by becoming active change agents rather than objects of change.

In the traditional view of staff development, workshops and conferences happen outside the school, but authentic opportunities to learn from, and with, colleagues inside the school do not. A challenge to the narrow assumptions about in-service education, proposing that schools become collaborators through group dynamics has been suggested by Lieberman (1995). She makes several summarising statements:

- teachers' professional development has been limited by a lack of knowledge about how teachers learn;
- teachers' definitions of the problems of practice have often been ignored;
- the agenda for reform involves teachers in practices that have not been part of the accepted view of teachers' professional learning;
- teaching has been described as that of technical skills, leaving little room for invention and building of craft knowledge;
- professional development opportunities have often ignored the importance of the context within which teachers work;

- strategies for change have rarely considered the importance of support mechanisms and the necessity of learning all the time, and
- time and the necessary mechanisms for inventing, as well as consuming, new knowledge have often been absent from schools.

Models which involve teachers and teacher educators working together are also typified by Hargreaves (1995), who places teacher education within the context of lifelong development. This is supported by Day (1991) discussing professional development and the role of teacher educators. Darling-Hammond and Ball (1998) also argue for an alternative emphasis in professional development. They say that traditional forms of professional development provide answers to questions, convey information, teach skills and provide curriculum materials with practice in how to use them. The challenge to teacher educators is to engage actively in the business of critical reflection, bringing teachers and schools within 'broad partnerships'. This fosters critical reflection and builds the inquiry skills which will enable teachers to develop understanding and reflection as a basis for continuous improvement throughout their professional lives. Hargreaves (1995) captures the dilemma in which many teacher educators find themselves. They are neither academics nor practitioners, they are caught in a conflict between a government policy which has raised the value of practical experience above all else; importing into teacher education that 'busyness' culture of school teaching and the scholarship in which they are judged by their colleagues elsewhere, who regard them as impractical or ideological. To school people, Faculties of Education are often seen as repositories of impractical theory and irrelevant intellectualism (Hargreaves, 1995). The issue of how children learn and interact with others, places teachers firmly at the core of educational research even when the teachers are not the instigators of the research project. The criticisms of current educational reformers for example, that our schools provide most children with an education that is too passive and too rote-orientated to produce learners who can think critically, synthesise and transform, experiment and create, are virtually identical to those of progressive educators at the turn-of-the-last century, in the 1930s, and again in the 1960s.

Progressive education, Cremin (1965) argued, demanded infinitely skilled teachers and it failed because such teachers could not be recruited in sufficient numbers. Because of this failure during each wave of reform, learner-centred education gave way to standardising influences that dumbed down the curriculum. This has happened through the efficiency movement of the 1920s, the competency-based curriculum reforms of the 1950s and the back-to-basics movement of the 1970s and 1980s, which all restricted teachers to being simply managers rather than innovators. In an effort to maintain standards for league tables, teachers felt pressurised from a variety of stake holders to identify and provide support for all children to 'perform better' and this has been done typically by revision classes, practice papers, checklists or child-speak criteria. Again these practices do not support creative, independent learning and do not sit well with current reforms.

Disappointment with the outcomes of these attempts to simplify and prescribe school procedures, however, led in the main to renewed criticisms of schools and attempts to restructure them. These comments relate to US schools but there are certainly familiar parallels in the UK education system, where accountability and a demand to maintain the status quo have held sway over curriculum development and a trust in teacher professionalism.

As Hargreaves (1996) in his address to the Teacher Training Agency (TTA) was critical of much educational research, arguing that schools would be more effective if teaching became a research-based profession, and blaming researchers for failing to make this happen.

Hargreaves also asked the question:

... just how much research is there which (i) demonstrates conclusively that if teachers change their practice from x to y there will be a significant and enduring improvement in teaching and learning, and (ii) has developed an effective method of convincing teachers of the benefit of, and means to, changing from x to y? (1996: 5).

However, one method researchers have used to strengthen the links between teachers and teacher educators has been through Action Research.

3.3 Action Research

Recent research has shown that continued professional development activities now take the form of collaborative action research (Levin and Rock, 2003) which is of a more long-term nature than the usual continued professional development activities. Levin and Rock claim that teachers who get involved in this type of continued professional development activity can become more reflective, critical, and analytical when they think about their teaching style in the classroom. Clark (1989) has given three ways to categorise relationships between research and teaching. First, there is no relationship: researchers pursue their own narrow and parochial interest, publishing in obscure language, in obscure journals and avoid all discussion of practical implications of the work. Teacher educators see this as irrelevant and impossible to understand. Secondly, there is a top-down model where teacher educators pass on knowledge gained second-hand from researchers to their students. Thirdly, members of the research community behave as consultants to the community of teacher educators. More powerful professional development is based more closely on the principles of active learning, short cutting the distance between new knowledge or skills learned and the applications to the classroom, using an inquiry orientation, rather than a problem solving approach.

Action research has been described as the study of the social situation involving the participants themselves as researchers, with a view to improving the quality of action within it, for example by Somekh (1998). Bennett *et al.* (2005) suggest that a piece of action research is also characterised by its relatively small scale. An action research project may employ a positivist (quantitative) methodology whereby analysis of data would contribute to the findings. This could be used as a measure of teacher confidence or as a measure of a difference in attainment using inferential statistics. In a positivist paradigm statistical significance would be valued highly, but an element of this could also be interpretivist, although the difference may be statistically significant the differences achieved may be due to several factors. Interpretivist (qualitative, or constructivist) methodologies would depend on a variety of anthropological methods, for instance, classroom observations because these depend upon the fact that humans construct reality, so there is a need to place the analyses in a context interpreted by the researcher. A mixed methods pragmatic paradigm would use a variety of methods to collect information each making a contribution to solving the problem. Multiple perspectives are needed to triangulate the information. Pragmatists would use a mixture of methodologies in dealing with practical problems that confront them and consider a range of methods that would contribute overall to a better understanding (Hinchey, 2008). Bruce and Rubin (1992) consider pragmatists as researchers who accept the interconnectivity of the data with the phenomenon they seek to change and they realise the tentative nature of their recommendations. Examples of Action Research have been given by McCutcheon and Jung (1990); McTaggart (1991); Elliot (1993) and Carr and Kemmis (2005). Because it is action orientated and linked to change it is easy to see why it is an attractive option for teacher educators. The inquiry in its own right can release educationists and educational research from domination by sociologists and psychologists; it is indeed an alternative paradigm (Elliott, 1991). However, there are problems in its adoption because collaboration between different sectors (with different priorities) is not easy. A common difficulty is a difference in core functions; schools teach children, universities teach adults and pursue research (Day, 1991). Further, a world which emphasises the systematic gathering of knowledge and formal examination of experience, professional criticism and seemingly endless discussion of possibilities rather than solutions, is likely to contrast sharply with a world dominated by action, concrete knowledge and 'busyness' (Day, 1991; Cuban, 1992).

Several researchers have set out requirements for Action Research in education:

- relationships between researcher and research to be equitable (Calhoun and Glickman, 1993; Wahlstrom and King, 1993);
- the possession of human relations, in negotiation and technical skills, and an ability to engage in collaboration which is not always comfortable (Day, 1991; Sumara and Luce-Kapler, 1993);
- an understanding of change processes;
- willingness to reflect upon and open to others the researcher's own values (Argyris and Schon, 1974);
- a willingness to service teachers' agenda rather than impose one's own;

- a belief that authentic settings are best researched by those practitioners experiencing them directly, but that outside view points may enrich these to challenge and support (McKernan, 1991), and
- an acceptance that those affected by planned changes, have the primary responsibility for deciding on courses of action which seem likely to lead to improvement and for evaluating the results of strategies tried out in practice (Carr and Kemmis, 1986).

These seem to sit well at least with the rhetoric of teacher educators.

The apparent benefits of Action Research are questioned by Johnston (1994), who debates whether Action Research is a natural process. Hammersley (1993) adds weight to this scepticism stating it is not in the best interest of the teacher or researcher for their roles to be integrated. Schon (1983, 1987) recognised that the teacher in Action Research is as an active constructor of meanings and thus capable of being a reflective practitioner, but with the need for a critical friend, or struggling other (Pope and Denlico, 1993). Grundy and Kemmis (1982) have said teaching may become parochial and insular unless at some point teachers choose to turn to higher education for intellectual, effective and practical partnership support. Here research and staff development are one and the same enterprise, and are both practical and emancipatory for all participants, therefore collaborative participation in theoretical, practical and political discourse is thus a hallmark of Action Research and of the action researcher (Grundy and Kemmis, 1982). Nias (1991) and Handal (1991) raise some very important issues and give examples of the pre-requisites for effective Action Research. They discuss the notions of empowerment of teachers; the recognition of a need to develop a new language for communication between teachers and academics (Nias, 1991) and that there are established self-critical, self reflecting communities (Handal, 1991). The goals of the research are determined by the people who conduct it; Action Research is a process that pursues improvement in 'practical situations'. According to Altrichter (2005), "professional learning is not just an intellectual process (a process of acquisition and application of knowledge), but also a process of practical action in which knowledge is enacted in reflecting and developing a specific practice".

Whilst attractive, these ideas depend, for fulfilment, upon the willingness, social skills and abilities of participants to create and negotiate contracts either collectively or individually, which are based on forms of critical friendship. The case for critical research friendship has been argued strongly by Thompson (1984), since it can increase the possibilities of moving through stages of reflection to confrontation of thinking and practice. Alone one only sees what one is ready to see and will only learn what is on the edge of the consciousness of existing knowledge (Thompson, 1984). Thomson summarises some key points about working in critical groups using Action Research.

It:

- creates cognitive dissonance;
- provides time for teachers to think of resolving the dissonance through discussion and other activities;
- ensures that dissonance-creating and dissonance-resolving activities are connected to the teachers' and students' contexts;
- develops a repertoire of practice, and
- provides continuing help in the cycle of new issues.

3.3.1 Applications of Critical Theory on Action Research

Critical theory, as part of Action Research, was applied to educational research by Carr and Kemmis (1983). This theory is not objective as thought by positivists, more it considers subjectivism and interpretation which cannot be based on logic and scientific analysis only. While stating that knowledge is never completely separated from the researcher's own experience, it rejects the notion that all analyses are relative. Critical researchers expose hidden assumptions and bring scrutiny to their work which includes the meanings of what is left unsaid as well as that which is stated. This research is verified by other members of the research community offering corroboration that has come from their own research experiences. The critical researcher continually criticises or questions both the methods and the outcomes of the research, and this leads to development within the research and re-formulation of ideas.

Tripp (1990) has outlined some key features of critical research. He states that critical research is self-directed, because interests of the participants will inform the way they themselves work as well as inform what they want to achieve. These are referred to as 'problematics' (problems such as lack of understanding on the part of the children which create a problem for the teacher), thus the primary audience for the research findings is the participants themselves. Rather than regarding knowledge as objectively verified facts, critical research sees knowledge as socially constructed and therefore artificial and held differently by different groups and this is the paradigm of social constructivists. It aims at understanding people's values and uses of their meanings rather than 'finding "the" truth' (Tripp, 1990). But Social Constructivism is a contradictory paradigm to Interactive Constructivism, where there is an accepted scientific view of phenomena which is the paradigm used in this research. Key to this research, and part of critical research, is the children understanding the difference between a prediction, which will be made before the investigation and which might be based on limited evidence, and that of further evidence obtained in the investigation. This leads to the children formulating ideas based on evidence rather than their original conceptions, so there is no right or wrong answer in their prediction but there is an accepted scientific viewpoint. Here the children are also behaving as critical researchers, because they are analysing the evidence for its strengths and weaknesses.

3.3.2 Impact of Action Research and Reflexivity

Action Research claims to integrate teaching and teacher development, curriculum development and evaluation, and research and philosophical reflection into a unified conception of reflective educational practice (Elliott, 1991). This should not mask the essential eclecticism of research which is aimed at improving understanding of teaching in classrooms and which matches the post modern pragmatism of teacher education very well (Calderhead, 1993). Thus Action Research serves the interests of teachers. Teacher educators here can be viewed as interventionists who pose questions perceived by the teachers as relevant to their needs and both parties investigate the solutions to these questions collaboratively. The role of the teacher educator is to promote a sustained environment which provides a challenge and support for research and is embedded in development and to place the responsibility for the sustained action on the teachers themselves.

Hart (1990) advocates reflection in action as a concept for reconstructing teacher education. This places emphasis on educational aims and consequences as well as the technical skills of teaching and teachers are encouraged to contribute to the formal formulation of policy. The reflection in action paradigm emphasises a process model of education where teachers and teacher educators monitor and evaluate their own practice reflexively. That is, an Action Research model, and is a cyclical process in which teacher action and reflection improve and adoption is seen as dialectic between theory and practice.

In a mixture of positivist data collection in which a measured reality is taking place and there is subjective interpretation of discussions with both teachers and children, the researcher would bring along prior knowledge and personal and cultural histories. Reflexivity requires self-awareness and creates a dynamic interaction within and between the researcher and the participants and the interpretation of data. Reflexivity is part of 'critical' qualitative research and relates to the degree of influence that the researcher exerts, either intentionally or unintentionally, on the findings. Thus reflexivity adds validity and rigour in research by providing information about the contexts in which data are located. By using reflexivity in our representation of research we gain and share with others 'reflexive knowledge' (Hertz, 1997).

Hertz (1997) also stated that reflexivity implies a shift in our understanding of data and its collection, and this is achieved through detachment, internal dialogue and constant scrutiny of 'what I know' and 'how I know it'. In discussions with teachers it is vital for the researcher to ignore any pre-conceived ideas, simply adopting a role of prompting, probing and encouraging.

This kind of reflexive interpretation involves situating ourselves not just in the stages of the research but also in relation to the data we have collected.

Identifying types of data and subsequent interpretation of these would require two different approaches. There would be data from the relationship between researcher and teacher and consideration of the role of researcher as teacher, both as an equal and expert and the researcher would have to judge whether or not teachers had other, alternative agenda. The researcher must use reflection in trying to interpret the data about the meaning of the type of discourse with the teacher distancing himself as far as possible from his own views and interpretation. These data are different from when considering what children may communicate about a given scientific topic and these data could be treated in a much more quantitative manner.

This mechanism helps researchers both to begin to see how they view the participants and to engage with the judgements and perspectives they have brought to the research. This elicitation and self analysis process would facilitate reflexivity, not only enabling researchers to see how they have come to know their participants but also to review their own biases (Savin-Baden, 2004). Thus it is through examining such biases that they learn, through self-critique, to develop a better interpretation of the data.

Niemi and Kemmis (1999) advocate sustaining a communicative action in terms of focussing on research being participatory and collaborative in nature. Reason (1994) provides a justification for collaboration as a research tool, the researcher here is acting as a collaborative inquirer, primarily as a researcher, recording and interpreting both the teachers' pedagogical view and children's scientific cognition. Secondly, as a co-inquirer eliciting children's ideas, and finally as a supporter of their change in epistemology, which involved continually making the switch from expert to facilitator. Thus the collection of data from semi-structured interviews, and discussion with the class teachers to interpret the meaning of actions, means the researcher must produce an account of how the teachers, in particular, perceive the situations or phenomena in question, which then require analysis to transcend the meanings of the participants (Schatzman and Strauss, 1973).

Action Research Networks can help teachers to introduce and improve education in their classrooms as well as improving the quality of learning in other areas of the curriculum. The principles have been set out by Corcoran and Blaze (1996) and include:

- an emphasis should be on personal and professional development rather than producing resources;
- there should be collegiate and collaborative approaches which underlie successful professional development;
- active participation in critical reflection is essential;
- learning should be participant-centred and experiential;
- practices should develop and encourage innovative teaching strategies, and
- developments should not be the finished product but should reflect a dynamic resource that evolves.

Those who have access to teacher networks have enriched professional roles and are more positive about staying in the profession (Darling-Hammond, 1996). Little and McLaughlin (1991) have also worked with partnerships and state that: these partnerships offer teachers development opportunities that differ from those inside the school. It is not the 'one size fits all' orientation of continued professional development , they are committed to topics that are of intrinsic interest to them, or that develop out of their work. The move from direct teaching in school, to facilitating learning has connected the school to a longer term strategy, aimed not only at changing its teaching practice, but at changing the school culture as well. Networks, collaboratives and partnerships provide teachers with professional learning communities that support changes in teaching practices. There is a need to move away from a traditional in-service training mould and toward long-term continuous learning in the context of school and classroom and with the support of colleagues (Lieberman, 1995).

3.4 Implications for Continued Professional Development

The focus of all continuing professional development is that it will promote change. This may be in the form of enhancing the quality of teaching by making this more effective, so the children produce higher attainment or it may be that the lessons are more enjoyable for all, because the children impress the teacher more or the children are being more effective with their science communication.

Many researchers have commented on the input and outcomes as well as the necessary environment within the school to support the continuing professional development. Lambert (2003) lists the types of activities required by effective INSET programmes: they must contain new ideas, be inquiring, reflective and reforming. The continuing professional development is directed towards adults so it needs to contain relevant and practical acknowledgement of the teacher's prior experiences, so it must be in part self-directed and towards problem solving and if possible linking theory with practice and be active. Guskey (2000) cites four principles of effective practice namely a clear focus, emphasis on individual and organisational change, small changes guided by a 'grand vision' and on-going professional development which is procedurally embedded.

Harland and Kinder (1997) have listed nine areas of categories of change and whether they occur in the workshops or in class are indicated in Table 3.1. These were adopted either in the workshops or within the in-class support. The latter is where a constructivist approach was implemented in the main.

Table 3.1 Nine categories of change (Harland and Kinder, 1997)

Harland and Kinder (1997) have stated that the impact of the continuing professional development will be greater if all nine of their categories are present. All of these ideas have influenced the style of the continuing professional development.

If the continuing professional development is to be part of everyday life, part of cultural norm, which is our ultimate goal, it has been found that the attitude of staff leaders has a strong influence. There must be high-trust rather than low-trust, in that they must value the development

TABLE 3.1 NOT SCANNED ON INSTRUCTION FROM THE UNIVERSITY of teachers. The high-trust seems to be prevalent in those schools which have as its aim a shared vision of development, whereas the teachers sense that anything that is imposed upon them from outside is low-trust, they often perceive this as teacher-proofing.

Teachers are adults and must be treated as adults. Adults are more self-directing and have accumulated more life experiences than children; also they adopt a problem solving approach to what they are doing. Therefore it is not appropriate to adopt a one size fits all approach, therefore a constructivist approach especially in the in-class support was adopted. The philosophy of a constructivist approach was emphasised in the workshops. The teachers are at the developmental stage so the principle of learning concept or demand must be applied to the learning outcomes. Observing networks, collaborating, sharing best practice, monitoring and reviewing, evaluating and keeping up to date are all important. Dempster (2001) uses the term 'professional sustenance' to describe these facets.

Cole (1992) states that teacher development, like development in others, is a complex and ongoing process of personal and contextual interpretation. It occurs naturally and gradually as teachers act and interact within their personal, professional, and social contacts. There are no unmoved universal truths about which specific conditions, or factors facilitate, or constrain a teachers' development because development is individual and not universally defined. This might be interpreted that for teacher professional development to be successful and sustainable it must intrinsically be based on constructivist principles. Robottom (1989) describes such a process as the antithesis of the technocratic paradigm of competency-based training that may follow from an uncritical adoption of the competences approach. Moreover, in response to increasing the accountability of educational institutions by government agencies there is a danger of over emphasis on the assessment of student knowledge of facts (Gilbert, 2004) and in primary teacher education, this is evidenced by the auditing and testing culture that has arisen within Initial Teacher Training (ITT) in recent years. To ensure progress, teachers must construct their own professional knowledge and not simply experience an information transmission from in-service specialists. Reflection and analysis are central to professional development (Panasuk and Sullivan, 1998).

Project planners (Maor, 1999) agree that if an observable change is to occur the participants need to be mutually respected and activities need to promote dialogical exchange. Teachers need to be positioned as learners in a new situation to engage them in epistemological change. Salomon (1996) suggests that teachers need to experience a novel learning environment as learners themselves, to implement changes in their teaching. This view is shared by Ainely and Pratt (1995) who recommend that professional development programmes be organised so that facilitators can work alongside teachers in the classroom to help teachers overcome anxieties associated with new experiences and that teachers' experiences as learners provide them with a better understanding of the learning process and helps them model teaching pedagogies appropriate for children working in a constructivist-orientated enquiry. Hand and Treagust (1994) noted this paucity of constructivist research in teacher education. In their study, they worked with a group of eight science teachers in Australia to explore, over an eighteen month period, questions such as: how do children learn; what teaching strategies do you use; and who controls the learning? The results indicate the possibility of creating a distinct change in the way that teachers understand classroom interactions.

It is essential to provide opportunities for teachers to experience different methods of teaching instead of simply hearing, or reading about them and finding that constructivist approaches have positive advantages. If we are to remedy this paucity of constructivist approaches in teacher education as noted by Hand and Treagust (1994), the time and resource implications required for this type of teacher professional development are unavoidable even if these might be considerable. What characterises these examples of professional learning is that it is not one or two days, instead they become part of the expectations for teachers' roles and an integral part of the teacher and school culture.

Transforming schools into learning organisations, in which people work together to solve problems collectively, is more than a question of inserting a new curriculum, or a new programme. It involves thinking through how the content and processes of learning can be redefined in ways that engage children and teachers in the active pursuit of learning goals; it involves a joining of experiential learning and content knowledge. Teaching as telling, the model that has dominated the pedagogy and the consequent organisation of schooling to date, is being called into question as professional learning for teachers increasingly connects this with the reconsidered view of schools (Resnick, 1987; Schon, 1991). The ways teachers learn may be more like the ways children learn than we have previously recognised. Learning theorists and organisational theorists are advocating that people learn best through active involvement and through thinking about, and becoming articulate about, what they have learned. Processes, practices, and policies that are built on this view of learning are at the heart of a more expanded review of teacher development that encourages teachers to involve themselves as a learner, in much the same way as they would wish their students to do (Grimmett and Neufeld, 1994). The concept of linking teacher development to student-centred pedagogy is becoming more prevalent. The change from 'teaching' to 'learning' is significant because it implies that teacher development opportunities must become integral in the restructuring of school. This broader approach moves teachers beyond simply hearing about new ideas, or about frameworks for understanding teaching practice, to being actively involved in decisions about the substance, the process, and the organisational supports for learning in schools, consequently locating broader support mechanisms, such as networks or partnerships, that provide opportunities for learning and innovation.

Being involved as a learner and a participant provides openings to new knowledge and broadens the agenda for thought and action. Below is a section of outcome statements about a project based on these principles (Falk and Darling-Hammond, 1993). It:

- encourages teachers to observe students;
- does not tell teachers what to do, it expands their understanding of what is possible;
- encourages teachers to be learners and experience the struggle for personal and intellectual growth that is an essential part of learning. Teachers then become sensitised to the nuances of learning and needs of individuals, and
- results in learning by integrating assessment and the curriculum.

An issue which is often neglected and inherent in the nature of current modules of teacher professional development is the one of evaluation. It is probably true to say that evaluation of the long term effect of workshops is rarely, if ever, carried out. For evaluation to be practical it must be part of a longer term programme of teacher professional development and it is unlikely that typical short term programmes would lead to this level of focussed evaluation of the outcomes. In one example to evaluate the effectiveness of a model of teacher professional development, three teachers who participated in workshops were followed in an attempt to understand the extent to which the workshop influenced the teacher's role in the classroom (Maor, 1999).Teachers completed journals of experiences and the teachers were interviewed. Some gains from the programmes quoted were:

- gathering information on children's prior conceptions in relation to the content of the particular topic of work;
- observing the roles of both the teacher and children in relation to knowledge construction;
- observing teacher-child and child-child relationships during the development of the topic;
- collecting information on the work studied at the end of the sessions, and
- comparing the results of teaching based on the newly acquired pedagogic principles with the more usual transmission of knowledge teaching.

This type of in-depth evaluation requires a much longer term commitment than a typical evaluation exercise at the end of a workshop.

3.5 Impact of teachers on learning

Darling-Hammond (1996) also describes the change in culture impacting on schools. They are now expected not only to offer education but to ensure learning. Teachers are expected not only to cover the curriculum but to create a bridge between the needs of each learner and the attainment of challenging learning goals. These objectives are a radical departure from previous education missions and demand that teachers understand learners and their learning as deeply as they comprehend their subjects.

Maor and Taylor (1995) describe the highly influential role of teachers' epistemologies in facilitating students' development of higher level thinking skills and although research concerning constructivist strategies and techniques seem to be accumulating and gathering strength, however, in the view of Fensham *et al.* (1994), the impact of constructivist thinking on classroom practice, still remains slight. Even while teachers may have some appreciation of constructivist principles these seldom find their way into the broad sweep of classroom practice. There is a general lack of consideration for children's previous knowledge: the emphasis is simply on the transmission of content, and teachers plan their class work in order to achieve this (Bentley and Watts, 1989). When the prior knowledge of the child differs from the teacher's explanation, it is all too often solemnly ignored without any real attempt to use it (Jofili, 1994). As teachers undertake innovation within their classes, they will become aware of real dilemmas concerned with the normal expectations and practices within their school. This requires them to confront social, political and historical issues in the practice of education in the context of their community.

Learners need the opportunity to reflect on their thinking and to explore it within context in order to ascertain how they are reasoning about it and where the conflict lies between their own explanation, and others including those of science (Parker, 2004). Changing children's conceptions about scientific ideas and theories has centred on the conceptual changes in the learner's thinking about science. This cannot be achieved without a teacher understanding the child's learning frameworks and the effect these have on the ability of the children to make sense of existing and new scientific concepts. To facilitate this, a change in teacher practice from the currently, predominantly didactic model has to be achieved. This applies not only to the teachers modifying their own science knowledge and understanding of the topics they teach but more significantly, modifying their epistemology about how they teach it, in short, their beliefs on how science education should take place. As Fullan and Miles (1995) state "Change is a process of coming to grips with new personal meaning, and so it is a learning process." Fishbein (1967) delineated attitudes from beliefs by identifying attitudes as affective constructs and beliefs as cognitive constructs. Science teachers' epistemologies affect the type of instructional behaviours that occur in science classrooms (van Driel, *et al.*, 1998), that is, science teachers' epistemologies frame their teaching paradigms. Prospective teachers enter professional development programs with certain core beliefs firmly in place (Cobern and Loving, 2002) and they enter teacher education programs with images and models of teaching that they expected as students (Laplante, 1997; Southerland and Gess-Newsome, 1999; Eick and Reed, 2002). That is prospective teachers make sense of practices promoted by the preservice education curriculum in terms of their personal epistemologies. So regardless of a teacher's place along the professional continuum, if an instructional strategy is perceived as incongruent with that teacher's teaching paradigm, it will generate a negative response toward that strategy. Luft (2001) found that an in-service program designed to promote inquiry teaching changed the beliefs of induction teachers but only changed the practices of experienced teachers. Strike and Posner (1992) have referred to the interdependence and interconnectedness of past experiences, epistemological views, prior knowledge, competing conceptions, analogies and metaphors, and formal instruction as 'conceptual ecology'. If prior experience is the strongest of these 'conceptual ecology' factors influencing the adoption of new ideas, this may mean that the relationship between concepts developed from the learner's own experience and those linked with instruction from professional development, would make integration of the new concepts inconsistent and strongly learner-dependent, therefore variable among participants. The result of this would be the typical bricollage approach cited by Huberman (1995), where teachers will adopt what they perceive as good ideas but not fully adopt the underlying philosophy which would alter their epistemology. Tinkering is quite practical and eminently sensible, but it is also quite conservative enabling the teacher to preserve the style and fundamental ideas about subject matter, teaching and learning. If the personal meaning of change for teachers is intrinsic in bringing about change in science education practice, Connelly and Clandinin (1988) ask workshop presenters and participants a soul-searching question: "If workshops train teachers to teach in certain ways, how is this any different, in principle, from bypassing teachers altogether in teacher proofing of curriculum materials?" Achieving this will depend upon INSET providers re-thinking how they perceive teachers as learners. In spite of the reforms in curriculum development, the traditional approach of using teacher development and in-service programmes as a setting to 'fix' schools is still in practice. Connelly and Clandinin (1988) find remnants of the teacher-proofing idea in government policy documents of centralised countries worldwide. In fact there have been several attempts to make curriculum materials teacher proof with published schemes of work, providing a complete set of prescriptive resources both for planning and delivery of the methodology as well as the content. These curricular materials minimize teacher influence and have been developed to support the existing school problems. The designers of such schemes may not intend to minimise teacher influence; but that is certainly the result in many schools. This is not to completely decry published schemes and the many excellent professional development and teacher workshops, but these alone will not change the mindset of teachers. Teachers will have a greater tendency to incorporate new ideas and approaches if they can judge for themselves whether the professional activities in which they engage are educational or whether they are designed as an alternative to teacher proofing. If we are to empower teachers to judge this aspect of continued professional development then the responsibility of adopting a new approach to teachers as learners will lie initially with the providers. If educational reformers consider in-service programmes as vehicles to remedy what they perceive to be lacking with teachers and schools, then this mindset produces teachers who never gain control of any area of practice where they are in charge, or are viewed as experts. This standpoint has been many teachers' perception of what lay at the heart of aspects of recent educational reforms, particularly the introduction of the Science National

Curriculum (Nicholson and Holman, 2003) and the Ofsted inspection process (Case *et al.*, 2000), although not of organisations such the Association for Science Education and Local Education Authorities, who were perceived as being supportive. Teachers see in these changes, pedagogy and practice which is dominated by people in roles outside the classroom and not by the teachers themselves. Abd-El-Khalick (2005) further asserts that the research about how teachers' epistemologies translate into actual classroom practice remains a crucial issue.

3.6 Considerations of adults as learners - Andragogy, Heutagogy and Capability

Several authors have begun with the assumption that principles of learning hold true for teachers as they do for all learners. Learners must build coherent structures of information organised around core concepts, thus teachers need a sound foundation in the major ideas of the disciplines they teach and a deep understanding of how children come to learn those disciplines. It is clear that teachers' prior beliefs and experiences affect what they learn and Cohen (1988) has pointed out that many teachers hold deep-seated conceptions of knowledge as facts, teaching as telling and learning as memorising. These beliefs are in effect anathema to the new reforms and only when they are dispelled, can teachers teach understanding. Hence a problem facing education today is the resilient nature of beliefs that shape teachers' classroom experiences and the need to provide teachers with opportunities to discuss and reflect critically on the pedagogies as highlighted by Maor and Taylor (1995). Research on the teacher's beliefs has shown that most teachers have transition type epistemologies which resist change in the classroom and although many teachers find new ideas received during in service training courses to be very interesting, back in the classrooms they resist application of what they have learnt. For example, during interviews conducted by Jofili and Watts (1995), primary and secondary school teachers of science claimed that a serious obstacle to the adoption of new, child-centred, methodologies was their insecurity in implementing them when feeling relatively comfortable with ones they already used. Studies of constructivist orientated approaches to teaching and learning have substantiated the importance of changing the role of the teacher in the learning process (Hand *et al.*, 1991; Treagust *et al.*,1996). So helping teachers with what they learn and how they learn it adds to the complexity of the learning challenge. Conceptual and real behavioural changes, however large or small, are not easy and teachers are no different from others in this adoption of significant change. Invitations to change or to try innovative teaching strategies are almost inevitably perceived as additions, requiring extra time and effort. The suggestion to innovate often comes as part of an external innovator's timetable and not at the point in the teachers' lives where they are dissatisfied with their present practice and are searching for alternatives to solve a problem they personally recognise. The uncertain outcomes of using alternative pedagogies are more likely to be seen as threatening the teacher's authority and stability in the classroom than as improving these relationships even when improvement may be the eventual outcome.

3.6.1 The need to match teachers' beliefs and continued professional development

Self-efficacy is concerned with peoples' beliefs about their capabilities of producing an impact on events. This has been founded on Bandura's (1997) theory of social learning which has provided a useful framework to examine the construct of personal science teaching self-efficacy from a cognitive science perspective and has been widely taken up due to its utility in research on science teaching and teacher education. Bandura's theory posits that we are motivated to perform an action if we believe that the action will have a favourable result (outcome expectation) and we are confident that we can perform that action successfully (self-efficacy expectation). So highly self-efficacious people approach difficult tasks as challenges to be overcome rather than threats to be avoided. The aim was to influence teachers so they would feel more self confident about facing the challenges of making their science teaching more open and less controlling of what the children learnt, because this would produce scientific thought in their children and would relinquish a tight control over classroom activities. More open science teaching was the preferred approach so that teachers were more confident about dealing with impromptu questions, such as those that indicated children were thinking about their science concepts, trying to link science concepts together and trying to apply science concepts to their own experiences. It was hoped that this would lead to teachers feeling confident enough to manage such situations with assurance.

According to Bandura (1994) the main influences on self-efficacy are, mastery experiences, physiological and emotional cues, explicit experiences, and verbal persuasion, but most effective are mastery experiences. Success builds on a strong belief in one's own efficacy so it was important to achieve this. To achieve mastery however, was challenging and the teachers needed to persevere and accept they will not be perfect at opening their science lessons for example to examine evidence and promote discussion, but until the teachers faced these challenges they would not develop the skills and experience to deal with them. They also need to appreciate the ideas that their children hold, would be similar to those of many other children and when the children put forward particular ideas and demonstrate the truth of these, on subsequent occasions, the teachers would be better armed with strategies to deal with the situation. It was not seen as a failure of previous teaching that a wide range of children hold these views and a more open style of teaching was an effective way of highlighting these ideas.

A technique for strengthening self-efficacy is modelling. Seeing someone else in the teacher's own classroom and with the teacher's own children achieving open science lessons would be a very powerful tool of persuasion that the ideas being proposed had merit. However, it was important that the knowledge, experiences and skills the teachers had, were used to achieve these goals and that they matched the techniques of the teachers. Through these experiences the teachers would believe that they could achieve a greater sense of self-efficacy, but if the models were very different from the teachers' capabilities they were unlikely to be adopted.

Social persuasion, both between the teachers themselves and by interaction with the researcher, is another powerful way of strengthening peoples' beliefs that they can succeed and rise to the challenge. These teachers by their own admission from the interviews, were looking for models and strategies to increase the effectiveness of their science teaching. It is important when building self-efficacy to convey positive appraisals and not set goals which were too demanding and therefore likely to lead to failure. If the researcher could work closely with the teachers and demonstrate the situations and activities that could be structured in ways that brought success, this would persuade the teachers, by deed as much as word, of the effectiveness of the strategies and develop an increase in self-efficacy. Linked with this building of confidence was the proviso that the teachers did not deflect stress at attempting the new activities into a belief of incapability. Here the researcher's presence in the classroom would give support at any instance of faltering or self-doubt. The researcher had to assess each teacher's needs and stage of development in self-efficacy.

According to Bandura (1994) self-efficacy beliefs are grounded in three forms of cognitive motivators:

- causal attributions of the teachers involved - that is their feelings about how self-efficacious they were,
- successful outcome expectancies and
- cognised goals set up between the researcher and teacher.

Each of these was used in the research because mastery of these would demonstrate to the researcher as well as the teacher that development was taking place.

High and low self-efficacious believers hold differing views on why failure to succeed occurs. Highly efficacious believers attribute failure to succeed as due to lack of effort whereas low self-efficacious believers tend to attribute failure to succeed as due to poor ability. Outcome expectancies relate to the belief that certain actions will produce certain outcomes, but included in this is the belief that the practitioner can perform those actions successfully. In this study, the cognised goals were to increase the confidence of teachers to develop more open ended activities and classroom discussions so this clear goal could be achieved by all teachers but to a greater or lesser extent according to their capabilities. The goals negotiated between the researcher and the teacher were self-influenced so success and achievable goals were more likely. Success would not be achieved every time but success rate will increase with practice and wider experiences and this view was supported by post lesson reflection.

Self-efficacy has implications for outcomes in the classroom. Teacher efficacy has been found to be one of the important variables consistently related to positive teaching behaviour and student outcomes (Gibson and Dembo, 1984; Ashton and Webb, 1986; Enochs *et al.*, 1995; Woolfolk and Hoy, 1990; Henson, 2001). Research on the efficacy of teachers suggests that behaviours such as persistence at a task, risk taking, and the use of innovations are related to degrees of efficacy (Ashton and Webb, 1986). For example, highly efficacious teachers are more likely to use open-ended, inquiry, student-directed teaching strategies, while teachers with a low sense of efficacy are more likely to use teacher-directed teaching strategies, such as children copying or a strong reliance on published materials. Research indicates that children generally learn more from teachers with high self-efficacy than those same children would learn from those teachers whose self-efficacy is low (Ashton and Webb, 1986). Specifically, little is known about what kinds of experiences have the greatest effect and what those effects might be. In general, content area training by itself has not produced increases in science teaching self-efficacy. Methods instruction has shown varied results (Cronin-Jones, 1991; Ginns *et al.,* 1995). Having an impact upon teaching self-efficacy may be inherently problematic, because self-efficacy is a construct that develops over time and with experience (Henson, 2001), hence the longitudinal aspects of this research.

Cochran-Smith (1991) and Grimmett and Neufield (1994) reported that much of the in-service training or staff development that teachers are now exposed to is of a formal nature, often unconnected directly to classroom life, and a mélange of abstract ideas that pay little attention to the ongoing support of continuous learning and changed practices. Outside experts view teaching as technical, learning as packaged and teachers as passive recipients of the findings of objective research.

This model predominant in changing teacher practice is itself pedagogical, in that the provider has full responsibility for making decisions about what will be learned, how it will be learned, when it will be learned, and if the material has been learned. This provider-directed instruction, places the learner, in this instance the classroom teacher, in a submissive role requiring obedience to the provider's instructions. The result is a teaching and learning situation that actively promotes dependency on the instructor (Knowles, 1984).

If, however, we consider the characteristics of adult learners as summarised by Hiemstra (1993) and Knowles (1980), namely that they are:

- motivated to learn;
- self-directed;
- responsible, and
- use prior experiences as a template for learning.

There is a conflict of control between the provider and the teacher. The providers do not take account of developmental changes on the part of adults, and this conflict produces tension, resentment, and resistance in individuals (Knowles, 1984). Knowles' dialogue, debate, and subsequent writings related to andragogy have been a healthy stimulant to some of the growth of the adult education field.

By contrast in constructivist learning environments, the rich source of life experiences that adults have serves as the basis of learning. According to Jonassen (1994), anchoring learning to larger, relevant, complex, challenging tasks can help the learner develop learning strategies for problem solving through scaffolding. This strategy provides support for the learner to accomplish a task he would be unable to achieve on his own and support is gradually removed as the learner takes more responsibility for his own learning (Duffy, *et al.,* 1998). Vygotsky's (1978) zone of proximal development is mirrored in this style of continued professional development and links with critical intervention. The goal of scaffolding is to enable the learner to go beyond the zone of proximal development (Dunlap and Grabinger, 1996). The zone of proximal development embodies a concept of readiness to learn that emphasises upper levels of competence. These upper boundaries are not fixed, however, but constantly changing with the learner's increasing independent competence. This learning environment will be much more effective when the learner understands the purpose of the new practices resulting in greater motivation.

3.6.2 A Constructivist environment

To achieve optimal learning by meeting the four educational needs of adults, a constructivist learning environment as described by Savery and Duffy (1996) and Hacker and Harris (1998) has been shown to be effective. The learning environment emphasises learning over teaching, encourages learners to engage in peer dialogue, supports collaborative learning, while encouraging learner autonomy, emphasises the context in which learning occurs, and anchors learning to real-world, authentic tasks, so as to link to teachers' prior experiences. Similar ideas have been put forward by Caffarella and Barnett (1994) who proposed that adults require more flexibility in their education due to career, family, and personal constraints. In a "situated cognition experience", the experience itself becomes the activity and takes on a dynamic role in learning: "Adults no longer learn from experience, they learn in it, as they act in situations and are acted upon by situations" (Wilson, 1993). According to situated cognition theory, knowledge is subjective, contextualised, and relative (Jonassen *et al.,* 1995), situated in the activity, context, and culture of the event (Brown *et al.,* 1989; Lave and Wenger, 1991). Context affects not only what information is processed, but also how it is processed. Learning is seen as a social, dialogical process in which communities of practitioners socially negotiate the meaning of phenomena (Jonassen *et al.,* 1995). Since knowledge is embedded in experience and personally constructed, instruction must situate learning in authentic, real-world contexts that involve collaboration and social interaction (Lave and Wenger, 1991; Jonassen *et al.,* 1995; Carr *et al.,* 1998).

Howard *et al.* (2000) detail a study in which professional teachers experienced a constructivist learning environment while learning about constructivist theory. As a result of these constructivist experiences, changes in the participants' personal epistemologies were documented and they concluded that epistemology is a less stable trait than had previously been supposed. Jadallah (1996) facilitated a constructivist process of preparation with several of his pre-service teachers. Reflective thinking strategies were encouraged as these pre-service teachers made curriculum and instructional decisions in actual school settings. Jadallah found that the pre-service teachers engaged in reflection were more mindful of their teacher mediation in their school settings and more insightful about their decisions than the pre-service teachers who were not engaged in the reflective process. Kerka (1997) advocates what she refers to as "key aspects of communities of practice," such as authentic activities, knowledge application, access to experts, and a "social context in which learners collaborate on knowledge construction." The organisational structure created by education often neglects the needs of teachers as adult learners.

3.6.3 Andragogy

The application of the pedagogical model applied to adults seems a contradiction in terms. In a number of ways the pedagogical model does not account for such developmental changes on the part of adults, and is prone to produce tension, resentment, and resistance in individuals (Knowles, 1984). The theoretical idea created to explain how learning in adults differs from the way in which children learn and must be accounted for in the instructing of adult learners, has been dubbed andragogy. Those involved in teacher professional development need to take account of how adults are different as learners from children as learners. Knowles' writings related to andragogy have affected the dialogue and debate about the provider's role and the learner's role in the field of educating adults. The notion that pedagogical approaches to learning were perhaps inappropriate for adults was an important leap forward.

Adult learning theorists such as Knowles (1984) and Mezirow (1990) believe that because adults are increasingly self-directed, their readiness to learn is stimulated by real life tasks and problems. This is the situation many teachers face with what they perceive as an overloaded curriculum and increased bureaucracy. Mezirow (1990) proposes that learning takes place through the analysis of problems and the generation of themes that become the content of a learning situation. Mezirow proposes a theory of perspective transformation which deals directly with learning through the process of critical reflection. This produces transformative learning, self-reflection and the realisation of how perceptions of practice can be changed to allow fresh interpretation. The teachers cannot necessarily achieve this in isolation as there is usually a need for intervention at critical stages in the learning process as cited by Bullough *et al.* (1991) and Britzman (1986, 1991).

Adult learning theorists emphasise that providers need to take account of andragogy when attempting to modify teachers' ideas about the methodology of science education. Through the work of Knowles, and those others involved in andragogical theory, there are now six assumptions about how adults learn which would apply to teachers as adult learners (Knowles *et al.,* 1998):

the need to know;

Adults need to know why they should learn something. Under the more standard pedagogical model it is assumed that the student will simply learn what they are told. Adults, however, are used to understanding what they do in life and they want to know the reason why they need to change their ideas and how it will benefit them, or their working practice. Adults need to be encouraged to be reflective, think how they might use new ideas and how they will help them meet their goals.

the learner's self-concept;

Knowles believes that adults have a deep need to be self-directing. Once the adult matures, they change from being a dependent learner to a self-directed learner. Adults should not be treated like children, a child is dependent upon the teacher for the "what, how, where, and when" learning will happen. This pedagogic approach places the learner in a submissive role requiring compliance with the teacher's instructions. It is based on the assumption that learners need to know only what the teacher teaches them. Adults are able to express what they need from the learning process therefore should be a part of the planning process.

the role of the learner's experience;

As adults grow, they develop and collect experiences. Adults have a much larger resource of past experiences that they can draw from while they learn. Because this is such a significant part of their knowledge it cannot be ignored by anyone seeking to change the learner's attitude, epistemology or practice. They will draw on their past experiences when and while they learn and the provider must use this to stimulate the motivation for change. Adults' own experiences also tell them that they do not need to learn in isolation but can learn from each other. This enables them to create their own support networks, as mechanisms whereby they can learn. These can be arranged as a formal consortium, or can be informal in casual conversation.

readiness to learn;

Most adults choose to learn because it is relevant to what happens in their daily practice, dissatisfaction with current practice, it answers problems that need to be solved, or they have a desire to know more. They are ready to learn because they see the immediate importance of it.

orientation to learning;

According to Knowles, adult orientation to learning should be based on problem solving, rather than by memorising content, giving an orientation to learning which is more life-centred than subject-centred. Adults are relevancy-based learners and learn better in real world situations, they want to apply their learning to the real life situations they live and deal with everyday.

motivation

While adult learners may respond to external motivators, internal priorities are more important. Incentives such as increased job satisfaction, self-esteem and quality of classroom experiences for children and teachers are important in giving the teachers a reason to learn. Activities that build self-esteem, or sense of accomplishment may help motivate. In addition, the participant's input into the development of the professional development programme, or in the prioritisation of issues can help participants to take ownership of the learning process.

3.6.4 Heutagogy

While andragogy (Knowles, 1980) provides many useful approaches for improving educational methodology, and indeed has been accepted almost universally, it still has some connotations of a teacher-learner relationship. It may be argued that the rapid rate of change in society, and the so-called information explosion, suggest that we should now be looking at an educational approach where it is the learner who determines what and how learning should take place. Heutagogy, the study of self-determined learning, viewed as a natural progression from the earlier educational methodologies may well provide the optimal approach to learning in the twenty-first century.

A major contribution to the paradigm shift from teacher-centred learning to heutagogy was made by Argyris and Schon (1996) in their conceptualisation of double loop learning. Double loop learning involves the challenging of our 'theories in use', our values and our assumptions rather than simply reacting to problems with strategies found in single loop learning. So many teachers are looking for the quick fix, or sticking-plaster approach to problem solving (single loop), rather than a fundamental paradigm shift (double loop). It is a brave or insightful teacher willing to change fundamental views to produce benefits in children's education that they can only foresee happening. In describing learner-managed learning, Long (1990) suggested that learning 'is an active process in which individuals either seek out education and experiences or obtain feedback and do evaluation as they move through life's experiences' (p 36). This is more than self-directed learning as Knowles (1980) defined it in that it recognises the value of everyday, unorganised experiences and the process of reflection.

3.6.5 Learning Capability

A model which challenges traditional concepts of learning and which looks at outcomes as well as process is that of Capability (Stephenson and Weil, 1992). Capable people are those who:

- know how to learn;
- are creative;
- have a high degree of self-efficacy;
- can apply competencies in novel as well as familiar situations, and
- can work well with others.

In comparison with competencies which consist of knowledge and skills, capability is a holistic attribute. Developing capable people requires innovative approaches to learning consistent with the concept of heutagogy. Graves (1993) and Hase (1998) designed strategies to enable people to become capable, to focus on the need to learn and how to learn and being a learner, rather than being teacher-centred. Helping people to become 'capable' necessitates new approaches to teacher education. Capable people are more likely to be able to deal effectively with the turbulent environment in which they live by possessing an 'all round' capacity. To make meaning, the adult makes sense of an experience and then interprets the experience to guide future actions. Modern organisational structures, such as schools, require flexible learning practices; and there is a need for immediacy of learning. In response to this environment there have emerged some innovative approaches that address the deficiencies of the pedagogical and andragogical methods. These methods take account of intuition and concepts such as 'double loop learning' that are not linear and not necessarily planned. It may well be that a person does not identify a learning need at all but identifies the potential to learn from a novel experience as a matter of course and recognises that opportunity to reflect on what has happened and see how it challenges, disconfirms or supports existing values and assumptions.

For many teachers this constitutes a major change in the way they consider education and not least how they can develop new strategies for teaching. Managing the change is strongly related to those individuals who have intrinsic 'capability'. Rogers (1969) suggests that people want to learn and have a natural inclination to do so throughout their life. Indeed he argues strongly that teacher-centred learning has been grossly over- emphasised. He based his approach on the following five hypotheses which equally apply to teachers' epistemology:

- we cannot teach another person directly: we can only facilitate learning;
- people learn significantly only those things that they perceive as being involved in the maintenance or enhancement of epistemology;
- experience which if assimilated would involve a change in epistemology tends to be resisted through denial or distortion of the ideas, and more so if perceived as under threat;
- experience which is perceived as inconsistent with the self can only be assimilated if the current epistemology is relaxed and expanded to include it, and
- the educational system which most effectively promotes significant learning is one in which threat to the self, as learner, is reduced to a minimum".

Capability includes active learning processes such as reflection, a wider view of interconnected factors, valuing experience and interaction with others. It goes beyond problem solving by enabling proactivity. Hodgins (2000) argues that what he calls "know-why" is more important than "know-how" or "know-what" since know-why is a deeper knowledge that underlies a discipline or practice. However, Hodgins also makes a case that all three types of knowledge are important and will be even more robust in the future. As science educators re-examine the purpose and the goals of teacher in-service programmes, an understanding of the pivotal role of teachers in the process of change and innovation in science education is of the utmost importance. As Goodrum *et al.* (2001) point out the teachers must be given the time to collaborate, evaluate and adequately prepare and these significant changes in teachers' instructional practices come only after there are fundamental changes in teachers' belief systems and that these changes will necessarily take time. Also if the teachers as experienced professionals are to re-examine and possibly change their epistemology, they must be treated by the providers as learning adults and the providers must encompass those aspects of learning which are peculiar to adults.

3.7 Summary

If teachers' expertise is considered to be one of the most important factors in learning, then much of what constitutes teacher development is too restrictive. There was little evidence of the adoption of constructivism in existing teaching because this implied teacher knowledge about, and belief in, constructivist principles. Much of what purports to be development of teacher expertise is delivered in traditional behaviourist modes and not constructivist modes. The norm being that teachers learn new strategies through a series of workshops or a conference and they are told what to do, but not how to do it.

If long term change in practice is to be achieved then it has been argued that the time allowed for continued professional development has to be extensive. The teachers themselves and their needs must be at the heart of staff development and whereas much of teachers' non-contact time is not spent on staff development, it is spent on the day to day mechanics of teaching and developing practical resources. The traditional method of training needs a radical rethinking, away from the underlying philosophy of making teaching teacher proof.

It has been argued here that Action Research and development of teachers over time in their own classrooms has been a much more effective method for teacher development especially if a change in epistemology is to be achieved. This allows a much greater dialogue between researcher and teacher. Action research is not simply a problem solving approach creating opportunities for reflecting and critical thinking, it is more inquiry orientated where both the researcher and the teacher will form a dialogue of future actions, but these will inevitably contain a problem solving element. In its most useful form there is a dialogue, where both participants are considered of equal standing, but having different skills and experiences to bring to the discussion. This critical friendship was considered an essential pre-requisite for this research and the learning must take place within the teacher's experiences and must relate to real situations in the teacher's classroom.

Both Critical Theory, where the data are interpreted by the researcher and teacher, and Reflexivity where there is a constant seeking for ways of doing things more efficiently or in a more rewarding fashion, pervade this research. The inclusion of both positivist (quantitative) and interpretivist modes of data collection allows the researcher to record the teacher's pedagogic view and the children's scientific cognition as a co-inquirer, thus demonstrating how to elicit children's views, leading to a change in teachers' epistemology. Action research involving critical and reflexive thinking would argue that the view of continued professional development should change from single events (for example workshops), to a more long term continuum with the support of colleagues within school. Learning is more effective if the teachers are involved and this is seen to be crucial because they will observe and take account of struggles in learning and achieving landmarks along the way. The importance of evaluation which ensures that the participants are reflecting on their change in practice, has been emphasised and this is inherent in both reflexive action and critical thinking. It has been acknowledged that this is more effective if formally done, but this may not be convenient in all circumstances.

Adults, as learners, are different from children. Adults have more life experiences, education experiences and greater maturity. However some adults hold deep seated convictions (as some children do) about education and the way learning takes place and what the requirements of the curriculum are, be it knowledge or skills or a mixture of both. As adults they make the decisions as to how their classroom is organised and teaching takes place and the researcher and the teachers have to take account of this. Simply laying down new practices is not sufficient if these are not going to be, or are completely incapable of adoption. For this reason, a dialogue must take place between the practitioner and the researcher. The dependence of the teacher on the instructor was not a solution to be adhered to as the initiative was limited in its timescale and a legacy of change was one of the requirements of the research.

Andragogy may have been considered as a starting point, but there are some teachers who change the way they consider education and take partial control of the learning process, this has been referred to as heutagogy. A further development is learning capability. Shown by those teachers who are creative and develop high degree of self-efficacy, it can take the ideas and adapt them to their own situations. They are capable of dealing with difficult circumstances as they arise and without always seeking help for a solution, they can find a solution to the problem themselves. The capable learner knows why a change must take place and places the learner at the heart of any continued professional development.

4 Methodology

4.1 Introduction

Teachers want INSET and if they are going to give up time they demand quality INSET. Not INSET which is the Senior Leadership Team or Local Authority idea, but INSET that will help them change their practice either for better or easier science teaching and not as an imposition from above. In this intervention various methods of data collection were considered appropriate, such as questionnaires, various tests and other activities as well as support in class and these are summarised in Table 4.1.

Table 4.1 Summary of data collection

Intervention	Personnel	Purpose	Data type
Questionnaires	Teachers	Information	Background
		Attitudes	Teacher Confidence
	Headteachers	Confirmation	Triangulation
Assessment	Teachers	Knowledge	Multiple Choice Questions
			Concept Mapping
			Elicitation Activities
	Children	Knowledge	National Test Items
			Science Reasoning Tasks
			Elicitation Activities
			Pre and Post Tests
			Class Discussion
			Class Observations
			Class Work
Support	Teachers	Expertise	Workshops
	Science Coordinators	Scheme of Work	Task
	Teachers	Development	Epistemology
	Children	Development	Confidence and Communication

Initially there would be a pilot survey of a selection of primary Headteachers to confirm the main research questions and these would be in the form of focussed interviews allowing the Headteachers to express their opinions. Also information will be collected about the schools' perspectives on the main research questions and the organisation of INSET, for example, the type and the topics, the needs of the school and the participants.

The problem with traditional workshops is that teachers do not necessarily have the skills to implement the new approaches so the workshops here could be used to raise awareness of the important science concepts within a topic, to provide more detailed information in the booklet and to try some of the activities recommended with the topic so the teacher could familiarise themselves with the new techniques. It would also be important that the teachers could engage in a professional dialogue and this would provide dissemination of ideas and activities developed during in-class support. Thus the teachers could share ideas with other professionals developing a community approach.

In order to develop the skills and adopt a constructivist approach to teacher continued professional development it was felt that in-school support was essential. This would develop teacher skills and demonstrate the effectiveness of the strategies being proposed. This was treating the learners as adults and professionals and the associated discussion between researcher and teacher would permit a focus on the skills and concepts for both the children and their teachers. So a professional dialogue between the more and less expert could take place.

In order to obtain feedback for the content of future workshops, there would have to be some assessment of teachers' basic knowledge to provide some baseline information. The methods of assessment were techniques that could be used by teachers themselves to assess their children's abilities and knowledge. These would include traditional tests, but containing some concepts that might not be assessed by national test items, as well as some strategies which might be used by the teachers such as concept mapping and elicitation activities.

Various concept mapping and elicitation activities will be devised by the researcher, based on commonly held children's ideas, yet the teachers might be unaware that their children would be holding these views. The devised activities could be used by the researcher and the teacher to assess the depth of knowledge and grasp of concepts (not revealed by traditional testing) of the children. For the purposes of research, the concept maps would be scored for the teacher, but for the assessment of children a simple inspection of the complexity of the map would be used to assess the complexity of knowledge.

An important aspect, as well as teacher knowledge and understanding, were teachers' beliefs in self-efficacy. Here there was no absolute measure of self-efficacy, I was looking for a comparison of the teachers' confidence over time. This would be indicated by the same teachers completing the survey. The in-class support would be the main vehicle for developing the teachers' feelings of self-efficacy. Lincöln and Guba (1985) argued that research designs must be emergent because:

- meaning is determined by context to a great extent;
- the existence of multiple realities mitigates the imposition of a design based on the researchers pre-ordained assumptions;
- what is uncovered is a result of the interaction between the researcher and the participants;
- the situation is not fully predictable, and
- the nature of the reactions cannot be known until experienced.

It soon became obvious from starting the research that teachers and science co-ordinators were lacking appreciation of the hierarchy of difficulty and progression within and between topics. Teachers' activities were limited mainly by the scheme of work published by the Qualifications and Curriculum Authority (QCA) mainly because they didn't know at the start, especially in the physical sciences, what activities could be carried out. For example chemical changes tended to be limited to bicarbonate of soda and acid and burning, being used mainly for transmission of knowledge and not using properties as a means of classifying changes.

There was initially a dilemma in assessing children but in assessing their concepts as opposed to their knowledge is a key to this research whereas traditional testing involves mainly knowledge of scientific information. Headteachers and their school managers have to take account of performance in external testing because these are widely acknowledged to be indicative of ability and performance by the school especially the teachers. Part of the role of assessment is to indicate increased performance by public testing, but of major importance is enjoyment of science and challenge within science and conceptual development. This was much more difficult to ascertain by simple testing, because it requires discussion, questioning and some form of interpretation. Factors such as enjoyment and confidence are more difficult to assess numerically since they are much more ephemeral. A pragmatic approach collecting a variety of evidence will be collected and this is intended to demonstrate progress both in terms of knowledge and concepts.

Class discussion will be analysed as part of this process and the complexity of the discussion and the nature of the expression of ideas can show development by both teachers and children. Although classroom observation is anecdotal and interpretivist, it remains an important form of assessment because it can reveal by timing, facial expression, or tone of voice, many other facets not revealed by written answers. This evidence would be collected by fieldnotes and recordings since it was not known when the incidents would occur. Recordings and fieldnotes can be used to show the development of discussion and the scientific story in the classroom. Also if skills are developed in class this would be indicated by the triangulation studies conducted at the end of the project.

Each of these will be dealt with in separate sections, but there will inevitably be cross references because of the complex nature of the interactions.

4.2 Background to Teacher Continued Professional Development

Teachers want to continue to update and develop their skills and knowledge for their own benefit and that of their children. Many years have elapsed since *The James Report* of 1972 made 'official' the requirements of in-service education for teachers (INSET) in order to develop their knowledge and skills and the National Foundation for Educational Research (NFER) survey of 2003 confirmed this continued desire. However, within the INSET they experience, teachers want training and development activities which are focused, well-structured, presented by people with recent and relevant knowledge and which provide opportunities for active involvement as highlighted by Harland and Kinder (1997). Although teachers value their professional development, they are reluctant to give up time for development activities which do not satisfy their definition of quality. Anecdotal evidence from teachers in this study associated continuing professional development with 'doing something new', and/or having something given to them, which they can take away and utilise, but this was also viewed as an additional burden by some teachers. There seems to be a contradiction in providing 'transmissive' INSET packages with the paradigm of life long learning, about learning communities, and about reflective practice. It may be that this 'transmission' orientation to continuing professional development is itself in part a product of a professional orientation to 'delivering' the curriculum. It was evident from discussions with the schools that although the vast majority had developed effective professional development learning communities, this was not the case in all the schools. Day (1999) has defined professional development as consisting "of all natural learning experiences and those conscious and planned activities which are intended to be of direct or indirect benefit to the individual, group or school and which contribute through these to the quality of education in the classroom". Welsh (2002) endorses a framework of collaborative professional development. He suggests that the linking of Universities and Colleges of HE to individuals and schools could integrate both individual professional and school development providing a strategy that enables teachers to initiate and sustain change by becoming active change agents rather than objects of change. Similarly, Barber (1996) argues that professional development should not be founded on 'narrowly conceived ideas about INSET but on the idea of the teacher being a life long learner, who is a member of a research-based profession.' It was important that the delivery was treating the learners as adults, they must see the relevance to the INSET with their own varied needs in the classroom, and if constructivism, as an epistemology, is to be promoted then the training must be constructivist in itself, mirroring Vygotsky's zone of proximal development. This approach has been advocated by Duffy *et al.* (1998) who favour teachers taking responsibility for their own learning.

4.2.1 Whose interests?

There were a number of concerns about the balance between national agenda, school priorities and teacher needs and the tension this engendered between the major drivers and the school's own needs. The schools felt very much driven by government initiatives aiming to raise standards in literacy and numeracy and its associated constraints on classroom practice. The appropriate balance between national initiatives, school generated issues and teachers' individual professional needs was focused on primarily by developing the skills, knowledge and expertise of the teachers, giving workable, practical solutions based on sound theoretical principles. The two quotes from teachers show the necessary emphasis. *"They have told me I am doing it wrong, but nobody has told me what good science teaching looks like,"* or another painful quote *"I'm fed up with having my awareness raised!"*

4.3 The Design and Use of Interviews and Questionnaires

At the outset the question styles and types to determine any additional main research questions were piloted with the Headteachers and because these were conducted as focussed interviews, modifications could be noted. This allowed the researcher to test the effectiveness and wording of the question and scaling methods used. The drawing up of the surveys took place at the beginning of the research project and the processes involved in designing the survey, where appropriate, are those set out in Oppenheim (1992). From the list he advocated, these were considered relevant:

- deciding the aims of the study and, possibly, the theories to be investigated;
- reviewing the relevant literature; discussions with informed professionals and organisations;
- preliminary conceptualisation of the study, followed by exploratory or 'depth' interviews; revised conceptualisation and research objectives;
- doing the necessary pilot work to try out the instruments, making revisions where necessary;
- selecting what the sample(s) were that is the selection of the people to be approached, and
- collecting the actual data through interviewing and completion of various questionnaires.

The interview technique requires:

- Interpersonal skills of a high order putting the respondent at ease,
- Asking questions in an interested manner,
- noting down the responses without upsetting the conversational flow, and
- giving support without introducing bias.

In a normal research situation, where the interviewer is not known to the interviewee s/he can be either limited or helped by his or her own sex, apparent age and background, skin colour, accent etc. but this was not the case here, in that the interviewer was known to the interviewees.

4.3.1 Conceptions of the interview

Kitwood (1977) has identified three major conceptions about the interview as a research technique:

- it is a potential means of pure information transfer;
- there is inevitably bias in any interview, and
- it is an encounter, which has flaws akin to many aspects of human interactions.

The most commonly identified problem with the use of questionnaires and interviews in educational research is one of bias. Selltiz *et al.* (1962) and Borg (1963) identified this, for instance the interview allows greater depth, on the other hand it is prone to subjectivity. This can be present initially in the format of the question influencing the interviewee in the responses made, for example, trying to 'please' the researcher and giving the 'expected' answers (Borg, 1981). Cohen and Mannion (1994) highlight three purposes served by interviews:

- the principal means of gathering research data;
- testing hypotheses, and
- to support other methodologies.

Although this interview was only a small part of the data gathering exercise it enabled the researcher to gain access to the interviewee's thoughts, preferences and beliefs (Tuckman, 1972).

For this study the most appropriate view would be that of Grebenik and Moser (1962) who see the interview as on a continuum, which would allow the researcher much more freedom to develop ideas highlighted in the interview. The interviewer/researcher can elicit data from the interview to substantiate or reject previously formulated hypotheses. As Merton *et al.* (1990) explain, "In the focused interview the interviewer can play a more active role: he can introduce more explicit verbal clues to the stimulus pattern".

Thus the focused interview would ensure that all the major themes are explored and allow the freedom to develop and clarify the responses and probe the thoughts of the interviewee. Focussed interviews have been defined by Kerlinger (1970) as 'those that supply a frame of reference for respondents' answers, but put a minimum of restraint on their answers and expression". These questions have the advantages of being flexible and allow the interviewer to seek clarification, take an issue further and may even introduce into the discussion issues that the interviewer might not have considered when devising the original schedule.

4.3.2 The Interviews

Two kinds of interview were used in this research:

(a) *Exploratory Interviews*, depth interviews, or free-style interviews used initially
(b) *Standardised Interviews* used latterly.

As is evident from their titles, these two types of interviews generally are used in the research process at different points, initially the exploratory interviews and then the standardised interviews. They also have quite different purposes and have to be carried out in quite different ways. It is normally recommended that interviews are recorded in order that they can be analysed in detail afterwards, but this was considered to be a little intrusive at a very early stage of the research. The triangulation interviews carried out at the conclusion of the research were recorded. In a structured questionnaire, notes could be jotted down on the main issues, whereas there would be disadvantages in using a technique that is too closed since it might fail to gather data, ideas and opinions from some very experienced members of the teaching profession. The purpose of the *exploratory* interviews is essentially heuristic: mainly developing ideas and research hypotheses rather than gathering facts and statistics. The interview was mainly concerned with trying to understand how people thought and felt about issues of concern related to the research.

Many research workers also like to use interviews because they feel that interviews are more valid in some sense. They would argue, that the interviewer has actually seen and talked to the person, has reported a written set of real responses made at the time and there cannot have been too many misunderstandings. This is considered to be worth more than little ticks in boxes returned by teachers whom you have never met and who are short of time anyway. Interview results may be genuine and rich, yet they can also be biased and unreliable. Selltiz *et al.* (1962:583) pointed out "interviewers are human beings not machines" and there is a danger that if the researcher carries out the interviewing there will be consistency but bias may go unnoticed, but awareness of the problem can help".

4.3.3 Descriptive and Analytic Designs

There were two reasons for conducting the questionnaires in the pilot study:

- to gain biographical data about the teachers for example qualifications, and
- to gain attitudinal data from the staff.

The purpose of the descriptive survey or questionnaire is simply to count the numbers in each category and this would be appropriate for biographical data from the staff and for this standardised interviews could be used. If the survey counts a large enough sample to be representative, this would allow inferences to be made about the whole population.
The purpose of an analytic survey which would be appropriate for measuring a change in teacher confidence, would give an indication of cause and effect. These two are linked by variables:

a) Experimental variables which are the 'causes' or predictors of the effects. These would be varied systematically so their effects can be observed. No one effect was experimentally verifiable, because one factor could not be isolated, many factors related to teaching and learning would be inter-related. There was however a variable of time in the longitudinal aspect of intervention and it would be possible to measure whether there was any statistical variation in the confidence of teachers.
b) Dependent variables. These are the results, the effects-variables, produced by the impact of the experimental variables, the predicted outcomes. These variables should be measured carefully and group differences tested for statistical significance. These may be factors such as do science qualifications have an impact on the attitudes of teachers teaching science topics.
c) Controlled variables. As a source of variation these should be eliminated in order to fulfil the condition of *other things being equal* when the effects or correlates of the experimental variables are stated. The only controlled variable in this study was that they all had an impact on the learning process –teacher, science co-ordinator, headteacher. The effect of controlled variables may well not be appropriate for such a small study.
d) Uncontrolled variables. These are 'free-floating' variables and can theoretically be of two kinds: (a) confounded variables and (b) error. The confounded variables sometimes called correlated biases have hidden influences on the results for example teacher reaction to the process or the issues. These can lead to errors and biases, which intrinsically are unwanted but may well lead to the development of new hypotheses. In analytic surveys, as in experiments, the influence of uncontrolled variables should be as small as possible. However since the same teachers would complete the same survey at a later stage in the longitudinal studies these errors could be minimised.

4.3.4 Reliability and validity of questions

Interview results may be genuine and rich, yet they can also be biased. In trying to assess how well each question, or group of questions, performs its function it needs to be assessed in terms of the concepts of reliability and validity. It is important to reduce bias here while still eliciting the views of the teachers. Validity, for example, may be concerned with whether the respondent is telling the truth, or whether the question measures what it purports to measure. Reliability refers to the consistency of a measure, to repeatability and reproducibility, so the probability of obtaining the same results again if the measure were to be duplicated. This can be checked between respondents from different schools and using the researcher's professional judgement and the concluding interviews with the Headteachers will be used to verify in part the validity of the various teacher responses. It is often possible in questionnaires to check reliability and validity by asking the same question in a different form.

To ascertain reliability in questions the researcher planned in some internal checks, for example, to assess the effectiveness of a science policy there may be different responses (in the same school) from someone who was involved in its development to someone who has it imposed upon them. Both opinions will be valid but could produce different data. It might be that different respondents produce the same data which may well indicate one measure of its effectiveness. This also illustrates validity, for example, is one school's view of a science policy, the same as another school's?

4.4 Teacher Continued Professional Development

4.4.1 Workshops

The problems associated with workshops such as teachers' lack of control, lack of time for discussion, are confirmed by other researchers, who have noted that workshops which comprise the most traditional staff development methodologies do not provide sufficient time, activities, or content necessary to promote meaningful change (Garet, *et al.,* 2001). Studies by Joyce and Showers (1996, 2002) showed that fewer than 15% of teachers implemented new ideas learned in traditional staff development settings such as workshops. The problem with these traditional approaches is that teachers often do not have the skills or knowledge needed to apply what they learn and have no possibility of receiving support or feedback when they do attempt to apply what they have learned. Teachers need time to see new strategies modelled during the school day and opportunities to use new skills in developing and implementing learning activities (Garet, *et al.,* 2001; Joyce and Showers 1996, 2002; Rodriguez and Knuth, 2000). Russo (2004) summarised these research findings and stated, effective staff development must be "ongoing, deeply embedded in teachers' classroom work with children, specific to grade levels or academic content, and focused on research-based approaches. It also must help to open classroom doors and create more collaboration and sense of community among teachers in a school".

Reports from Ofsted (1999, 2004, 2008) have shown that science in the primary school is generally a success in their terms, which may be the raised priority of science, the time devoted to planning science activities, the universal prescription of content. However the evidence from the pilot study and reinforced nationally (House of Commons report, 1995) where teachers concentrate on 'doing' science rather than using tasks to draw out the underlying scientific ideas means that the links between process skills and the underlying conceptual developments are not being made. There is strong anecdotal evidence, from a wide range of observers including Hacker and Rowe (1997) that teachers concentrate on disseminating knowledge rather than developing skills and understanding. This continues with the ever greater stress placed by Headteachers, Local Authorities and political organisations on league table performance of National Testing data. According to some researchers, including Bishop and Denley (1997), good quality science teaching depends on strong subject knowledge and is in danger of being squeezed for time in Post Graduate Certificate in Education (PGCE) courses, Wallace and Louden (1992) also emphasised the importance of good subject knowledge. Included within good practice, is an understanding of children's learning in science, the good teacher should be aware of the conceptual difficulties children have with some areas of science and should be able to address any misconceptions that may occur. The researcher believes the latter part of this statement has far more significance than simply the transmission of knowledge and this determined the format of the workshops basing them on a minimal number of fundamental science concepts that teachers could assimilate and then apply to their teaching. This dilemma was further explored by Wallace and Louden (1994). Several authors (McNamara, 1991; Kruger, 1990; Shulman, 1986) have carried out research on how to transform content knowledge into pedagogic knowledge - into forms which are acceptable to children - and to reflect on how best to accomplish this transformation. In addition, research into Children's Learning in Science (Johnston, 1987) and their cognitive development as highlighted by Shayer and Adey, (1981, 1989, 1994) have had a strong influence on the methodology found both in the workshops and classroom approaches in this research, yet still allowing modifications.

4.4.2 Teacher needs from continued professional development

Key factors, underlying what teachers consider good practice and want to gain from the workshops, have been identified by the NFER (2003) as:

- relevance of content for teachers' needs;
- opportunities for 'hands-on' practical experience ;
- well structured and focused sessions;
- good delivery by presenters who have recent and relevant experience, and
- opportunities for sharing ideas with other teachers and the providers.

NFER (2003) also quote that "Discussion, practical involvement, workshops which are run on relevant school/child issues that help inform and allow reflection on classroom practice and curriculum knowledge". Research on science content courses have given conflicting results as to whether they have improved the confidence of teaching science (Appleton, 1995; Dobey and

Schafer, 1984; Dooley and Lucas, 1981; Goodrum, *et al.,* 2001; Skamp, 1989; Stepans and McCormick, 1985). A more positive picture was found in studies where a constructivist framework (Appleton, 1995) and inquiry based learning was used (Huinker and Madison, 1997), indicating that in their study they concluded that pedagogy was at least as important as content. Relationships between science teacher educators and pre- service teachers (Rice and Roychoudhury, 2003), have been shown to be crucial and Hardy and Kirkwood (1994) and Skamp (1995) also showed the establishment of a successful learning environment to be vital. Teacher- centred and open environment approaches have been advocated by Appleton (2003); Cahill and Skamp (2003); Korthagen (2004) and Rice and and Roychoudhury (2003) and this points to developing a learning environment where reflection and risk taking are part of the everyday science learning environment.
Cordingley (2001) found that teachers consulted by the Teacher Training Agency most value research evidence when it:

- is collected through genuine partnership between teachers and researchers;
- is collected in authentic classroom contexts;
- derives from rigorous, transparent research methods;
- makes claims which are backed up by appropriate evidence;
- is communicated through vivid and detailed classroom case studies, and
- is related to improving aspects of teaching and learning that are relevant to them.

In a similar vein Oliver *et al.* (2001, pp 157-61) argue that practitioners need, but find it hard to get:

- access to relevant and appropriate research;
- skills to judge whether the research is reliable and applicable to current local needs, and
- research training when/where they need it, particularly in appraisal techniques.

This increasing recognition that continuing professional development needs to be closely allied to classroom practice conflicts with the notion that too often teachers have felt that their particular interests and needs are not 'centre stage'. There is also widespread cynicism amongst teachers resulting from bad experiences of courses that have little connection with the day-to-day job of improving teaching and enhancing learning.

Using new ideas, approaches or knowledge from continuing professional development requires teachers to make explicit their existing knowledge and beliefs to enable them to consider the relevance of new approaches for their own practice and the needs and context of their children and curricula. In the current climate of imposed reforms and a target-based culture it was important to the researcher that these new methodologies were not an imposition of extra, but were a means to enhance their teaching skills, so they felt more confident of their own ability and better able to provide a better learning experience for their children. However in this work there are other smaller, but equally important components, if innovation is to actually happen in the classroom. There needs to be communication between the practitioners themselves so they can debate, appraise and support each other in the change as well as feeding back to the 'experts' who may well modify their own thinking as a result of discussions with practitioners. Teachers value highly the sharing of good practice and each workshop provided opportunities to do this, leading to a typical learning cycle based on Kolb (1984) of plan, do, review and re-apply, with an internal loop to illustrate practitioner interaction.

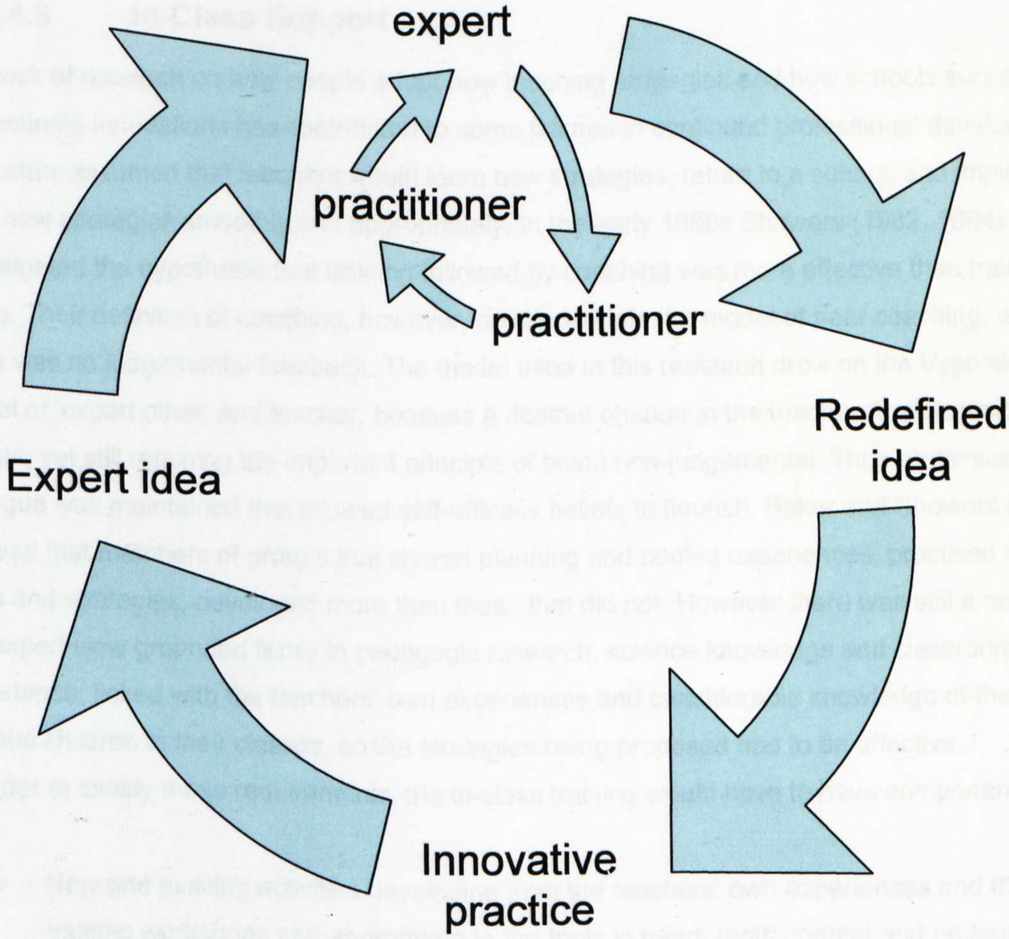

Figure 4.1 Learning cycle

Harland and Kinder have identified nine areas of categories for effective workshops and the more of these that are present the more effective the INSET will be. The importance of personal cognition and social collegiality in the learning process is highlighted by Brown and Sinclair (1993). The constructivist approach considers it anathema for workshop presenters that is 'the experts' to transfer new ideas from the presenter to the participants by delivering content-based curricular materials that will provide a quick fix or will provide them with a body of knowledge. They have not assimilated the content in the past, so are not likely to assimilate these ideas this time. This also indicated to the teachers, that the way these ideas were transmitted to them when they first encountered them, did not produce understanding or confidence, so these approaches are not likely to produce these attributes in their own children. The presenter must actively engage the participants in hands-on/minds-on activities to improve the teachers' abilities to engage children in scientific inquiry and the use of 'evidence-based learning'. The NFER survey (2003) emphasised that perhaps the single most important tool in the continuing professional development armoury is teacher coaching. However in most training this does not happen and its importance is only just being recognised (Birman *et al.*, 2000).

4.4.3 In-Class Support

The lack of research on how people adopt new teaching strategies and how schools successfully disseminate innovations has contributed to some failures in continued professional development. Educators assumed that teachers would learn new strategies, return to a school, and implement their new strategies smoothly and appropriately. In the early 1980s Showers (1982, 1984) investigated the hypothesis that training followed by coaching was more effective than training alone. Their definition of coaching, however, developed into the model of peer coaching, where there was no judgemental feedback. The model used in this research drew on the Vygotskian model of 'expert other' and teacher, because a desired change in the teachers' epistemology was sought, yet still retaining the important principle of being non-judgemental. Thus professional dialogue was maintained that allowed self-efficacy beliefs to flourish. Baker and Showers (1984) showed that members of groups that shared planning and pooled experiences, practised new skills and strategies, developed more than those that did not. However there was still a need for the expert view grounded firmly in pedagogic research, science knowledge and classroom experience; linked with the teachers' own experiences and considerable knowledge of the school and the children in their classes, so the strategies being proposed had to be effective.
In order to satisfy these requirements, the in-class training would have to have components of:

- New and existing activities developing from the teachers' own experiences and the training workshops and appropriate to the topic in hand, (both content and pedagogy);
- Planning of the activities that were within the expertise of the teachers;
- Demonstration and modelling of new pedagogic strategies to elicit children ideas; and
- Practice of the activity types with support from the expert other.

This importance, that the activity types which were grounded in classroom experience, demonstrating the impact they had on the children, also implied the greater would be the impact, the greater the period of time over which this took place. Joyce and Showers (1995) pointed out that staff development in schools must be organised to allow for meaningful interventions in the classroom. A survey of 107 teachers by Knight (2007) provided insight into when coaching should and should not model instructional practices in the classroom and his survey demonstrated, from the teachers' perspective, watching an expert other model pedagogies in the classroom was an important part of professional learning. Teachers would agree that watching another person in action made it easier for them to implement the strategies and would increase their belief in the teaching model, increase their confidence, and enable them to learn other teaching techniques. However, teachers would not perceive value in watching someone else teach specific course content.

4.5 Self-efficacy Beliefs

Enochs and Riggs (1990) devised a 25 item Science Teachers Efficacy Belief Instrument, or STEBI and this has maintained Bandura's model. STEBI has a 5 point scale for each Likert item (Likert, 1932). Some items were not appropriate for experienced teachers, however the principles of STEBI have influenced this researcher's survey, particularly in the five point scale. The survey did not match directly what the researcher was enquiring into, but the principle of self-efficacy beliefs and its implications were relevant. On this five point scale the researcher used the principles behind the STEBI questionnaires, with examples such as:

- able to help students and other teachers with difficulties in understanding science;
- know steps to effectively teach science;
- understand science well enough to be effective in teaching;
- welcome students' questions about science;
- able to answer students' and other teachers' science questions, and
- will find better ways to teach science.

4.6 Assessment of Teachers' Knowledge and Concepts

Heywood (2007) highlights two strands that are necessary for teacher effectiveness which are the area knowledge of science and the development of pedagogical knowledge appropriate to the learning of science. Although the supposition that secure personal knowledge of subject automatically results in more effective practice is not without question (Cochran-Smith and Lytle, 1999; Poulson, *et al.*, 2001), others consider a strong knowledge base as essential in developing effective pedagogic knowledge (van Driel, *et al.*, 1998). Teachers and teacher educators have strong beliefs that primary teacher's knowledge of science is relatively low anyway (Holroyd and Harlen, 1995). The level of scientific knowledge of primary school teachers is likely to be higher than that of the general population, but considerably less than science specialists. The teachers did in fact, in discussion, acknowledge this to be true and their responses to questionnaires would indicate the stage to which they studied science and this would indicate the level of their science expertise and the self-efficacy survey would indicate their own level of confidence about science knowledge and understanding. This led to the emphasis both in the workshop sessions and the in-class support, not being on vast amounts of subject knowledge but more on pedagogic knowledge based on a few underlying core scientific principles. It was important that the non-threatening learning environment was maintained, so that the teachers could realise that there were ideas that they held that were typical of the adult population as a whole, whether or not they had studied science. These views that they held were probably those held by children and needed to be addressed if a constructivist epistemology was to be adopted in the classroom science lessons. It was important for the teachers to realise that formal testing as typified by National Testing would often obscure a level of misunderstanding not revealed by the tests about underlying concepts. To achieve some measure of teacher knowledge initially teachers completed a survey whereby they self-evaluated their knowledge in science. Concept maps, short tests, and other elicitation activities were all perceived by the researcher as less threatening methods as for instance those used by Jarvis, *et al.* (2003) and these could in turn be used by teachers to assess children's knowledge. The results from these baselining activities fed into the content, concepts and design of the workshops.

4.6.1 Questionnaires, Concept Mapping and Elicitation Activities

Questionnaires such as the one developed by Pendlington *et al* (1993) on materials in the form of a questionnaire using multiple choice items were thought to be useful as a means of assessing teacher knowledge. Some of the questions from the 80 statements in the questionnaires were considered useful, but lacking were some concepts and ideas that the researcher had specifically identified as causing particular problems to teachers and which they needed to be confident about in order to teach the concepts to children effectively, so these would need to be included.

A further technique used in this study to assess teacher knowledge and understanding and that teachers could in turn use in the classroom was concept mapping. This technique developed by Novak and Gowin (1984) and based on the theories of Ausubel (1968), represents a person's structural knowledge about a certain concept or subject. The importance of prior knowledge in being able to learn about and assimilate new concepts was one of the fundamentals of Ausubel's (1968) work. Among his many conclusions, Ausubel stated "the most important single factor influencing learning is what the learner already knows." In the 1980s, Novak outlined the potential use of concept mapping for the improvement of teaching and meaningful learning (Novak and Gowin, 1984) and Novak concluded that "Meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures". In addition, Novak and others, have refined the original technique (Novak, 1998) and others such as Trowbridge and Wandersee (1994), McClure *et al.* (1999) and Nicoll *et al.* (2001), used concept mapping both as an instructional tool and as a method of assessment of learners' knowledge and understanding of a topic which is present in their long term memory, whereas Trochim (1985) has used concept mapping as a developmental tool. Equally as powerful and useful, concept mapping can be used to indicate the complexity or hierarchy of a learner's conceptual thinking.

In a concept map crucial terms, or nodes (the concepts), are related by means of explanatory links (the propositions) and these declare the relationships between the concepts. Links can be uni-, bi-or multi-directional. According to Novak and Gowin (1984), concept maps should illustrate a hierarchy of concepts where more specific and less inclusive concepts are linked together by valid and meaningful propositions and therefore are subsumed under the broader, more inclusive concepts. Because concept mapping links subconcepts to more general, inclusive, and abstract concepts, it has, therefore, been accepted as a valid tool for assessing the level of understanding of concepts, namely the hierarchy of learner's conceptual thinking. According to constructivist theory (either radical or social), learning is considered a process of enlargement and enrichment of the interrelations established between different kinds of information and eventually their integration into his/her existing knowledge framework (Glaser and Bassok, 1989). According to Chi *et al.* (1981) and Baxter *et al.* (1996), the quality of the learner's mental model either prevents or enables the accessibility of the processed information on later occasions.

The concept maps were used as a way of informing the workshop provider of the nature and complexity of the scientific knowledge of the teachers. The teachers' epistemology of the nature of science will lie somewhere along a spectrum of positivist - considering that science is a set of facts, or anti-positivist, considering that science is not a set of facts. The concept map can be used to assess the extent to which the knowledge they possess is factually based or conceptually based. Thus the concept maps were used to:

- assess the complexity and extent of understanding of the teachers' concepts;
- assess the validity of the conceptions the teachers hold; and to
- assess the teachers' views of the nature of science be it factually, or conceptually based.

In particular "Seeded terms concept mapping", known also as micromapping, (Trowbidge and Wandersee, 1996), was used. The teachers were provided with a set of concept labels (nodes) for the key ideas to be assessed, then the teachers constructed concept maps using these labels and/or others they could think of prompted by those nodes provided.

In scoring concept maps, Novak and Gowin (1984) recommended the analytical scoring of the maps according to the criteria: Propositions: 1 point, Hierarchy: 5 points, Cross links: 10 points. Other workers, such as Markham *et al.*, (1994) have felt that there is a level of hierarchy between different learners doing a concept map on the same topic, so they have used a scoring system whereby the degree of completeness or validity of the statements is assessed. This study also showed a hierarchy of conceptual thought, so a hierarchy linked with a quantitative method of scoring was preferred here over a simple numerical tally, which would add up the number of links but take no account of hierarchy of conceptual thought. This facilitated the identification of different levels of sophistication in teachers' understandings – by comparing a concept map which showed high levels of conceptual understanding, containing many layers and cross links with a map containing few nodes and cross links showing a low level of conceptual understanding. Since cross linking indicated a much higher level of conceptual thinking and understanding, the scores for cross linking were given a higher weighting. These relatively weak areas as indicated by the concept maps, were where the researcher wanted the teachers to develop their use of science concepts in the classroom.

The reasoning behind this method of scoring was matched by the threefold reasons for doing the concept maps namely:

- to provide a correlation with the teachers' responses to the confidence questionnaires
- indicate the depth and breadth of teachers' knowledge and understanding and to
- give an indication for the workshops on how the new ideas could be incorporated into teachers' existing knowledge and ideas.

The scoring was initially based on the attributes advocated by Novak and Gowin (1984) and Wallace and Mintzes (1990). Since the degree of conceptualisation could be judged by the overall complexity of the concept map and the use of concept maps in this research was only an indication of understanding, rather than for a complete analysis and justification of reliability, only five attributes were used for scoring. In addition an expanded scale of 4 – 0, as advocated by Shaka and Bitner (1996), allowing for more discrimination between teachers, was used for attributes 1-4, but cross linking which demonstrated higher level thinking and the degree of conceptualisation, was given double the weighting.

In a concept map a proposition consists of two or more concepts connected by a labelled link. The propositions are then connected to each other to form a hierarchical and branching structure that represents the organisation of knowledge. The basic assumption of the concept map is that interrelatedness is an essential property of knowledge, and that understanding can be represented through a rich set of relations among important concepts. The rubric used for scoring the concept maps is given in appendix 10.1

A third type of assessment given to the teachers attending the workshops was elicitation activities which could be used to address many of the well researched (Driver *et al.*, 1985) scientific ideas that children (and teachers) hold. There would be a certain amount of stress associated with the answers to these activities because either, the teachers were being asked to form opinions about topics they had not been asked before, or were being asked about topics which were at the limit of their knowledge because they assessed concepts rather than learned responses. However, the ease whereby these could also be administered to children and the use for eliciting children's ideas should keep the associated stress to a minimum. These were not high stakes tests, they were simple activities to elicit scientific ideas. One such example was for the topic of forces, where the teachers had to draw arrows to represent the forces operating on a rolling ball and on a ball tossed in the air. This was to show that many of the ideas that adults held were the same as those held by children and would not be assessed by simple true/false testing. These were of the type not normally asked in National Tests but were valuable in assessing children's (and teachers) underlying understanding and were illustrations of the developing ideas in science.

4.7 Working with Science Coordinators: aids to developing continuity, progression and assessment

Primary schools were relying on subject coordinators who, possessing a greater knowledge and understanding of how to teach and assess progress, would be there to support colleagues. However with such a lack of science expertise nationally, there would not be sufficient expertise within these schools to provide this support. Although the confidence of many primary teachers in their ability to deliver a science curriculum was increasing, there was strong evidence from surveys the researcher carried out with primary teachers that there was still a desire for further support and continued professional development. As has been stated many primary teachers have little or no science qualification past the age of 16 (approximately 14% according to the DES 1988 survey) and this was supported by the present study. This has been confirmed even to the present in the USA and in Australasia where similar research has been carried out (Croninger *et al.,* 2007). Also there has been evidence from HMI (Fourth Report Science and Technology in Schools, 1995) that teachers are doing investigative work without the real purpose of increasing the scientific knowledge and understanding of the children.

Although many Local Authorities and science education providers have attempted to remedy this with a variety of courses, the need for continued professional development persists. However for many teachers the emphasis has moved away from purely a content/knowledge towards pedagogy, thus moving from what do we deliver to how do we deliver? The importance of this change of emphasis has been supported by Richardson and Placier (2001).

The lack of continuity and progression in planning was demonstrated in the initial stages of this research, since it became evident that many of the teachers writing their medium term plans lacked awareness:

- that some topics in a unit were best tackled in a particular order;
- of the confidence to decide on the conceptual level at which the topic should be approached, and
- of the amount that should be covered and the detail that was necessary.

These points illustrate that teachers had not reconstructed the science content within the National Curriculum. They recalled from published sources or from their own scientific background, but their pedagogy appears to be that of as transmitters of factual content. Several teachers commented that one of their priorities was to make sure they covered the content, but they did not feel confident with it. This again has been supported by findings from the Fourth Report Science and Technology in Schools (1995), which stated that "there was unanimous agreement that there remain serious problems with primary teachers' confidence in teaching science".

In addition to content the national curriculum operates at a range of levels for each of the areas of science referred to as Attainment Targets and associated levels based on Bloom's Taxonomy (Bloom, 1956) and produced by the Task Group on Assessment and Testing (TGAT) committee (1988). The scheme of work for Key Stage 1 and 2 Science was the first of the curriculum documents to be introduced by the Qualifications and Curriculum Authority (QCA). This scheme was introduced to meet the demand of many primary teachers who stated that they lacked the experience in science to structure a scheme of work and that they felt they needed support in order to be able to achieve this, or if they were science coordinator, support their colleagues in devising and implementing such a scheme.

The QCA scheme of work also addressed two other problems that teachers had, namely thinking of suitable activities that would engage children and teach them the science involved and organising the various components of the National Curriculum into convenient units or modules. However, examination of the QCA scheme shows that it does not dictate to teachers how the science should be taught and almost certainly never intended to do this. In order to transform these units into medium term plans for class science teaching, the independent statements needed to be placed in a logical developmental sequence and if the teachers were to do this, they needed to be able to identify the key ideas or concepts. This advice was given in the appendix of the QCA scheme, but the experience was that teachers who had the confidence and expertise probably did not need telling, but teachers who did not feel confident in teaching science and who had limited scientific background found this a difficult, if not an insurmountable task. If they had not reconstructed the science knowledge then they would not be able to place them in a logical order. This would also apply to many science coordinators, some of whom had limited scientific expertise. Also every school in the country that wanted to adopt this scheme would be going through this task. The logical outcome was that many would not attempt this lengthy process and some would not do it well throughout.

4.8 Assessment of Children

This included analysis of various test items, some published and some devised as part of the research implementation, examining children's work, through analysis of class discussion and through fieldnotes and recordings of classroom observations.

4.8.1 Test-score evidence

There are difficulties associated (as indicated subsequently) with gathering test-score evidence related to increasing Key Stage 2 children's knowledge of science, particularly in a political climate where increased knowledge is interpreted as gaining higher scores in a test. Convergent assessment used for testing fundamental knowledge would be adequately assessed using a traditional written test. A more divergent assessment, requiring children to explain the basis for any conclusions they make, or checking any precepts underlying children's reasoning, or even allowing for valid diagnoses that might not have occurred to the questioner, would present more difficulties using a written test. Assessment of a process can give more information about skills (Currie, 1986), so is the test measuring simply recall (curricular validity) or application (construct validity). A marking scheme can be devised that gives a smaller weighting for less demanding skills such as recall, but in a Standard Assessment Test (SAT) an equal weighting is given for all levels and this has led to simply adding up marks to a total. Recall, explain and apply are three different conceptual levels of attainment, but one mark is awarded for each. Then final levels are awarded according to the number of marks gained, so the children could achieve the higher levels by revision of all the knowledge, rather than by answering questions testing the more demanding skills or concepts. In addition formal assessments may cause stress to the individual (Heywood, 1989), so a difficulty arising in a timed assessment, is what level is the child truly operating at if the child was one mark below the level threshold, yet did not finish the test in the time prescribed? In this research, judgements had to be made about a child's ability, so a summative assessment was still considered appropriate to judge overall performance, but this technique was not considered useful for communicating complex data, so a detailed analysis of each item in the test was also considered.

Following a single group experimental design, pre-test and post-test measures of children's scientific knowledge before and after teaching each topic would be carried out, and showing whether the children's performance had improved or not. This was an example of ipsative referencing, comparing performance against prior performance and could be particularly useful for diagnostic or formative purposes. Any difference in performance could be statistically measured using paired *t-test* analysis. This approach may lack internal validity since the improvement in test scores may be attributed to the teaching approach adopted, the impact of the pre-test, or other factors (Verma and Mallick, 1999). However the approach was adopted as part of the evidence gathering since a statistically significant improvement in a wide range of post-test performance over pre-test performance would be an indicator of improving scientific knowledge.

In classical experimental design, two similar age classes from the same school would be chosen, one subject to intervention and one not: pre-tests and post -tests would be administered and the performance of the two groups compared. It was not possible to use this design here as the primary schools were small and mostly had only one class in each age range. Comparing similar age classes between project schools and with other non-project schools also would prove to be problematic since there would be a complete lack of randomisation and little confidence that the classes compared would be equivalent. The same problems would apply in comparing SATs performance in different schools. In view of this, it was decided to use Facility Values, these are published annually by QCA and show the results for each test item for a large sample of children nationally, so could be used for a comparison of the project classes' facility values. Such a comparison would involve examining SATs data, and for each item in the test comparing the project classes with the national average in terms of the percentage of children who answered the item correctly. Again any statistically significance in the differences would be shown by *t-test* analysis. A *t-test* was used to demonstrate a statistical difference in attainment between the pre-test and the post test and the children's attainment relative to facility values for national tests. The *t-test* analyses the means for the two groups of tests and accepts or rejects the null hypothesis that the results could not be simply a result some random effect or could be caused by some other effect for example the teaching. The difference could be caused by some other effect such as enthusiasm amongst the participants and the relevance of the two possible effects would have to be interpreted by the researcher. As single higher attainment could lead to errors in conclusions, but a consistently higher attainment in specific types of questions for example recall or application items would minimise errors allowing valid conclusions to be made.

4.8.2 Children's Work

Samples of work to illustrate the ideas and concepts that children typically hold would be collected and used to gather evidence that progress towards a more scientifically acceptable explanation of what was happening within classroom discussion. There were samples collected at the start of a topic to show to the researcher and the teachers, what the children's ideas were but these were not collected to any systematic pattern, but simply used to illustrate children's understanding of ideas (typical of those highlighted by Driver *et al.*, 1985) which tended not to be elicited by traditional test materials. These samples of work also demonstrated to the teachers that the ideas that these children held were similar to those held by many children nationally.

4.8.3 Class discussion

Science has a particular way of using language, the words may have a specific meaning and the sentences are constructed in a logical way often to present an argument or explanation based on evidence. Cummins (1979) referred to this as Cognitive and Academic Language Proficiency. Science can have very specific meanings in its vocabulary, for example, steam or power, and these words might have a different meaning to the general public. Academic language is also recognised by the complexity of the sentence structure. For example, a sentence may provide a logical argument such as a statement of the evidence, an explanation of the evidence and some elements of analysis, based on current scientific thinking. Wertsch (1991) referred to this as social language (in the science classroom) which may be distinctive in different contexts and will be different from everyday social language. Scientific social language refers to the speech genre being used at the various times in the lesson (Mortimer and Scott, 2003). The teacher's aim should be to let the children practise scientific language in the appropriate context. The teacher is central to developing the language of science and while it is important to encourage and support the children in their science social language development, it is also important that the teacher does not re-interpret their explanations. Interpretation is a commonly observed teacher intervention for example, "yes you mean.... using the correct scientific language. This means the children will find it more difficult to develop their own science language and to apply their knowledge. The children will not internalise the concepts as fully. The development of scientific communication is dialogic, with sometimes the teacher being centre stage and sometimes the children.

In staging the scientific story, the teacher needs to be aware of the existing and developing understandings of the children, being sensitive to the kinds of things they say in class, as well as drawing upon their knowledge of children, and their everyday views in the topic. To develop children's ideas, teachers often have to put the children's random ideas into a more structured order so that the children can internalise the concepts more readily. The teacher needs to think of activities that will confirm or challenge the existing ideas. One benefit to the teachers of this research project was that it allowed the researcher time to reflect upon and provide such activities, whereas practising teachers have other lessons to think about and may well not have the time always to do this. Also they may lack the scientific background to develop appropriate activities, however children's ideas are quite commonly held so the teacher can have an armoury of activities for when they are appropriate. According to Sutton (1996) a fundamental feature of the way in which the teacher develops the scientific story is that it must be 'persuasive' in character as the teacher seeks to convince the children of the reasonableness of the scientific story, which is being staged on the social plane of the classroom. Teachers should acknowledge the importance of this persuasive aspect of staging the teaching performance, as children are introduced to the school science social language. By being 'persuasive' in this context we are trying to persuade the children to use clear scientific communication because all members of the community will then have a clearer idea of what is being proposed, but we are not trying to 'persuade' the children that our ideas and concepts are correct and theirs are incorrect. The child must be dominant in the dialogue process (Wood *et al.*, 1976, p 21). They need to practise the scientific ideas themselves. Initially they will need support from the teacher, or from other children, which aligns itself to the Vygotskian principle of effective learning taking place with other help of an expert other. Bennett *et al.* (2004) found in their review of research on small group discussion that children improved their understanding of both the concepts and the evidence. In developing this scientific language the teacher needs to avoid the use of 'Verbal wrapping paper' (Prestt, 1980) namely allowing the child to use scientific vocabulary which hides a lack of understanding of the basic concepts. Prestt says "words introduced too soon are part of that 'verbal wrapping paper' of science . . . many teachers say that children 'like' to use technical words, even though their understanding of them is very limited. I would suggest that wrapping paper can be very gaudy and attractive but it still covers and obscures the contents of the parcel."

4.8.3.1 Analysis of Classroom Discussions

To examine the children's development of powers of communication and the developing complexity of their responses in the discussions that took place, it was deemed necessary to categorise these discussions. These would be recognised by both the teacher and the researcher alike focussing particularly on the use of correct scientific vocabulary in the correct scientific format. Later analysis of the discussion using the analytical framework devised by Mortimer and Scott (2003) based on their earlier work (Driver at al., 1994) uses 5 interlinked aspects shown in Table 4.2 and grouped according to focus, approach and action.

Table 4.2 Analytical framework for classroom discussions

	Aspect of analysis	
Focus	1 Teaching purpose	2. Content
Approach	3. Communicative approach	
Action	4. Patterns of discourse	5. Teacher interventions

The first aspect of analysis examines the teaching purpose that they have identified:

- opening up the problem;
- exploring and working on students' views;
- introducing and developing the scientific story ;
- guiding students to work with the scientific ideas and supporting internalisation ;
- guiding students to apply, and expand on the use of the scientific view and handling over responsibility for its use, and
- maintaining the development of the scientific story.

The second aspect focuses on the content of the classroom interactions in terms of three categorisations:

- Everyday – Scientific;
- Description - Explanation – Generalisation, and
- Empirical – Theoretical.

In the second category Mortimer and Scott (2003) refer to a description as involving an account of an object or phenomenon, an explanation uses a theoretical model or mechanism to account for the phenomenon and a generalisation involves applying the ideas independently of a specific context. However, in this work the researcher will consider applying as referring scientific ideas to just more than one context. These descriptions, explanations and generalisations can be empirically or theoretically based; empirical descriptions provide accounts in terms of observable features for example, dissolving a coloured substance and theoretical ones involve using some sort of scientific idea or model which is not directly observable for example the use of the particle model in a description or explanation or generalisation.

The third aspect looks at the communicative approach, examining any dialogue that takes place between teacher and child and whether both are contributing and whether the teacher takes account, or not, of the children's ideas. They have identified four fundamental classes, but also point out that classroom talk rarely fits neatly into one of four boxes and will inevitably lie somewhere on a continuum. They characterise their classroom talk as lying along each of two dimensions: dialogic-authoritative and interactive-non-interactive (Table 4.3). The dialogic-authoritative dimension refers to whether the teacher hears what the student says from the student's point of view or hears what the student has to say only from the school science/ lesson focus point of view. The dialogic dimension examines whether there is an interaction or exploration of ideas between two or more people.

Table 4.3 Classification of dialogue type (Communicative Approach)

	Interactive	Non-interactive
Dialogic	A interactive /dialogic	B Non-interactive/dialogic
Authoritative	C interactive/authoritative	D Non-interactive/ authoritative

A interactive /dialogic	the teacher and students explore ideas, generating new meanings, posing genuine questions and offering, listening to and working on different points of view.
B Non-interactive/dialogic	the teacher considers various points of view, setting out, exploring and working on the different perspectives
C interactive/authoritative	the teacher leads students through a sequence of questions and answers with the aim of reaching one specific point of view.
D Non-interactive/ authoritative	the teacher presents one specific point of view

The fourth aspect examines the Patterns of Discourse and very commonly seen in science lessons is the *triadic* 'I - R - E' interaction as described originally by Sinclair and Coulthard (1975). Since its original description in 1975, it has evolved and expanded to allow the application of less-structured discourse, through the works of Coulthard and Montgomery (1981), Sinclair and Brazil (1982). In this pattern the teacher asks a question (I) the student responds (R) with a right or wrong answer and the teacher evaluates (E) the correctness (according to what the teacher wanted) of the response. The danger with classroom interactions of this type between teacher and children is placing the child in a win-lose situation because often there is only one possible answer, the consequence is that some children are reluctant to expose their insecurity. This leads to the next problem in that only a limited number of children respond, so they are only telling you what they know already. This leads to assessment but it is not necessarily developing learning. An alternative form of triadic discourse occurs when the teacher gives *feedback* (Sinclair and Coulthard refer to *follow-up*) rather than giving a straight evaluation. Mortimer and Scott (2003) refer to this pattern as I - R - F and there can be a chain of these interactions giving an I - R - F - R -F pattern, thus promoting a dialogic interaction. Discussions in the classroom before and after input from the project were analysed in terms of the interactions between child and teacher and those between children.

Teaching interventions, the fifth aspect, is designed to make the ideas or content more accessible to the student. These have been observed and classified by Scott (1997, 1998) and similarly by Edwards and Mercer (1987) and Lemke (1990). Scott (1997) defines six forms of teacher intervention set out below in Table 4.4 and shows how this is used to develop the scientific story and make it available to all the students.

Table 4.4 Teacher Interventions (from Scott, 1997)

Teacher intervention	Focus	Action the teacher might take
1 Shaping ideas	Working on ideas developing the scientific story	Introduce a new term; paraphrase a students response, differentiate between ideas
2 Selecting ideas	Working on ideas developing the scientific story	Focus attention on a particular student response; overlook a student response
3 Marking their Ideas	Working on ideas developing the scientific story	Repeat an idea; ask a student to repeat an idea; a confirmatory exchange with a student; use a particular intonation of voice
4 Sharing ideas	Mulling ideas available to *all* the students in a class	Share individual student ideas with the whole class; ask a student to repeat an idea to the class; share group findings; ask students to prepare posters summarising their views
5 Checking student understanding	Probing specific student meanings	Ask for clarification of student ideas: ask students to write down an explanation; check consensus in the class about certain ideas
6 Reviewing	Returning to and going over ideas	Summarise the findings from a particular investigation; recap on the activities from the previous lesson; review progress with the scientific story to far

4.8.4 Classroom Observations

Observation is a basic source of human knowledge and Hills (1992) noted that observation is the most effective strategy for getting to know children; therefore, approaches based on observation are often used as a form of assessment even though the validity of observation has been criticised by Adler and Adler (1998). Lundesteen and Tarrow (1981), in contrast, stated the importance of observation as being an integral aspect of planning. Beaty (1990) noted the advantages and disadvantages, and that not every event can be recorded as it happens and, therefore, the tendency in this research was to record that information of most interest to the teacher and the researcher. This is the case in this research and they often confirmed children's ideas as highlighted by many researchers. Here, the researcher, with the teacher, will be identifying such episodes, so that they could be used to explore children's scientific thoughts. Observations written after the incident might not be considered as accurate, or be taken out of context or misinterpreted, but since these observations are recording shorter, more interesting episodes the use of fieldnotes recorded immediately after the classroom session was considered reliable. Hills (1992) and Gordon and Browne (1985) described methods of observing and recording and from the narrative methods, a mixture of diary description, which is a chronological record of individual children's responses, made after the responses occurred and were used for both recording interesting episodes and devising engaging materials. An anecdotal record, which was a descriptive narrative recorded after the responses occurred, was used to identify specific activities for planning to explore further, children's thinking, and specimen description which involved detailed notes or transcription of classroom discussions, recorded while the situation was occurring. These latter techniques can often be used with the aid of video or audio recordings. The disadvantage of this method was that there was no way of knowing in advance what will occur, however since valuable incidents occurred in most sessions, the techniques were valuable in discovering cause and effect relationships in individual children's responses and to analyse the effectiveness of classroom activities. Narrative records like these have the advantages of being open-ended and flexible, and they can provide a wealth of information about children and the programme, but they are time consuming to both record and interpret. Event sampling, where the activity has been defined in advance and the impact on children's responses with the researcher or teacher and other children can be recorded briefly. This method can be helpful to teachers trying to gain insight into individual behaviour and developing their own self-efficacy beliefs.

4.9 Summary

This chapter has shown a mixture of methods, so that a pragmatic approach will be needed for both assessment of teachers and children. The emphasis for the development of teachers has changed from simply delivering new ideas/methodology to a much more practical approach with an emphasis on adults as learners, taking account of their agenda as well as that of those who are their managers. In order to achieve this, constructivist methods would be adopted both in the classroom and in the workshops.

Simple questionnaires will be used to find out factual information about teachers and a questionnaire based on the STEBI principles used to assess teachers' efficacy beliefs, a comparison of their beliefs over time could be used to measure progression. This would be counted as valid because the same teachers would be answering the same questions. An indication of increased self-efficacy would be demonstrated by higher scores. Whereas the initial research questions and final triangulation of assessments were both carried out using structured interviews. This freer method was used because this would allow the Headteachers and science coordinators to add any comments they wished.

Support for the science coordinators in deciding the order for topics, the conceptual level for a particular topic and the content covered by a particular topic could be provided both within INSET sessions and an associated task of restructuring the QCA scheme of work (appendix 3). Teachers' knowledge of content and pedagogy would need to be assessed and this could be done by using traditional tests, but a SATs type test is considered completely inappropriate for adults, also a purpose of the research was to provide them with new methods of assessment they have not used with children before. So concept mapping and elicitation activities can be used. Although concept mapping was not completely new to them, they had not used the technique for the assessment of children. The third form of assessment was the use of elicitation activities which could be used equally well with adults or children. At the initial stages of a topic they could elicit the extent of knowledge, or at intermediate stages to compare progress within a topic.

Assessment of children by traditional testing was within all the teachers' experience and in-class support could provide a lot of feedback on development of confidence of thinking scientifically and expressing ideas using the appropriate scientific terminology. Assessment of development of children's concepts could prove to be more problematic because traditional written tests such as SATs items which contain many more closed responses could only assess what children write down, and this could be recalled. I am attempting to assess understanding and conceptual development. To assess development, the use of Science Reasoning Tasks, pre and post tests which contained some free response questions and the feedback from classroom observations could all be used. Also analysis of the classroom discussion can be carried out at length by the researcher.

With a variety of needs for the research, both children learning and teachers teaching being such complex and interrelated activities, this will necessitate a range of data collection strategies followed by varying but in each case appropriate analyses. Some are objective, such as children and teacher knowledge data, and could be analysed by inferential statistics, some are more subjective requiring interpretation of the findings, however the researcher is aware of possible bias and will use previously tried methods of interpretation.

5. Methods

5.1 Introduction

Teaching is a complex process involving many interrelated and multi faceted demands, which means that research into any one of these facets in isolation, whilst supporting developments in these areas, is fraught with difficulties. The researcher continually adopted a critical approach (Carr and Kemmis, 1983) taking cognisance of the fact that many of these facets would have an impact on the outcomes. This developmental part of research focussed on two main areas: a) improving teachers' confidence and measuring this increasing confidence by a number of outcomes and by a range of methods, some quantitative and some qualitative, and b) improving children's motivation and attainment. Lincoln and Guba (1985) argued that research designs must be emergent, thus the researcher entered the process with a collection of different methods and these were trialled and developed constantly throughout the project, the focus of the actions by the researcher was on a list below:

Initial phase

- ascertaining teacher needs through a survey of their requirements;

Main phase

- teacher development of knowledge and confidence in workshops;
- teacher development of knowledge and confidence with in-class support;
- teacher assessment of knowledge;
- children's development of scientific communication and application of scientific ideas;

Evaluation phase

- children's assessment related to internal and national performance, and
- evaluation of Headteachers' views.

A timeline of the phases of the research is given in figure 5.1, it should be noted that there are frequent times when one part of the timeline continually feeds back for example devising activities for evidence.

Pilot study questionnaires and SRT activities

Devising and implementing INSET workshops

Teacher confidence survey (at various times during the research)

Developing class discussion

Time

Class support teachers and children

Devising activities to provide evidence

Gathering and analysing SATs data

Analysing class discussion

Triangulation interviews

Figure 5.1 Timeline of research

These items will be discussed in turn in subsequent sections.

5.2 Background to teacher continued professional development

The teachers were from a range of schools with a range of experiences and expertise, and they had to be respected as adult learners and adopt an andragogic approach to their learning being increasingly self-directed, their motivation to learn is stimulated by real life tasks and problems Knowles (1984) and Mezirow (1990). This has been discussed in Chapter 4. Jonassen *et al.* (1995) perceive learning as a social, dialogical process in which communities of practitioners socially negotiate the meaning of phenomena. Hence because of the wide range of experiences of the teachers, there was an avoidance of the 'one size fits all' format. However, all the workshop sessions were based on constructivist principles and because the teachers had not assimilated the content in the past, so were not likely to assimilate these ideas this time. These methods had been successfully employed by Howard *et al.* (2000) and Jadallah (1996) in changing the participants' epistemologies both with pre-service and in-service teachers, encouraging reflection on their practice, so these strategies would be effective in getting teachers to apply these strategies to circumstances in their classes. Also a transmissive format, when the teachers first encountered the science topics, did not produce understanding or confidence, so these approaches were not likely to produce these attributes in them, or in their own children. The presenter's role was by actively engaging the participants in constructivist activities and by engaging the teachers mentally as well as physically, would improve the teachers' abilities to engage children in scientific inquiry and the use of "evidence-based learning". The constructivist method of learning was introduced as an innovation to most of the teachers so the instructional strategies used were congruent with the constructivist epistemology and have been successfully employed by Chiapetta and Koballa (2002) and Mariano *et al.* (2001) and included:

- the use of the science process skills by using evidence gathering, reasoning the implications of this evidence;
- the value of data-processing including the use of ICT to gather and process data;
- peer discussion with sharing and challenging of ideas;
- questioning skills that provoke discussion and communication of ideas rather that simple recall, and
- the use of discrepant events as a stimulating technique.

All these methods were used in the workshops and in the classroom support.

5.3 Practical Issues

5.3.1 Surveys

There were surveys related to the pilot work obtained by interviewing Headteachers and experienced teachers and these would contribute towards research questions and background information. Some interviews were used to detail previous experiences and attitudes of teachers to teaching science and topics for workshops. There were questionnaires to elicit self-efficacy and confidence of teachers and in the final stage interviews were carried out for evaluation of the intervention and triangulation.

5.3.1.1 Pilot work

In order to design more definitively the style and content of the continuing professional development, data from a pilot study carried out by the researcher were used and this was based on six schools in a closely networked cluster with their partner secondary school. This proved to be reasonably easy to do in the pilot study, since the teaching staff involved and the heads were very co-operative and the interviewer was well known to the interviewees which enabled a frank, honest and relaxed interview to be conducted. The researcher used structured interviews so that notes could be jotted down on the main issues, but avoiding the use of a technique that was too closed. This might fail to gather data, ideas and opinions from both very experienced, and relatively inexperienced, members of the teaching profession, that the researcher had not considered. This was at quite a formative stage of the research, however the final evaluation interviews were conducted by an independent, experienced Senior Leader from a secondary school.

An interactive questionnaire was used so the question styles and types and scaling methods used could be piloted with the Headteachers and because these were conducted as structured interviews, modifications could be noted. These surveys were constructed according to the general methods of Oppenheim (1992). There were three main aims for the survey part of the initial and pilot studies. These were to:

- gain factual data , for example qualifications, existence of appropriate documentation;
- discuss with staff to aid conceptualisation of the project, and
- gain attitudinal data from the staff.

Open questions were used to form the basis of the continuing professional development elements and closed questions with scaled answers (Likert,1932), for quantitative analysis and interviews for further evaluation of impact. Doing pilot surveys helped with the wording of questions leading to more structured questions, which were easier to analyse. By first experimenting with the question in 'open' form it is possible to discover how respondents spontaneously interpret the question (their frame of reference). The items could then be modified in accordance with its defined purpose and analysed as discussed in Hittleman and Simon (2002).

5.3.1.2 Surveys used

Youngman (1986) lists seven question types and two types were used from his list.
Open questions were used in the pilot study to determine some possible research questions. List questions were used to determine experience, qualifications and to provide some background information. Scale and quantity question responses were used for selecting the INSET topics and to focus the teachers on the topics to consider for the in-class support sessions. For the survey on teachers self-efficacy beliefs, a list of science topics was used, accompanied by a five point scale to indicate the self-efficacy belief according to prescribed categories.

From the initial interviews with the Headteachers, the various teacher surveys could be designed. The purpose of the descriptive survey was to count the responses and decide on the most requested core topics to be covered in the workshops. It used a large enough sample of staff (n= 88) covering the full range of schools to be representative. This allowed inferences to be made about the whole population of teachers. The analytic surveys were used to give an indication of cause and effect in teacher practices.

The results (dependent variables) are produced by the impact of the experimental variables and these variables were measured numerically. The initial conclusions from the results only become evident when the data were being analysed, but the researcher was alert to this issue, both when conducting the pilot interviews and when staff were filling in the questionnaires. There was an advantage to this particular pilot study in that most participants were known in a professional capacity to the researcher. In practice it is not usually possible to distinguish between hidden additional causes and pure error. In analytic surveys, as in experiments, the influence of uncontrolled variables should be as small as possible. However since the same teachers would complete the same survey at a later stage in the longitudinal studies, these errors could be minimised. Changes in their own responses to the same questions over time were looked at.

The sample size in this study initially was large (88 teachers) but only small at the end of the intervention(10 teachers), so there is a possibility of statistical errors. Although the number of teachers in the sample at the end is small, if, for instance, the increase in teacher confidence is large then the data can still be statistically significant, this can be ascertained by comparing mean values of efficacy beliefs. Also the researcher is knowledgeable about the issues involved and knowledgeable about the teachers based on classroom observation, so will attempt to filter out some of these significant errors. This would then mean collecting subsequent data in future parts of the study and matching these data to the original pilot sample. The pilot did help with the wording of questions and with procedural matters, such as time taken and the best way of allowing teachers the opportunity to fill them in.

5.4 Workshops

A series of workshops were held for clusters of schools and were, necessarily, twilight sessions open to all teachers. The workshops needed to be twilight sessions in order to make them accessible to a larger number of teachers and avoiding considerable supply teacher costs.
In order to decide on the most preferred topics for the science workshops the science coordinators were asked to list what teachers wanted as priority topics for workshop activities. They were asked to give the highest priority 15 and the lowest 1. The preferences were summarised in appendix 10.2 and the matching of these to the teacher confidence data provided a further check on reliability of the responses.

The discussions with the Headteachers, science coordinators and teachers shaped the format for the workshops. The problems associated with workshops such as teachers' lack of control, lack of time for discussion, which the researcher had concerns about are confirmed by other researchers (Garet, *et al.,* 2001, Rodriguez and Knuth, 2000). The teacher needs were obtained following exploratory interviews with the Headteachers, science coordinators and other key teachers involved in the cluster of schools. There was a desire to cover both content and pedagogy in the workshops, but in a way that teachers could assimilate the ideas and use them in future lessons, thus improving teacher confidence. Modelling a risk-averse environment, where there is an atmosphere of freedom to express opinions was encouraged in these workshops, so that teachers could then use this confidence to engender more open discussions in their classrooms, using phrases such as "Tell me what you think, not what you think is right".

The underlying principle therefore was to develop the self-efficacy beliefs of the participants by providing them with key scientific concepts (appendix 1) and suitable activities so that they could use these strategies in their own classrooms. Most teachers feel that practical applications were the most important factor contributing to successful INSET and the aim was to meet these needs. Confidence was developed much more in class which the researcher felt was the most appropriate environment for this to take place. This research was child-focused and aimed at raising teacher confidence, or self-efficacy beliefs, and certainly was not telling them that they are doing things wrong. So the emphasis was much more that here is an alternative way of doing things, or 'if you did that activity this way', or 'if you did that activity and asked this question – this could be the effect you are likely to see'. According to constructivist principles the researcher needed to develop practice starting from the teacher's epistemological position and using an adult learning perspective. The teachers wanted to move to the next level for example by asking a question which would provoke discussion. Thus there was a strong emphasis on practical applications that teachers could use in the classroom and they are being 'refreshed' by contact with new people and outside experiences.

The nature of the practical sessions in the workshops, provided an opportunity for teachers to converse with each other and to feed back to the presenters on the likely success of these activities in class. The activities encouraged the development of a reflective culture amongst teachers where they could discuss in some depth and on the basis of evidence or shared experiences, the ways in which they and other colleagues teach. Through this discussion, they could develop their understanding of new ideas and approaches, which is in harmony with the constructivist principles in the design of various teacher centred approaches.

There were opportunities in the workshops for teachers to explore learning in these inquiry-oriented situations and in class to develop their effectiveness at using them. They could share ideas related to experiences in their classrooms and integrate the different areas of science. Instructional strategies that were used congruent with the constructivist epistemology included:

- the use of the science process skills by using evidence gathering and reasoning the implications of this evidence;
- the value of data-processing including the use of ICT to gather and process data;
- peer discussion with sharing and challenging of ideas;
- questioning skills that provoke discussion and communication of ideas rather that simple recall, and
- the use of discrepant events as a stimulating technique.

As stated in the main aims, the teachers' needs were threefold, they wanted relevant content to the science curriculum and effective strategies for delivery of that curriculum and they needed confidence to be comfortable with the content. They agreed and freely stated, traditional methods of teacher transmission of content had not proved to be successful, and because there was no intention to develop their scientific knowledge to degree level by providing a lot of factual information which they would then forget, the input was restricted to the basic principles on which all the necessary content lay. They were not scientists, but they were adult learners, having the ability to apply ideas and use the concepts and teaching strategies. As the workshops were being carried out in tandem with the in-class support, then, actual examples that occurred in their schools could be used which increased the relevancy. The presenter said "this is what the children will think and say" and when the children were asked in an actual classroom situation it is indeed what they said. This prediction of what the children would say gave more credibility to the activities.

5.4.1 General structure of workshops.

A common framework for all the teacher workshops was devised:

- Discussion of children ideas;
- Cognitive conflict for teachers;
- Summary in terms of key concepts for the topic, and
- Activities to stimulate discussion and model good communication.

The format of the workshops was essentially the same, there was a structured input and discussion about the ideas children might hold and these were used to address possible teacher ideas. This research did not attempt to find initially and in a systematic way what ideas children had, but assumed they would have the ideas typical in countless data widely available in research papers (Driver *et al.,* 1985). These typical ideas occurred in the classrooms in the schools where the research was carried out and some of these examples which arose from discussions with their own children, were used in the workshops. These real examples of children's ideas placed considerable weight on what children thought and produced an added dimension to the workshop experience. The workshops were dual purpose, that is in eliciting what children (and teachers) actually thought and finding strategies to address these children's (and teachers') ideas. The principle being that if it would work for the children and help them to make sense of scientific ideas, then it would work for teachers, then they would be positive about the strategies because it had helped their own understanding. As the teachers were learning from a limited number of basic principles then that same strategy would be appropriate for use with children, therefore the teachers could develop their own skills of applying scientific ideas linked with their own and others' experiences. The full list of key scientific concepts is given in appendix 1.

The teachers would try out several activities that were designed to elicit children's ideas and in this format the activities would elicit the teachers' own ideas and promote discussion between colleagues. This hands-on experience was used for two purposes, one was to give them experience of trying out new activities, and the second was to use equipment that they might not have considered, for example, electricity kits, balances, data logging equipment. As well as choosing from resources, the researcher's own experience as a scientist and educator was used to select activities that would be appropriate. There were opportunities for teachers to understand new ideas and approaches; to see theory demonstrated in practice and be exposed to new expertise and the activities provided with convincing evidence that the strategy or method being taught had direct benefits for children's learning.

The teachers were also provided with a booklet (a partial example of a support booklet is given appendix 2) which gave a wider range of activities for the teachers to use in class. This enabled the teachers to review their knowledge when the children asked questions to which they did not know the answer immediately. Each booklet contained a 'children's ideas' section, where more detail and a wider selection of children's ideas about topics was given and discussed. There was a scientific ideas section which developed concepts from the workshop slightly further, and which would provide additional background reading to support teachers' existing knowledge and understanding, as well as providing knowledge in areas about which children might ask questions, for example, the use of particles to explain changes, and the use of the atomic model including electrons to complement the understanding of electricity, which satisfied some of the categories identified by Harland and Kinder (1997)

The venues used for the workshops were the partner secondary schools the effect of this partnership was not researched directly, but the liaison had a beneficial effect in that the teachers in the partner primary and secondary schools 'got to know each other' and this provided networking opportunities for the primary and secondary phases. This is a highly significant issue and was indeed recognised as such by the Report of the Central Advisory Council for Education (1967) (the Plowden Report) "Primary and Secondary teachers not only need to know each other, but to know each other's work". Thus studies have shown that in many cases there are links across the two phases but there is very little evidence of providing continuity of education for the children.

The workshops were divided into categories of Key Stage1 and Key Stage 2. The Key Stage 2 activities focus was to develop using scientific language and elicitation of ideas whereas the Key Stage 1 was to stimulate awe and wonder since a lot of these experiences were very new and provoked children's responses to their various stimuli. Also some specialist workshops on Key Stage 1 activities were provided since these teachers gave feedback that they often felt neglected when INSET was provided.

The workshops were designed to introduce new ideas and strategies and develop subject expertise and confidence, content and pedagogy by modelling a risk-averse environment so that teachers could engender more open discussions in their classrooms, thus developing their self-efficacy beliefs. Providing an environment where communication between 'expert' and practitioners took place and was a significant component of the time spent and where diffusion of an innovation began, enabling the link between theory and professional practice possibilities to be concretely experienced. Teachers wanted to explore new ideas through discussions with teachers in their own and other schools and with education 'advisers'. There was a strong emphasis on the important factor here of being 'refreshed' by contact with new people and outside experiences. The workshops were based on a typical learning cycle of plan, do, review and re-apply. See Figure 4.1 in Chapter 4

There were opportunities provided in the workshops for teachers to explore learning in inquiry-orientated situations, where they could share ideas related to experiences in their classrooms and thus develop their effectiveness for using them in class. The teachers experienced the model in the workshops and then applied the concepts and ideas learned, to the construction of personal knowledge about science.

5.5 In-Class Support

The workshops were never designed to be stand alone and they were part of the comprehensive package of continuing professional development, which included in class support as an essential feature. Teacher self confidence was developed much more in class as this was considered the most appropriate environment for this to take place. The teachers were not scientists, but they were adult learners, having the ability to apply ideas, use the concepts and teaching strategies in their own classrooms. As the workshops were being carried out in tandem with the in-class support then real examples that had occurred in their schools could be used to demonstrate relevancy and credibility. It was said in the workshops "this is what the children will think and say" and it is indeed what they said in class.

Although the model was not peer coaching, the planning was shared but based on the expert view grounded firmly in pedagogic research, science knowledge and classroom experience; linked with the teachers' own experiences and considerable knowledge of the school and the children in their classes. Their children, in their classes, in their school were being used to demonstrate the effectiveness of the strategies being proposed.

The in-class training had four components:

- new and existing activities from their own experiences and the training workshops;
- planning of the activities;
- demonstration and modelling of new pedagogic strategies to elicit children ideas; and
- practice of the activity types with support.

The focus of the interventions was broadly related to:

- developing teachers' knowledge, understanding or skills within science;
- developing teachers' beliefs, behaviours and/or attitudes, targeted at increasing dynamic learning and teaching exchanges with children; and
- developing children's use of evidence and communication of ideas scientifically.

The schools would typically have a 90 minute session per class per week over half a term. Some schools opted for longer quantities of time with particular classes, and others wanted a wider range of teachers to gain experience. Together they could create opportunities to understand new ideas and approaches, to see theory demonstrated in practice and be exposed to new expertise which provides support for experimenting with new ideas and approaches. Teachers could then work out the implications for their own lessons. The children, school and community provided sustained feedback and support over time for teachers engaged in changing their practice and providing convincing evidence that the strategy or method being taught had direct benefits for children's learning. It was felt strongly, by the researcher, that the more extended the period of time over which this took place the greater would be the impact.

The positive outcomes for children concentrated on measurable changes in children's performance in pre-tests and post-tests, or SATs performance, all of these were directly quantifiable. Less quantifiable and more interpretive were learning achievements, including demonstrable enhancement of children's motivation, increased sophistication in response to questions, increased satisfaction with their work, increased confidence and increasingly active participation. Even though these were less quantifiable, they could be demonstrated nevertheless to the teacher and researcher.

5.6 Self-efficacy Beliefs

The principle of self-efficacy beliefs and its implications to the classroom experiences for the teacher in particular were relevant. On the five point scale the principles behind the STEBI questionnaires were used, with criteria set out in appendix 10.6. These criteria were used to assess teachers' own opinions about their self-efficacy. For the survey on teachers' self-efficacy beliefs, a list of science topics accompanied by a five point scale was used to indicate the self-efficacy belief according to prescribed categories. These were used at various stages and with various levels of involvement within the intervention process. This survey was focussing on changes in their own responses to the same questions over time.

5.7 Assessment of teachers

It was not possible to absolutely base line the subject knowledge of each teacher and this indeed was an issue surrounded by personal, professional and ethical dilemmas. To achieve some measure of teacher knowledge initially, concept maps, short tests and cognitive conflict activities were used, since these were perceived as less threatening and which they could in turn be used by teachers to assess children's knowledge. Prior to this, teachers completed a survey whereby they self-evaluated their knowledge in science. The results from these base lining activities fed into the content, concepts and design of the workshops. A questionnaire of a materials topic assessed the knowledge of teachers by using traditional multiple choice items about particles, changing state, irreversible changes and mixtures. This method of assessment was felt, by the researcher, to be time consuming, threatening to the teachers with low scores and not as valuable as other methods for assessing children's knowledge. Also the technique was assessing knowledge, so the responses could have been learnt by rote and these responses would be difficult to distinguish from conceptual understanding. Concept mapping and elicitation activities were considered by the researcher to be the most valuable of the assessment exercises because they were both quick and easy to administer and elicited children's ideas because they were based on what children thought (Driver *et al.,* 1985).

5.8 Working with Science Coordinators

In order to try to assess the required level and sometimes the content, primary teachers would use National Test papers to decide what should be covered. However they did not always realise that information sometimes given in a test question was not demanded by the National Curriculum and that the question was simply providing a context in order to test a skill. Teachers were interpreting these questions as being something the children should know and therefore would teach the topic from then on. Also there were instances of teachers using the level statements given in the National Curriculum, to decide content and not being able to use the level statements as exemplars but as literal statements of both the content and the level at which the children were performing. For example, a child had drawn, correctly, a diagram of a flowering plant, roots etc. and then described the process of how the leaves of the plant used sunlight, water and carbon dioxide to photosynthesise. The teacher placed this work at level 2 (Level 1 *name parts of a plant*, Level 2 *describe conditions needed for growth*) because that is where parts of a plant and growing plants are mentioned in the level statements. However, the child was actually describing with confidence a biological process using the correct terminology so should have been identified in this piece of work as level 5 (but the Level 5 statement specifies *describing organ functions for the human body* but not for plants). In addition, teachers were sometimes spending a long time doing one topic at the expense of others, for example spending more time doing topics they liked or felt comfortable with and less typically on the physical sciences. All these issues fed into the support given to science coordinators.

To address this need, the science coordinators and one other experienced teacher from the schools were released to reassess the QCA scheme of work as this would be the most likely to be used within any school. Since they had no experience in prioritising activities from the scheme of work, this would be firstly outlined, and then the teachers would put the ideas into practice throughout the day. This would provide the science coordinators with valuable INSET on prioritising, ordering concepts and levelling concepts, as well as matching available activities to these concepts and differentiating each Key Learning Outcome. The coordinating of these efforts and the final editing was left to the researcher. This amended scheme (appendix 3) could then be used for medium term planning.

In the initial stages of the intervention, it became evident that many of the teachers writing their medium term plans were not aware that there is a preferred order teaching, levelling according to content and concept and suitable activities would promote discussion and others would close down the responses. These points illustrate that teachers have not reconstructed the science content within the National Curriculum. The science coordinators' efforts were pooled and the process was used as a staff development exercise in assessing the required level and to prioritise the order of content.

Each school was allocated two contrasting units from the QCA scheme of work, which gave us coverage of 48 possible units, which enabled us to use two schools to cover the more problematic units. This acted as a quality control check on the contributions made. They had to identify key concepts which was a training exercise for both the science coordinators and the teachers involved; any group of 3 or 4 teachers would ensure a debate and justification for the key topics included in a unit, as well as ensuring that there was a sensible outcome. Also the teachers need to have ownership of the scheme and by being involved in the process they would understand the processes that went into each unit and would feel that they had contributed to it. There was final editorial control by the researcher, this was to ensure a quality check in the final edition. This was done in two ways i) by a subject specialist for scientific accuracy ii) for continuity within topics through the various years where topics are covered regularly iii) to provide a house style in terms of language and terminology. The teachers were asked to decide on the key learning objectives within any unit up to a maximum of five. This provides flexibility in the following ways:

- it allows one week's work to be extended to two if an unanticipated *'event'* occurs;
- It allows time for an extended investigation;
- It allows the teacher to develop any particular topic, which interests them or the children;
- It fits in each half term (the usual method of dividing and planning work in schools), and
- some units were less than five topics and the remaining time can be used to develop investigative skills.

Accompanying the Key Learning Outcomes was a set of assessment statements designed to demonstrate the children's knowledge and understanding. They were behaviourist statements, that is the children must produce evidence of achievement which could be done in a variety of ways appropriate to the abilities of the child and the Key Learning Outcome. The assessment contained differentiated objectives in the style of:

- All children must be able to do this (often recall and statement exercises);
- Most children should be able to this (often describe/give reasons exercises), and
- Some children might be able to do this (usually explain a phenomenon in scientific terms).

The assessment was an important feature of the scheme because it supported the teachers in what they had to do - it provided a focus and an aim for the activity. There was an expectation of what the child had to do for the teacher to demonstrate achievement. The scheme could stand as a document on its own but there is also linked with the scheme with an assessment database which enables the teacher or children to record their achievements and this can provide reports in a variety of formats for example individual, group, summative which can be used for reporting back on individuals, classes, schools, trends. The learning outcomes were expressed in 'behaviourist' terms i.e. the children must provide some evidence of their achievement. The layout of the detail for each topic is shown in appendix 3.

5.9 Assessment of children

5.9.1 Written tests

Following a single group experimental design, pre-test and post-test measures of children's scientific knowledge before and after teaching each topic were carried out routinely. Detailed performances for children were collated for each pre-test and post-test. The summary data were subjected to a *t-test* analysis.

It was not possible to analyse two similar age classes from the same school as the primary schools were small and comparing similar age classes between intervention schools and other non-intervention schools also proved to be problematic due to a lack of randomisation with little confidence that the classes compared would be equivalent. The National Testing performance of the intervention classes' performance was analysed according their increasing percentage at each level year on year and relative question performances compared to national facility values. Again the significance of these differences was shown by t-test analysis of significant items. Here two schools were subject to more detailed case studies. These had significant weaknesses in science teaching identified from Ofsted reports and the Key Stage 2 SATs results were lower than other schools in the area.

5.9.2 Children's work

Samples of work to illustrate the ideas and concepts that children typically hold were collected and used to gather evidence that progress towards a more scientifically acceptable explanation of what was happening within classroom discussion. There were samples collected at the start of a topic to show children's ideas but they were not collected in any systematic pattern but used with the teachers at the time to illustrate children's understanding of ideas which tended not to be elicited by traditional test materials. These samples of work also demonstrated to the teachers that the ideas that these children held were similar to those held by many children nationally. A variety of activities were undertaken to elicit these children's ideas, for example paper tasks and 'discrepant events' to encourage Socratic dialogue and the topics were mainly focussed on the physical sciences, for example reversible and irreversible changes, forces, electricity and light, simply because they were the most requested topics for the teachers.

5.9.3 Class discussion

Many class discussions were recorded and later transcribed and many were simply taken as anecdotes from fieldnotes taken immediately after the session. These were used to provide evidence of what the children said for later interpretive analysis. Scientific discussion was analysed according to the format laid out by Mortimer and Scott (2003). This analysis was assessing developing of the social scientific language rather than re-interpretation, using the correct scientific language. A first stage was putting the children at a dominant position in the dialogue process. Initially they will have received support from the researcher which aligned itself to the Vygotskian principle of effective learning taking place with other help of an expert other. An indication of increasing teacher efficacy was the teacher's ability to think of activities that will confirm or challenge the existing children's ideas. The analysis focussed on patterns of discourse whether they were moving from the triadic 'I - R - E' interaction, to the alternative form of triadic discourse which occurs when the teacher gives feedback rather than giving a straight evaluation. Developing a chain of these interactions gives an I - R - F - R - F pattern, thus promoting a dialogic interaction.

Discussions in the classroom before and after input from the project were analysed in terms of the types of child-teacher and child-child interactions. The aspect of teaching interventions was also analysed. The analytical frameworks, patterns of discourse and teaching interventions are summarised in Tables 4.3, 4.4 and 4.5 in Chapter 4.

A feature of this research is that the science word was introduced only when the children had grasped and could explain the concept. An example occurred where children and teacher were discussing sound waves, but they visualised them as transverse waves because that is the way they were represented in the published text they were using. In this project we would probe these concepts because using incorrect models at this stage may possibly lead to problems in later explaining phenomena related to transverse and longitudinal waves. The researcher wanted the models and ideas to be simple enough for the children to make sense of their observations, be appropriate for their current level of conceptual development and still allow development of these concepts at a later stage. This will have an impact on the nature and content of the scientific story.

5.9.4 Classroom Observation

Again this was done by use of fieldnotes completed immediately after each session and noting particular features of what children said or indications that they were thinking about the activity. In some cases complete recordings were made, but the difficulty here was that the researcher or teacher could not predict the outcome. However in most cases something was noted about the effectiveness of the activity in providing evidence or the children would make a comment or make a conceptual move upward.

5.10 Summary

A range of data collection strategies will be employed because teaching is such a complex process and the data collection will centre on three main facets: the development of teachers and children, the assessment of teacher's development and the assessment of children's attainment. The development of teachers will be via the workshops to further their scientific knowledge hence they would have an input (by survey) as to what their requirements were, and the development of teacher confidence, will be mainly by in-class support. Both the training and support must be constructivist in nature and treating the learners as adults, hence the design of the workshops will be in the format of a structured input session, with the emphasis being on children's ideas and a discussion/practical session where the teachers can share ideas and discuss the use of the activities.

The development of the children's ability to discuss science will be by class discussion which will be recorded either directly or by use of fieldnotes and their attainment will be assessed by performance in pre and post tests and national tests and the work they produce in class.

6. Analysis and Discussion

6.1 Introduction

In order to ascertain teachers' general qualifications and experience, a questionnaire was completed for a comparison with the national picture. This provided some background information about qualifications and attitudes, but was not be analysed in great detail. Although teachers' scientific knowledge and experiences are always increasing, their understanding might not. The hierarchy of science within the general school curriculum and the preference for teaching the various science topics and their attitudes generally to teaching science was collected. This would provide some information about the relevance /priority for INSET topics, in addition the teachers would be asked about their preference for INSET topics and their evaluation of INSET sessions would be summarised. Finally, for confirmation of what was achieved, comments from randomly selected Headteachers would be summarised. These would be interviewed by a person independent of the project yet was an experienced senior leader in a secondary school.

The assessment of teachers would serve two purposes a) to assess the teachers' depth of knowledge about science topics for INSET sessions and to confirm their preferences for INSET topics and b) to demonstrate to teachers other forms of assessment that could be used in the classroom. These various assessments would be analysed in greater detail to make more in-depth conclusions about the knowledge and understanding of these teachers about various key science topics that they had shown a lack of preference for teaching and were higher ranked in their INSET preference survey.

Teacher confidence is seen by many researchers as a key aspect in teachers' efficacy at teaching science. It is intended that the questionnaires are distributed at various intervals throughout the project and the analysis grouped in terms of the three main science areas and scientific investigations. Initially the sample would be large, but the numbers receiving intensive support over two years would be quite small. The results would be displayed for all teachers in the sample and analysed to determine whether there had been a change in teacher confidence in teaching science in the areas highlighted.

Also a change in teacher confidence longitudinally would be analysed to compare changes in teacher confidence between the initial stages and the final stages of the intervention.

Forces is one of the most problematic areas to teach in the primary science curriculum, since the teachers and the general population have a weakness in understanding this topic and they have a tendency to compartmentalise the various topics within forces and do not formulate a coherent strategy. This will be an area of special study since the researcher feels that this area is not taught generally for understanding and if the principle of constructivism works, it will work with forces. The classroom activities will be constructivist, in that they will build on what the children already know from their experiences and presenting the materials in a way which will allow the children to reason out what they had previously held to be true. This is a topic which contains activities which have to develop, dictated by what the children say or believe. Within this topic many aspects are considered as important, the learning environment, the successful use of their prior experience and the building on these, developing the child's knowledge framework. These will all be discussed in detail.

It is important that the teachers' epistemology changes and this will be illustrated by a recording of a discussion with a class group which will illustrate the various aspects of the new epistemology. There should be a change from didactic teaching to a more open style of teaching with its concomitant aspects namely, the learning environment, the type of discussion, non-judgemental (immediately) about children's ideas and the use of evidence to formulate conclusions. Further examples illustrate and explore children's ideas, developing the discussion of known experience into a new area of learning. Developing scientific skills again depends upon the activities chosen as well as the approach to the activities, in particular asking general questions, such as, how does the temperature affect dissolving more so than, which type of sugar dissolves the best, although this is a perfectly legitimate investigation. This also links to the capability of the teacher involved. Development of classroom discussion has been examined as well as the contribution of appropriate activities to this and these have been shown, anecdotally, to teachers.

The more detailed analysis of the development of the discussion according to the methods proposed by Mortimer and Scott would be analysed at length by the researcher.

The assessment of children has been carried out using several techniques. The observation of children, the assessment of their work in post lesson analysis, the use of Science Reasoning Tasks, devised by Shayer and Adey (1981), the comparison of performance in pre and post tests and comparison of general performance in national tests compared with Facility Values and Cognitive Ability Tests (CAT) scores. The CAT scores for three selected schools that were focussed on constituted more than one hundred children. There has been a comparison of specific items which address different cognitive abilities in national tests. These are mainly subdivided into those items which assess recall of scientific facts and those which apply scientific principles – an ability which the teachers and the researcher were trying to develop within the classroom.

6.2 Data and analysis of teacher information

6.2.1 Background information on teachers

In order to ascertain some background knowledge of the teachers and their needs, a series of teacher audits were sent out to schools at the start of the project (see appendix 10.2). The teachers were asked to summarise their previous science experiences, rank subjects and topics in order of preference and these were added for all teachers responding to produce a relative preference value that is the number of teachers multiplied by the rank order from 1 to 9. A reasonably large sample (n=89) of teachers completed this return (the summary is shown in Figure 6.1) and this sample is large enough to compare with the findings of the House of Commons report (1995) about the nature of primary teachers' science qualifications. The teachers' responses indicating the extent to which they had studied science, show that the teachers in this sample were typical of the national picture, where less than 10% of primary teachers hold a science degree.

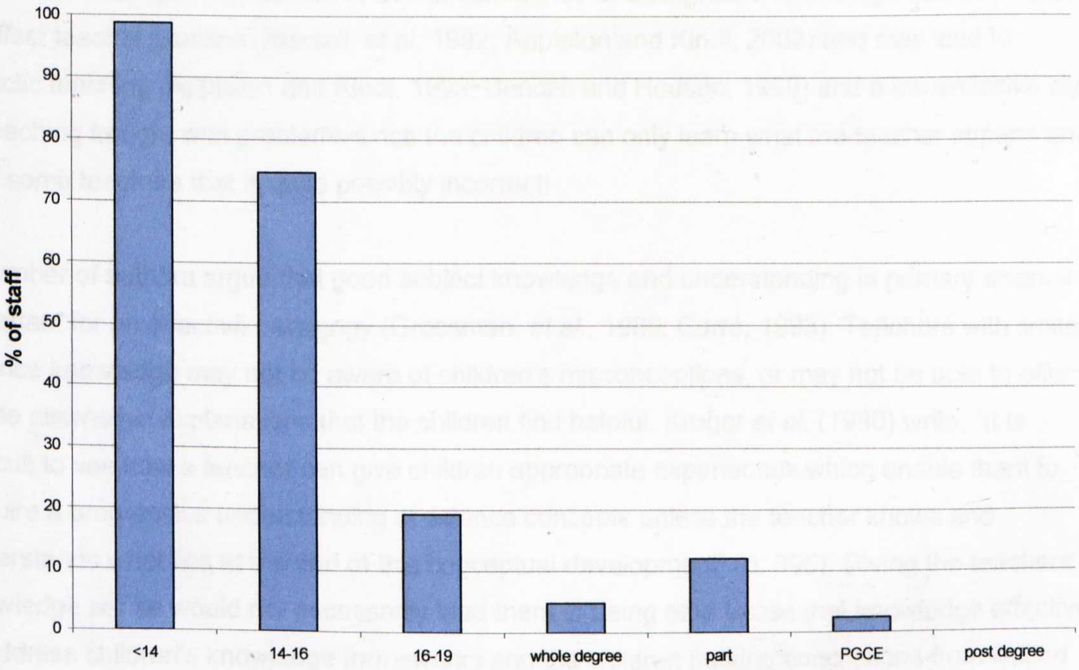

Figure 6.1 Personal scientific study of the intervention teachers

Figure 6.1 shows that less than 20% of staff have studied science beyond the age of 16 and detailed examination of the responses showed that the 14 - 16 qualifications were predominantly biology biased. This is in line with national figures (Ofsted, 2004), which also show that primary teaching remains a predominantly female occupation and, nationally, few girls studied science and even then their main subject was biology. Of the 76% who had studied a science to GCSE or O-level, 68% of those had only a biology qualification. Anecdotally, the vast majority had studied no science at primary school. The figure for those who had studied science from the age of 5 to the age of 16 and who had studied all three sciences, will increase steadily as more and more teachers are appointed who have followed the National Curriculum. In the decades leading up to the National Curriculum, teachers' lack of scientific knowledge was seen as a major barrier to the development of a primary science curriculum. Tosun (2000) assessed prospective teachers' experiences and self-efficacy and found that they had overwhelmingly negative attitudes. Today primary teachers' scientific knowledge is widely recognised as having increased, both because those entering the profession have studied more science, and those established in the profession are expected to cover science as part of their teaching requirement. However the assessments of teachers' ideas and the complexity and depth of those ideas, as discussed in section 6.2.3 leaves the debate still active about the extent of teacher knowledge for effective primary science teaching (Ofsted, 2004). The level of teacher knowledge and experience was an issue that had to be dealt with, these were not science teachers and could not be expected to have the depth of knowledge that someone with a science degree would have, so the amount of knowledge that had to be given to them had to be limited to the amount they could absorb. If they achieved a grade C at GCSE this may mean that they only scored approximately 50% of the marks, so there was a possibility that there was a whole body of knowledge that they either did not know, or worse had incorrect ideas about. A lack of confidence or background knowledge has been shown to affect teacher practice (Russell, et al, 1992; Appleton and Kindt, 2002) and may lead to didactic teaching (Appleton and Kindt, 1999; Bencze and Hodson, 1999) and a transmissive style of teaching fraught with problems since the children can only learn what the teacher imparts and with some teachers that is quite possibly incorrect!

A number of authors argue that good subject knowledge and understanding in primary science is important for an effective pedagogy (Grossman, *et al.*, 1989; Carré, 1993). Teachers with limited science knowledge may not be aware of children's misconceptions, or may not be able to offer viable alternative explanations that the children find helpful. Kruger *et al.* (1990) write, "It is difficult to see how a teacher can give children appropriate experiences which enable them to acquire a progressive understanding of science concepts unless the teacher knows and understands what lies at the end of this conceptual development" (p. 395). Giving the teachers knowledge per se would not necessarily lead them to being able to use that knowledge effectively to address children's knowledge frameworks and the children making conclusions from limited experiences. It was not expected that the teachers would be experts in science but more be able to support the children so that they could progress with sound knowledge and skills to the next Key Stage. This meant that there was a need to empower the teachers, by using key concepts that they in turn could use to answer children's ideas as well as providing them with activities which would elicit children's ideas.

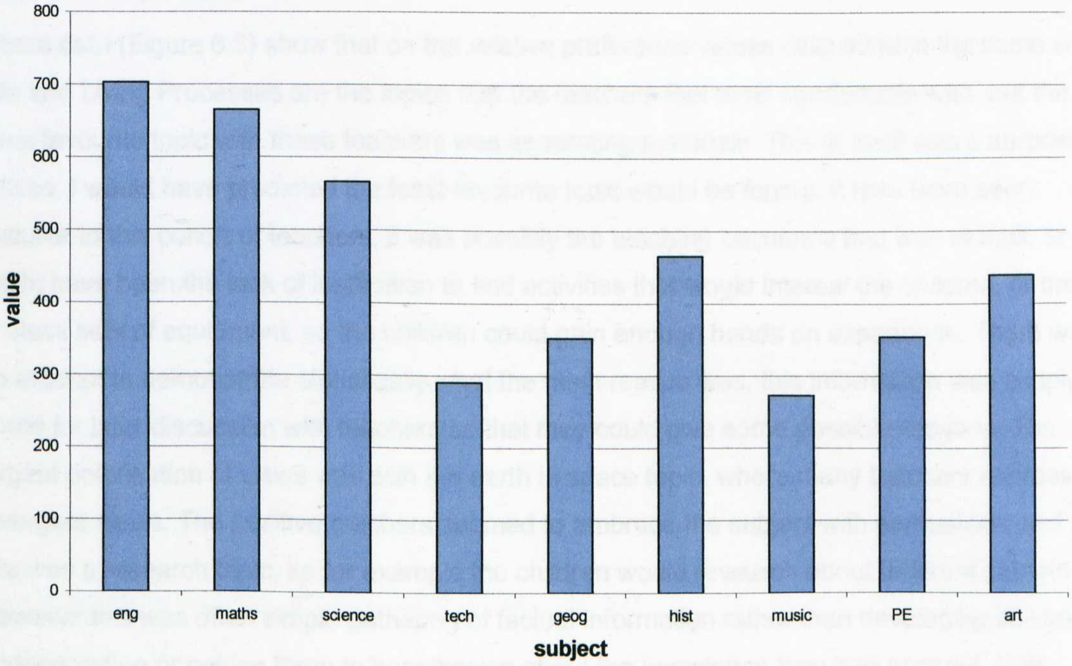

Figure 6.2 Preference of subjects within the general curriculum.

Figure 6.2 shows that teachers find science among their favourite subjects to teach, that they are positive towards it and in this survey only English and Maths were more favourably looked upon. Science has often been found to be lower in the preferences in other surveys (Harlen *et al.*, 1995).

Similarly a survey was carried out for science topics.

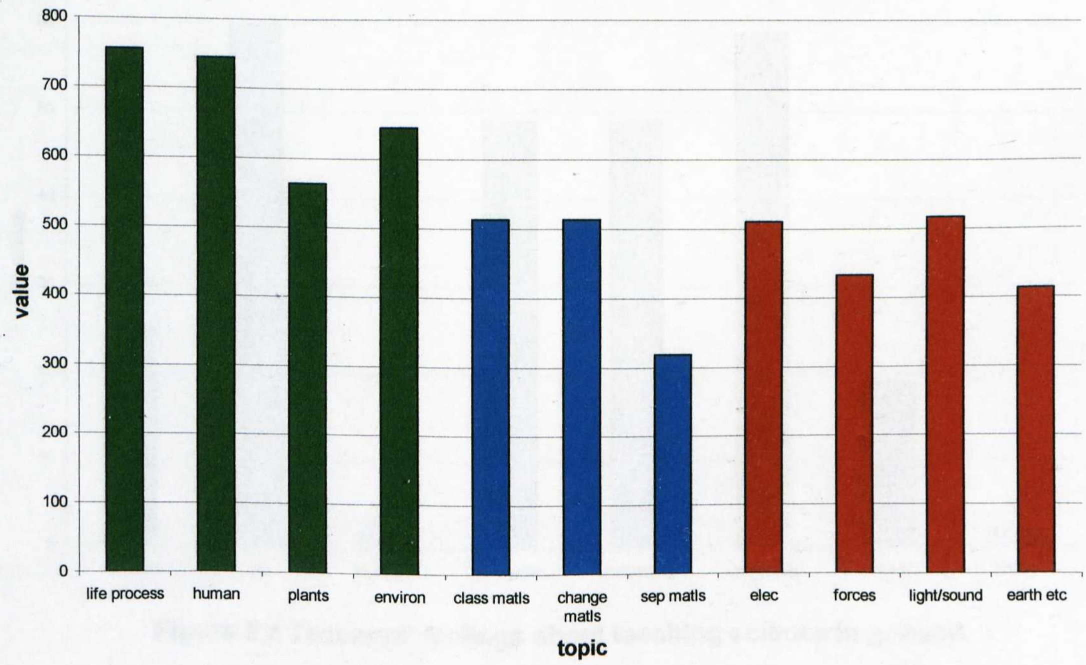

Figure 6.3 Relative preferences for topics within the science curriculum

These data (Figure 6.3) show that on the relative preference values calculated in the same way, Life and Living Processes are the topics that the teachers feel most comfortable with, but the least favourite topic with these teachers was separating materials. This in itself was a surprising choice, I would have predicted the least favourite topic would be forces. It may have been peculiar to this cohort of teachers, it was possibly the teaching sequence that was at fault, or it might have been the lack of inspiration to find activities that would interest the children, or the lack of class sets of equipment, so the children could gain enough hands on experience. There was no attempt to demonstrate statistically what the main reason was, this information was simply noted for later discussion with teachers so that they could give some possible reasons. The largest polarisation of views was with the earth in space topic, where many teachers expressed divergent views. The positive teachers seemed to embrace the subject with enthusiasm and often this was a research topic, so for example the children would research about different planets. However this was often simple gathering of factual information rather than developing children's understanding or getting them to hypothesise about the knowledge they had accrued. This information contributed to INSET workshops for example separating materials was given more emphasis, where the main teaching points were reinforced, the teaching sequence was highlighted and interesting activities were tried. These questionnaires also raised issues which could be dealt with and researched further when giving support, in class, alongside the teachers.

Teachers were asked to give their feelings about teaching science.

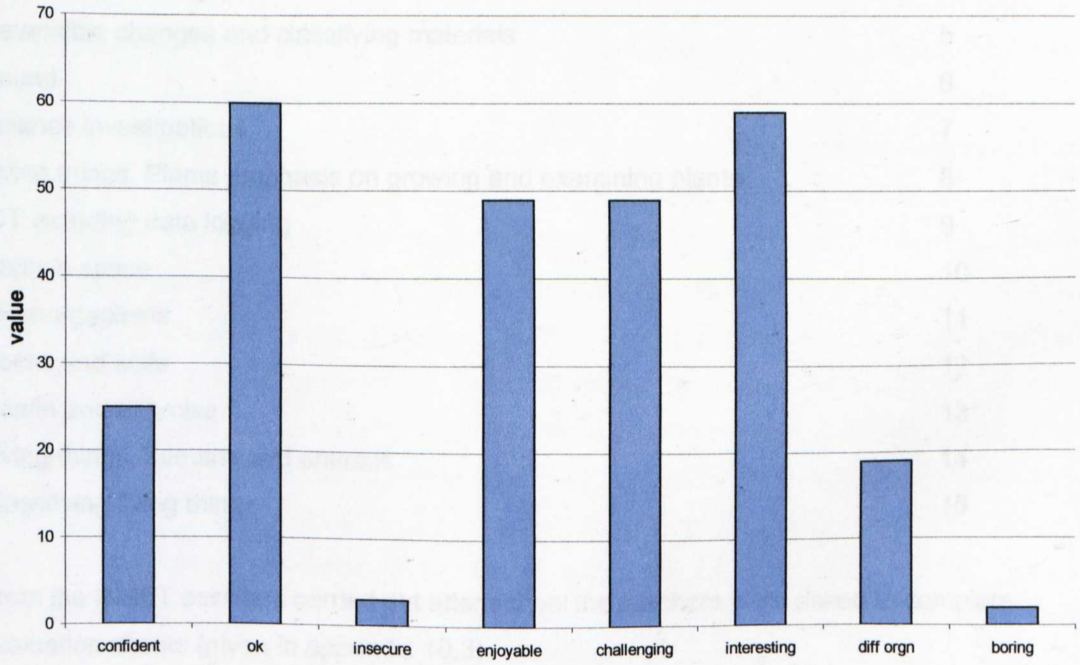

Figure 6.4 Teachers' feelings about teaching science in general.

Figure 6.4 shows that less than 30% of these teachers felt confident about teaching science, but comfortingly only a very small portion felt insecure. The confidence of teachers in relation to different topics in science is discussed in more detail in section 6.3. The data show that the teachers had a positive attitude towards science, that they found it enjoyable, challenging and interesting. This had an impact on how they received the interventions and the feedback shows that they perceived the intervention as being supportive and not judgemental. As one teacher stated:

"Initially there would be some planning that would take place and we would identify where we wanted to work together, which areas, and naturally we tended to focus here on the areas that we felt less confident with".

6.2.2 INSET preferences and evaluation

A survey of teachers' preferences for INSET topics was completed and is shown in Table 6.1.

Table 6.1 Teacher preferences for INSET topics.

Topics	Preference
Forces	1
Electricity	2
Light	3
Non reversible changes	4
Reversible changes and classifying materials	5
Sound	6
Science investigations	7
Living things. Plants emphasis on growing and examining plants	8
ICT including data logging	9
Earth in space	10
Microorganisms	11
Rocks and soils	12
Health and exercise	13
Living things, humans and animals	14
Classifying living things	15

From the INSET sessions carried out after school the teachers were asked to complete evaluation sheets (given in appendix 10.3).

The number of teachers varied from 29 to 38. The data for all the workshops are summarised in Figure 6.5 below:

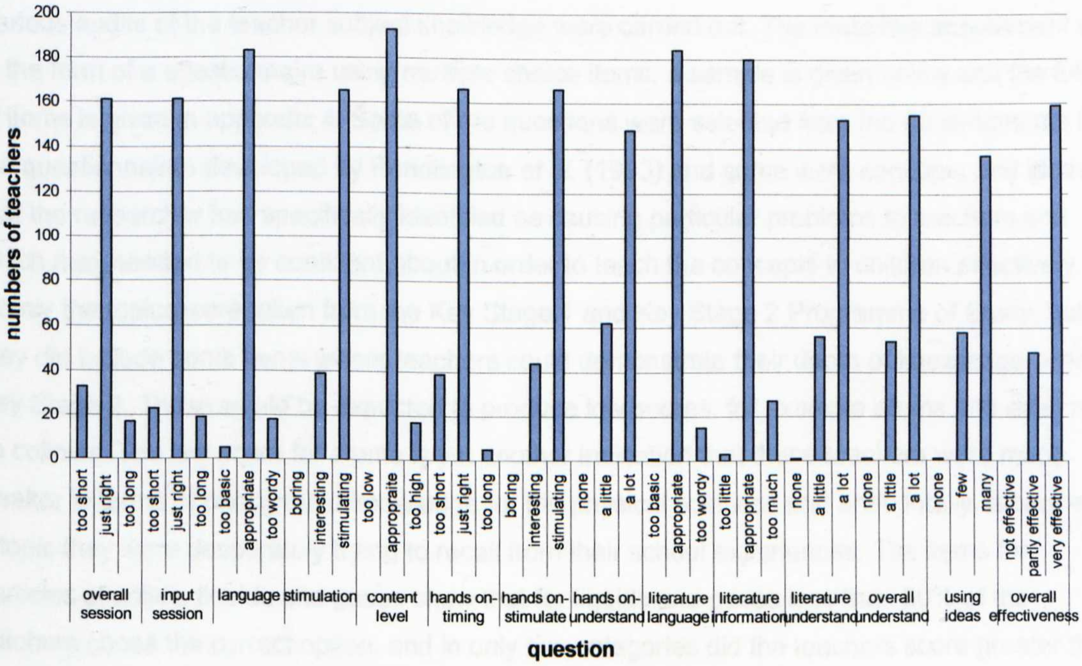

Figure 6.5 Teachers views about INSET sessions

These data show the addition of all the responses for all the INSET sessions and the high scoring (more than 80% of the teachers), indicate that the sessions were pitched at the right level and covered the main points for them in terms of developing their subject knowledge and addressed the misunderstandings about the key points of subject knowledge they might have. This applied to the input sessions, the hands on sessions and the support booklets. The information in the support booklets was considered by more than 90% of the teachers to be appropriate both for their teaching requirements and their own personal knowledge. The researcher, having experience of science and science teaching, had identified certain topics that should be included in a school's medium term plan. The courses emphasised this by focussing on the main teaching points that the researcher wanted the teachers to include in their lessons. In addition each course was accompanied by a subject booklet (see appendix 2) that the teachers could use as a reference manual in order to check or extend their subject knowledge and included some useful ideas and activities the teachers could use in class. The data show that these aims were met within the INSET courses. The data provided feedback on the appropriateness of the course but there was, in addition, anecdotal evidence in the way of teacher comments such as:

"I've understood that for the first time", "now I understand" and *"I wish you had been my Physics teacher at school"* and continued high attendance at what were twilight sessions.

6.2.3 Assessment of teachers concepts and knowledge

6.2.3.1 Questionnaires

Various audits of the teacher subject knowledge were carried out. The materials assessment was in the form of a questionnaire using multiple choice items, a sample is given below and the full set of items is given in appendix 4. Some of the questions were selected from the 80 statements in the questionnaires developed by Pendlington *et al.* (1993) and some were concepts and ideas that the researcher had specifically identified as causing particular problems to teachers and which they needed to be confident about in order to teach the concepts to children effectively. Mainly the topics were taken from the Key Stage 1 and Key Stage 2 Programme of Study, but they did include some items where teachers could demonstrate their depth of knowledge beyond Key Stage 2. These would be expected to produce low scores, for example atoms and even more so colloids. The low score for atoms is yet another indication that these teachers were much weaker in terms of background knowledge for the physical sciences and anecdotally, atoms was a topic they were desperately trying to recall from their school experiences. The items for particles of solids, liquids and gases show that for liquids and gases less than 50% of the teachers chose the correct option, and in only two categories did the teachers score greater than 70%, so if they engage in a transmissive type of teaching they are more likely to tell the children the wrong answer. In fact for this questionnaire only for particulate arrangement in solids, physical properties of gases, change of state and making solutions did the teachers score more than 50%, which again demonstrates their lack of knowledge in the physical sciences.

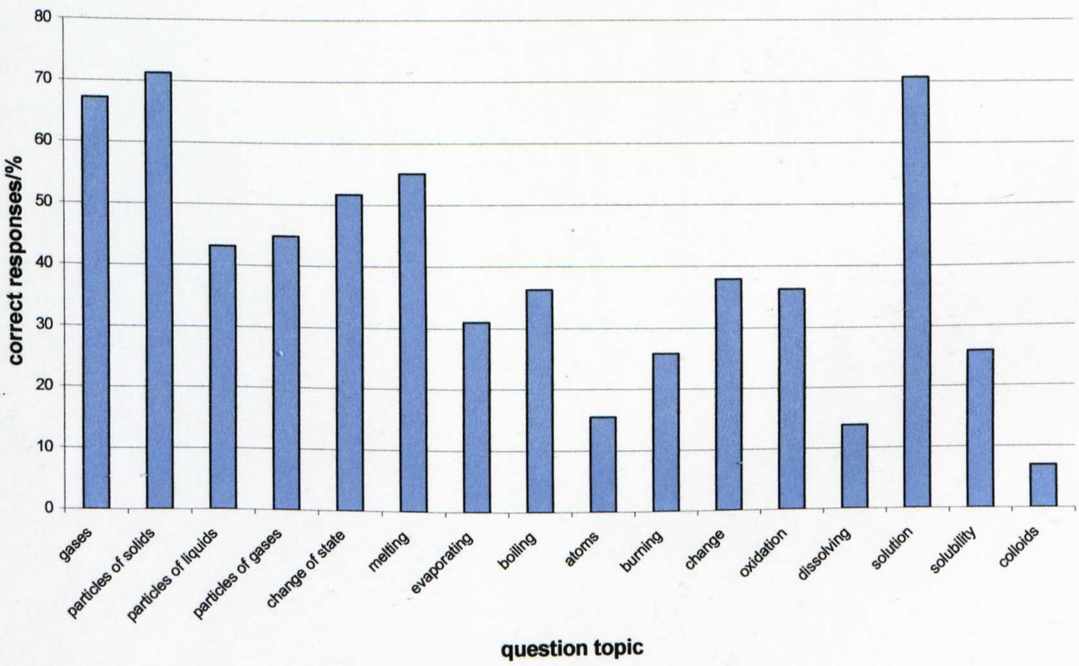

Figure 6.6 Teachers' responses to materials questionnaire

6.2.3.2 Concept mapping

A second technique used in this study was concept mapping in fact 'seeded micromaps' (Trowbidge and Wandersee, 1996), were used. This was felt to be non-threatening and was a technique they could use in the classroom. In some studies the maps are scored as a coefficient relative to expert maps (McClure *et al.,* 1999), this was done but not analysed in detail statistically since the purpose was to provide information for planning the workshop structure and in class support, rather than a precise assessment of teacher's learning frameworks.
The rubric for scoring the concept maps is given in appendix 10.1 and since cross linking indicated a much higher level of conceptual thinking and understanding, the scores for cross linking were given a higher weighting.

'Expert T' refers to the score for a concept map from the course tutor
Expert 1^0 refers to a concept map that covers the knowledge likely to be used by a primary teacher. This involves the programme of study for the national curriculum plus other concepts or examples that might arise from children's questions. These are only provided as an approximate reference point.
Numbers 1-29 represent the teachers attending the workshop.
The raw scores for teacher's concept maps on the topic of light is given in Table 6.2 and the groupings of the scores are shown in Figure 6.7.

Table 6.2 Raw scores of teachers' concept maps for the topic light.

Person	Propositions	Hierarchy	Branches	Example sets	Cross links	*Total*
Expert T	37	25	8	8	6	336
Expert 1^0	20	14	8	5	2	204
1	10	3	4	3	0	63
2	17	7	8	4	2	154
3	7	1	3	3	0	41
4	12	3	3	5	1	101
5	15	5	4	4	1	122
6	8	4	3	4	0	57
7	9	4	4	5	0	73
8	11	7	5	4	1	111
9	7	3	2	2	0	44
10	5	2	2	3	0	32
11	8	4	3	4	0	61
12	9	4	3	3	0	62
13	5	2	2	3	0	38
14	7	2	2	2	0	39
15	9	4	4	5	0	70
16	10	6	2	4	1	84
17	16	8	6	5	1	137
18	6	3	1	2	0	37
19	8	4	3	3	0	59
20	7	3	2	2	0	42
21	10	4	4	4	1	81
22	13	6	4	5	0	85
23	7	4	3	3	0	49
24	8	3	2	2	0	42
25	8	3	4	3	0	58
26	9	4	4	3	0	68
27	7	2	2	3	0	38
28	15	6	5	5	1	129
29	7	4	3	4	0	55

Some statistical analyses were carried out on the raw data and the distribution of total scores (grouped) and these are shown below.

Parameter	Value
Mean	70.07
Standard Deviation	33.19
n	29
Minimum teacher score	32
Median teacher score	61
Maximum teacher score	154

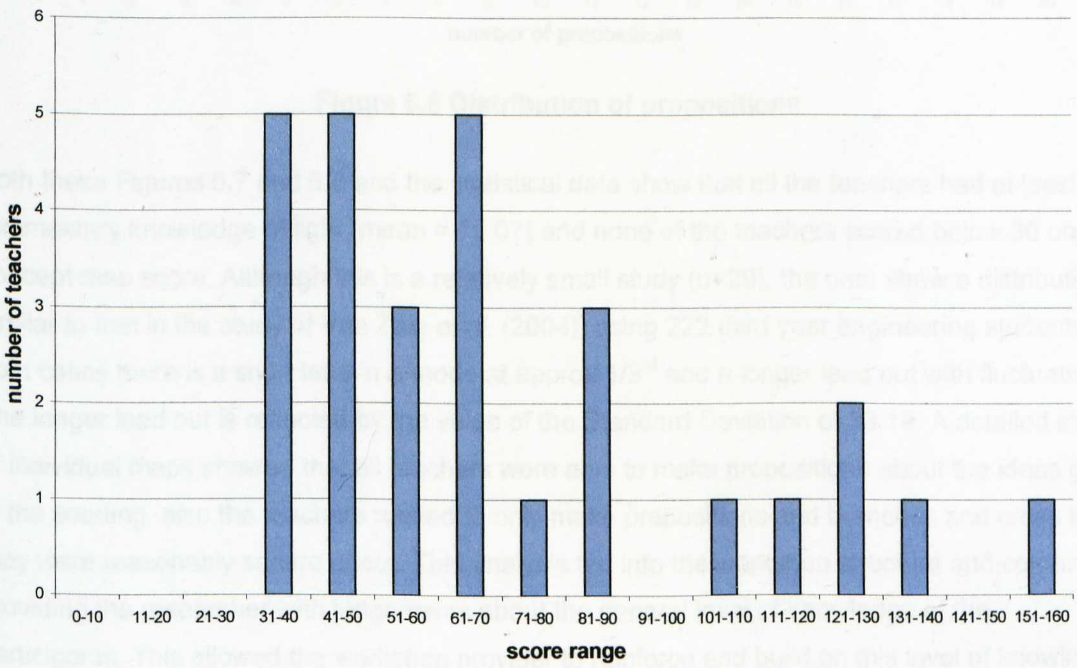

Figure 6.7 Distribution of concept map scores

The distribution of propositions in each teacher's map is given in Figure 6.8

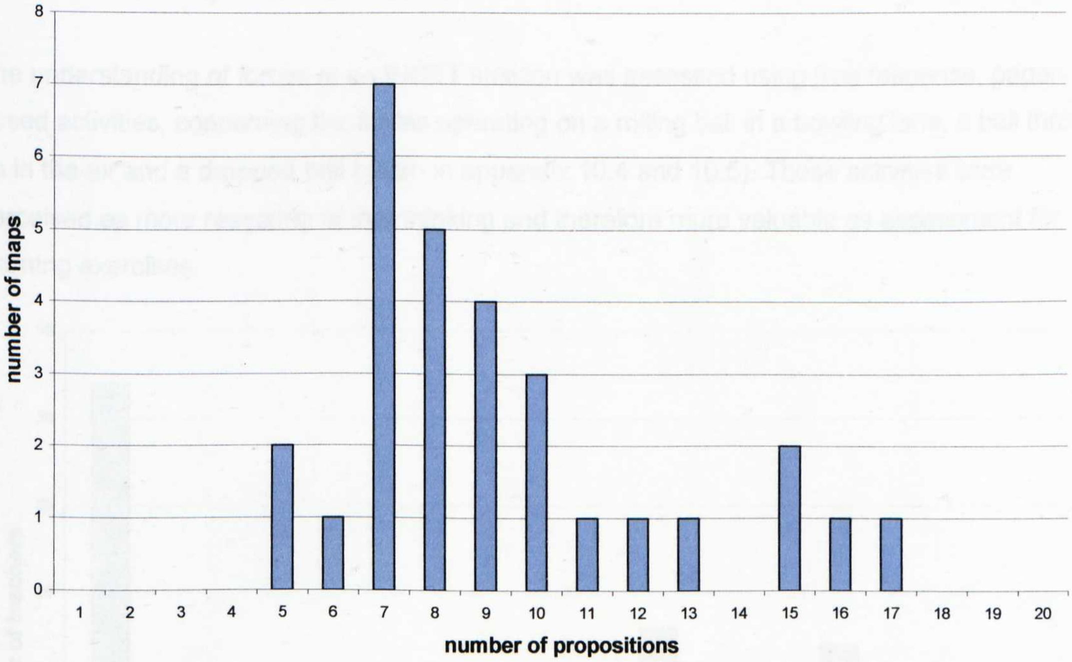

Figure 6.8 Distribution of propositions

Both these Figures 6.7 and 6.8 and the statistical data show that all the teachers had at least a rudimentary knowledge of light (mean = 70.07) and none of the teachers scored below 30 on the concept map score. Although this is a relatively small study (n=29), the data show a distribution similar to that in the study of Van Zele *et al.* (2004), using 222 third year engineering students. In both cases there is a short lead in a mode at approx 1/3rd and a longer lead out with fluctuations. The longer lead out is reflected by the value of the Standard Deviation of 33.19. A detailed study of individual maps showed that all teachers were able to make propositions about the ideas given in the seeding, also the teachers tended to only make propositions and branches and cross links they were reasonably secure about. This analysis fed into the workshop structure and content providing the researcher with judgements about the general level of knowledge of the participants. This allowed the workshop provider to reinforce and build on this level of knowledge, extend the teachers' understanding beyond that required for the Key Stage 2 programme of study and identify the key concepts that needed to be reinforced in the workshop. In addition the teacher could use concept mapping to quickly and visually assess children, especially before and after an activity or series of activities.

6.2.3.3 Free response activities

The understanding of forces at an INSET session was assessed using free response, paper-based activities, concerning the forces operating on a rolling ball in a bowling lane, a ball thrown up in the air and a dropped ball (given in appendix 10.4 and 10.5). These activities were perceived as more revealing of true thinking and therefore more valuable as assessment for learning exercises.

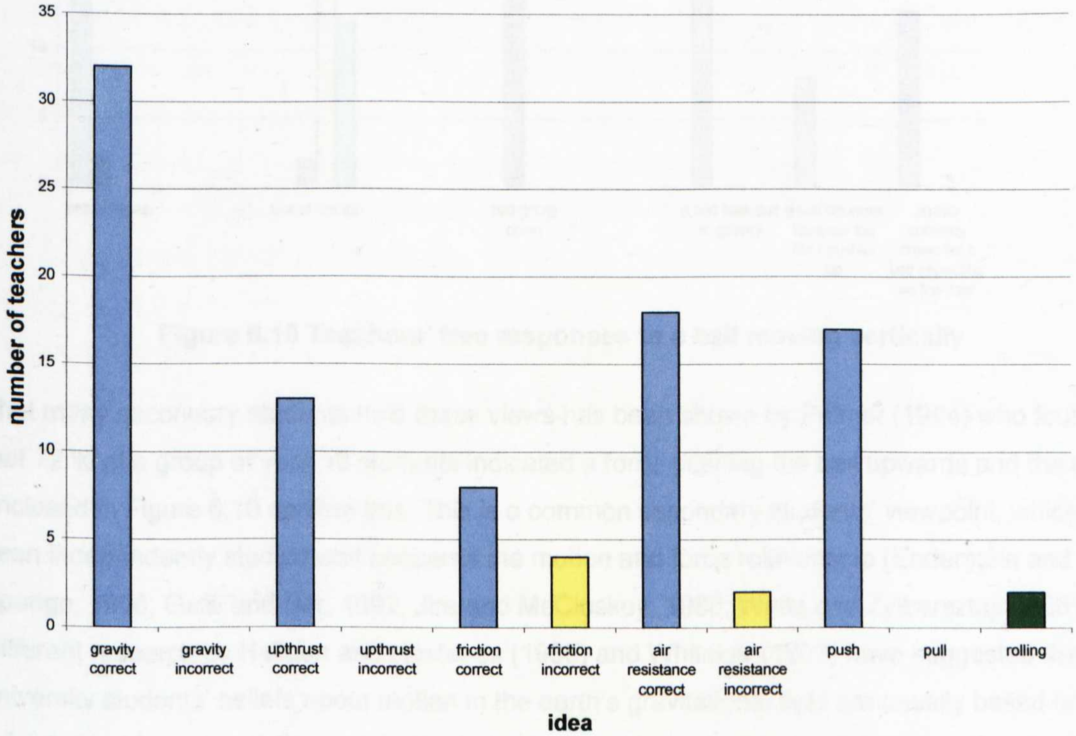

Figure 6.9 Teachers' responses to a rolling bowling ball

The data (n = 34) show that most teachers, at this workshop, correctly denoted gravity, but only 13 teachers freely represented upthrust on the diagram. Surprisingly more teachers referred to air resistance than friction even though friction has a greater effect on the ball. This is an illustration of both teachers and children learning names of forces but not integrating them into the whole picture of forces acting on the ball. Their learning is contextualised. The incorrect responses had friction and air resistance acting in the wrong direction. Approximately half of the teachers were saying that there was still a push force acting on a rolling ball thus complying with the Aristotelian view that a force is needed to maintain movement. This is similar to the views held by children. Two teachers referred to a rolling force, again a view held by some children. These responses show that many adults hold the same ideas that children do. The teachers were asked to indicate on a diagram a shown in appendix 10.5, the name and direction of forces on a ball thrown upwards. The results of teachers doing this exercise are shown in Figure 6.10.

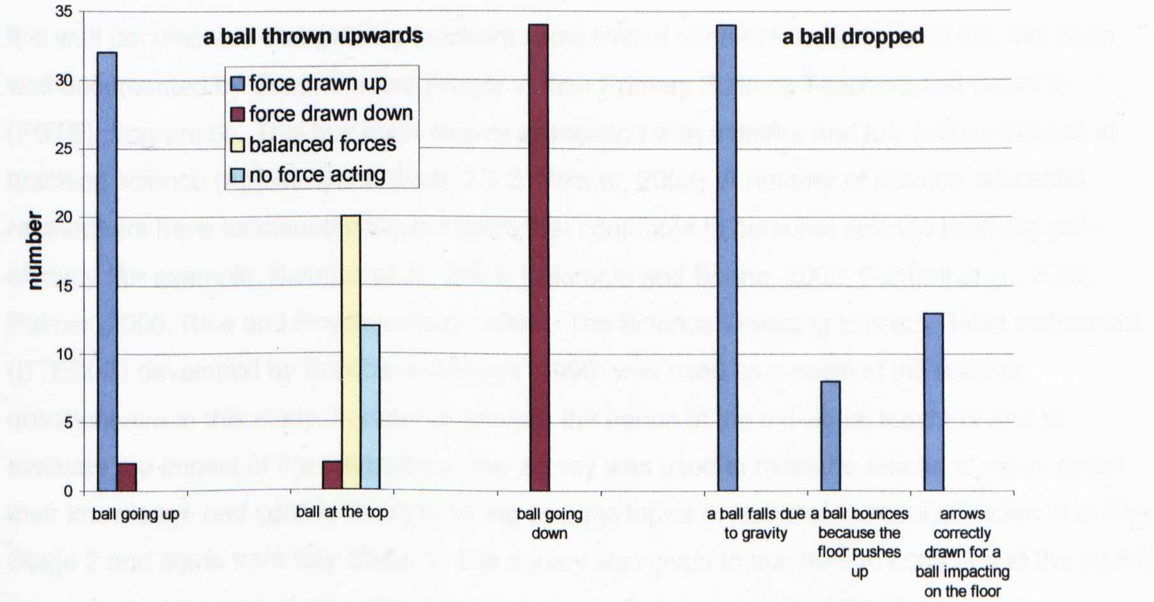

Figure 6.10 Teachers' free responses to a ball moving vertically

That many secondary students hold these views has been shown by Palmer (1994) who found that 72 % of a group of year 10 students indicated a force pushing the ball upwards and the data enclosed in Figure 6.10 confirm this. This is a common secondary students' viewpoint, which has been independently studied and concerns the motion and force relationship (Enderstein and Spango, 1996; Galili and Bar, 1992; Jira and McCloskey, 1980; Watts and Zylbersztajn, 1981). Different research by Halloun and Hestenes (1985) and Whitaker (1983) have suggested that university students' beliefs about motion in the earth's gravitational field are usually based on Aristotelian ideas. Again these data illustrate the lack of knowledge about forces and their effect on movement and these figures are typical of any adult population. When a ball is travelling upwards only two from thirty four teachers thought the force was down (they were told to ignore air resistance), when the ball was at the top of the throw (and not moving) almost two thirds of the teachers designated the forces as balanced, because what they had been led to believe is that when an object does not move, the forces were balanced. In their learning about forces, they had not had the lack of movement distinguished as the object being at a position of equilibrium or not. Similarly a significant number of teachers thought that no forces operate on an object which is not moving. For a falling ball and a bouncing ball all the teachers correctly identified gravity as acting down, but less than a quarter could correctly identify the floor as playing an active part in the ball bouncing, although more teachers did say there was an upward force, but some of these teachers thought the upward force came from the deformation of the ball. The implication for teaching and learning is that if the teachers' epistemology was didactic then these incorrect ideas would probably be perpetuated through the children they teach, because the children would be unlikely to experience conflicting evidence. These results would affect the way the workshops were structured and the strategies used to teach the children about forces and movement.

6.3 Teacher confidence

It is well documented that primary teachers show limited content knowledge and this has been well documented by Summers and Kruger in their Primary Schools Teachers and Science (PSTS) programme. This has been closely associated with a dislike and low self confidence in teaching science (Appleton and Kindt, 2002; Palmer, 2002). A number of science education researchers have examined various factors that contribute to personal science teaching self-efficacy (for example, Balunuz *et al.*, 2001; Cakiroglu and Boone, 2002; Cantrell *et al.*, 2003; Palmer, 2006; Rice and Roychoudhury, 2003). The Science Teaching Efficacy Belief Instrument, (STEBI-B) developed by Enochs and Riggs (1990) was used as a basis of the teacher questionnaire in this study. In order to analyse the needs of the individual teachers and to evaluate the impact of the programme, the survey was used to measure teachers' views about their knowledge and confidence in teaching specific topics in National Curriculum Science at Key Stage 2 and some from Key Stage 3. The survey was given to teachers to complete at the start of the project, at the end of year 1 and the end of year 2. It is recognised that there may be a difference between teachers' self-expressed confidence and actual competence which was assessed informally, but attempts to use more rigorous methods of testing subject knowledge were not used. A copy of the survey is given in appendix 10.6.

6.3.1 General discussion

The discussion focuses on how the survey was used to examine whether the programme had a measurable effect on teacher confidence. Teachers' opinions about their confidence were collected throughout the project, using the questionnaire illustrated below.
By comparing data between the start of the project (I) (n=89) and end of the project (F) (n=10), interpreting these data provides a consistent interpretation for each category in an attempt to bring meaning to the findings. Since the data were being interpreted by the researcher and the same teachers were answering the same questionnaire, consistency was maintained as high as possible. The questionnaire was seeking to elicit teachers' confidence in being effective teachers of science. The categories where teachers express confidence and an ability to answer children's and colleague's questions were highlighted in categories 4 and 5 and this can be considered a desirable goal for effective teachers when delivering a science curriculum. These have been regarded as the suitable categories where teachers had sufficient professional scientific and pedagogic knowledge to be as effective as they would wish. Teachers answering in these categories would, for example, feel that they could not only deliver the curriculum but also could develop and enhance the science curriculum in an effective manner and contribute to the effectiveness of their colleagues. The corollary of this is that where teachers have given category 1 or 2 responses, this has been interpreted as teachers identifying themselves as lacking in

scientific knowledge and lacking in confidence when teaching science. This is supported by Russell *et al.* (1992) who noted that teachers who had low confidence, felt unable to plan science lessons conceptually and is further supported by Dr Robin Millar in his evidence to the fourth House of Commons report (1995): "the level of understanding of science that you need to have to help [children] take those early steps [in conceptual development] really requires quite a demanding and subtle knowledge of the subject".

6.3.2 Life processes and living things

The data from Table 6.3 are then summarised and displayed in Figure 6.11 to show the comparison of teachers' confidence at the start and end of the programme.

Table 6.3 Teacher confidence for life processes and living things

Life Processes and Living Things	Level 1		Level 2		Level 3		Level 4		Level 5	
	I	F	I	F	I	F	I	F	I	F
1 reproduction in plants (germination pollination fertilisation naming reproductive parts of flowers	11	0	13	0	54	20	15	40	7	40
2 human life processes for example circulation system digestive system reproductive system	3	0	24	0	50	30	18	20	5	50
3 photosynthesis	13	0	23	10	49	40	8	20	7	30
4 use of keys	14	0	22	0	37	20	20	30	7	50
5 food chains and webs, biomass	14	0	26	0	47	0	8	70	5	30
6 micro-organisms, decay processes	15	0	40	0	31	50	7	20	6	30

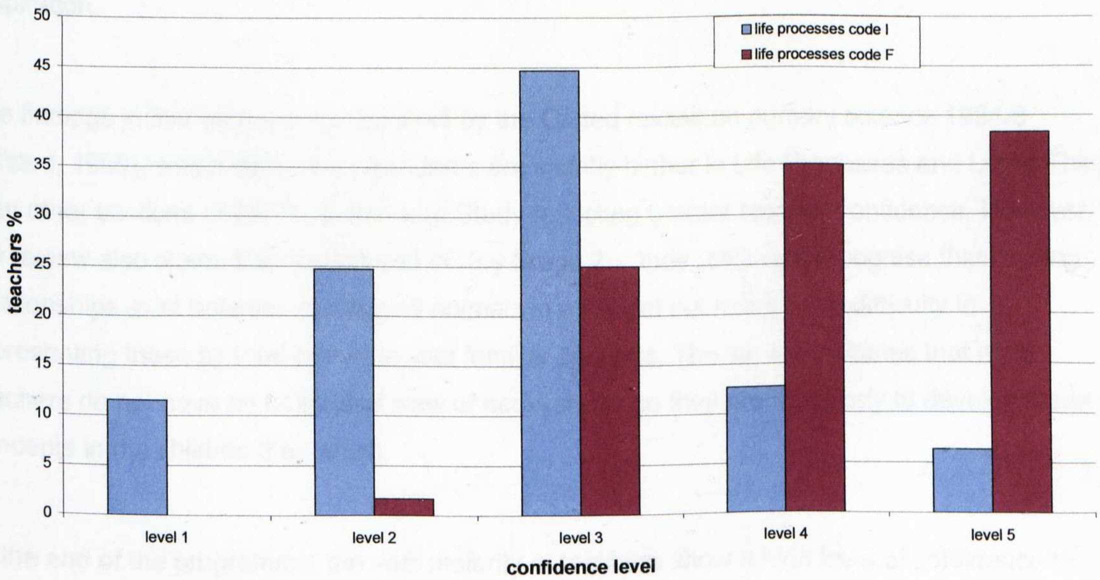

Figure 6.11 Teacher confidence about life processes and living things

Figure 6.11 shows that the data follow a normal distribution for the initial data but for the final responses are heavily skewed to the higher levels of confidence, thus making many of the usual statistical interpretations, based on normal distributions, difficult. A mean value initially and finally for each response has been calculated to illustrate the shift in teacher confidence. The mean level of response for Life Processes and Living Things initially was 2.8, but this increased to 4.1 finally, which is a substantial increase in teacher confidence. The responses in Table 6.3 for the start of the programme show that the majority of teachers' responses (80%) fall into categories 1 to 3. In selecting categories 4 and 5 as meaning sufficient teacher confidence, only 20% of the teachers felt they were confident. The majority of these teachers in the survey have insufficient scientific knowledge of science skills and processes as they relate to Life Processes and Living Things. However, Table 6.3 highlights that the largest number of responses fell into category 3, *reasonably secure in the subject and can deal with simple children's questions.* These data show therefore that most teachers are close to having this knowledge since the responses in category 3 tend to be fairly high and when taken together with responses for categories 4 and 5 include the majority of teachers (64%).

However, data referring to item 6, micro-organisms and decay processes, is an exception to this trend, where more than half the teachers (55%) express a lack of confidence, or lack of knowledge in this topic (category 1 and 2). This is true to a lesser extent, for item 5, food chains and food webs where 40% of teachers selected categories 1 or 2. Little research data on primary teachers' knowledge of these topics is available but a comparison can be made to data obtained for GCSE students, since the vast majority of primary teachers will not have studied science beyond this level. For instance, Leach *et al.* (1992) found that most 16 year olds did not have an integrated view of matter that involved photosynthesis, assimilation of food, decay and respiration.

The findings in this survey are supported by the Ofsted review on primary science 1994-8 (Ofsted, 1999), which states that standards are slightly higher in Life Processes and Living Things than other sections of the Programme of Study reflecting greater teacher confidence. However, the review also states that "by the end of Key Stage 2....they (children) recognise that feeding relationships exist between plants and animals in a habitat but many have difficulty in representing these by food chains in less familiar contexts. The survey indicates that most teachers do not have an integrated view of ecosystems so they are less likely to develop these concepts in the children they teach.

At the end of the programme, the vast majority of teachers show a high level of confidence in teaching Life Processes and Living Things, even in those topics in which initially they were very apprehensive, for example items 5 and 6. None of the teachers felt they lacked confidence in areas such as microorganisms (categories 1 and 2), whereas at the start of the programme at least 50% of the teachers lacked confidence with this.

6.3.3 Materials and their properties

The data from Table 6.4 and Figure 6.12 show teacher responses for materials and their properties

Table 6.4 Teacher confidence for materials and their properties

Materials and their Properties	Level 1		Level 2		Level 3		Level 4		Level 5	
	I	F	I	F	I	F	I	F	I	F
7 classifying materials for example conductivity, magnetic, strength, metal, non-metal	4	0	19	0	51	30	19	30	6	40
8 classifying as solids liquids gases	4	0	19	0	44	20	24	20	8	60
9 change for example permanent chemical, role of oxygen in burning, respiration	6	0	33	10	46	40	10	20	6	30
10 or reversible - change of state for example water cycle	13	0	22	0	43	10	14	50	8	40
11 particle theory to explain change	28	0	36	20	22	40	10	20	4	20
12 separating mixtures, evaporating, crystallisation	18	0	38	10	29	30	10	40	6	20

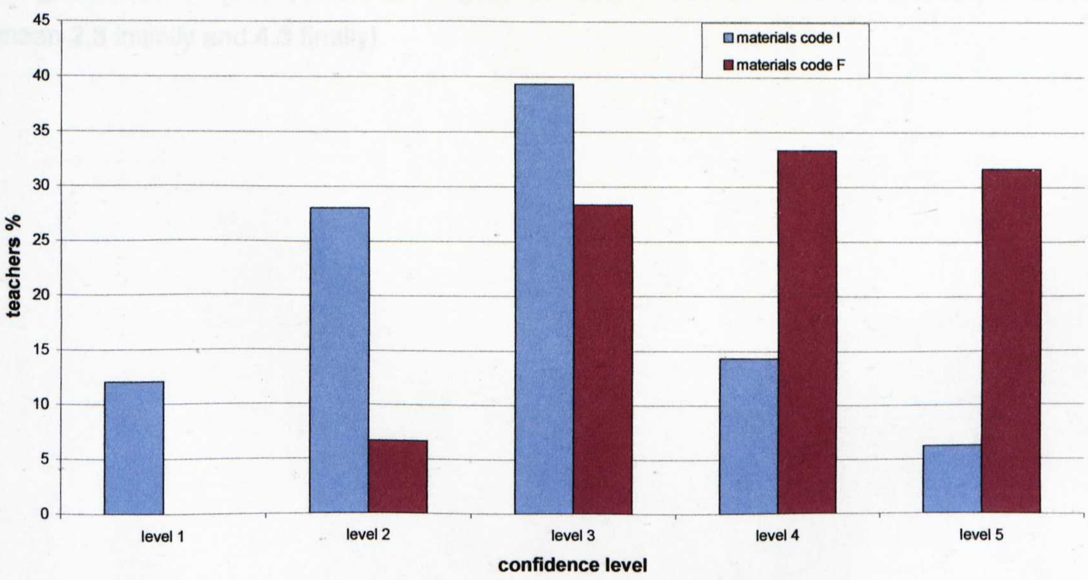

Figure 6.12 Teacher confidence about materials and their properties

Data in Table 6.4 indicate that teachers feel more comfortable with classifying materials but significantly lack knowledge and confidence when dealing with particle theory and separating mixtures where the scores for categories 1 and 2 are 64% and 56% respectively. The mean value for question 12 is 2.5 which links to the data in Figure 6.3 that separating mixtures was a topic they did not feel confident about. Grouping and classifying is a relatively low level skill (level 3 in National Curriculum Attainment Target level descriptors), but using concepts, models and scientific ideas to explain natural phenomena such as evaporation is a much higher level skill (level 6). This pattern mirrors the abilities of children in the Ofsted review 1994 -8 (Ofsted, 1999), "children are able to explain how materials can be classified by their properties... although dissolving, evaporation and condensation are often not well understood". Research by Holroyd and Harlen (1995) has shown that most primary teachers commonly understand the idea that water exists as a solid, liquid or gas. However, the change from one state to another, which involves the use of the particulate theory of matter, is significantly less well understood and rarely used. This was also supported by discussions from the INSET sessions that were held, in that very few teachers could explain the link between temperature decrease and the phenomenon of evaporation. However the use of particle diagrams of solid, liquid and gas are becoming more common. At the end of the programme these topics still presented more difficulty, particularly with some teachers, but overall there was a significant shift to feeling more confident. The data show a highly significant change in confidence when dealing with reversible changes (item 10) where initially almost half of the teachers responded in categories 1 and 2 and at the end of the programme no teachers responded in these categories, also 90% of the teachers said they were in categories 4 or 5. Similarly for irreversible changes (item 9) almost half of the teachers responded in categories 1 and 2 and separating mixtures (item 12) more than half replied they lacked confidence, by the end of the programme only 10% of the teachers responded in these categories. Item 9 also produced the largest increase in confidence in this set of responses (mean 2.8 initially and 4.3 finally).

6.3.4 Physical processes

Table 6.5 and Figure 6.13 show the responses for the strand of Physical Processes.

Table 6.5 Teacher confidence for Physical processes

Physical processes	Level 1		Level 2		Level 3		Level 4		Level 5	
	I	F	I	F	I	F	I	F	I	F
13 interpreting simple circuit diagrams	7	0	23	0	50	20	14	30	5	50
14 ways of varying current in a circuit	17	0	33	10	36	20	11	40	3	30
15 explaining current and voltage and resistance, parallel circuits	20	0	41	10	30	60	7	20	2	10
16 gravity for example explaining weight and weightlessness	14	0	45	10	32	30	6	30	4	30
17 friction including in air and water	13	0	39	0	35	20	10	50	4	30
18 balanced and unbalanced forces for example in floating, flying, stretching, compressing	14	0	43	10	33	30	7	40	3	20
19 density	23	0	40	20	27	50	8	20	1	10
20 reflection and refraction, images, mirages, spectrum	6	0	38	20	47	30	7	30	3	20
21 how we see objects, shadows	1	0	29	10	54	10	10	40	5	40
22 sound and vibrations, loudness and pitch, waves, echoes	11	0	32	0	42	40	11	30	4	30
23 movement of sun, earth and moon, solar system, eclipses	8	0	26	0	46	40	14	30	5	30

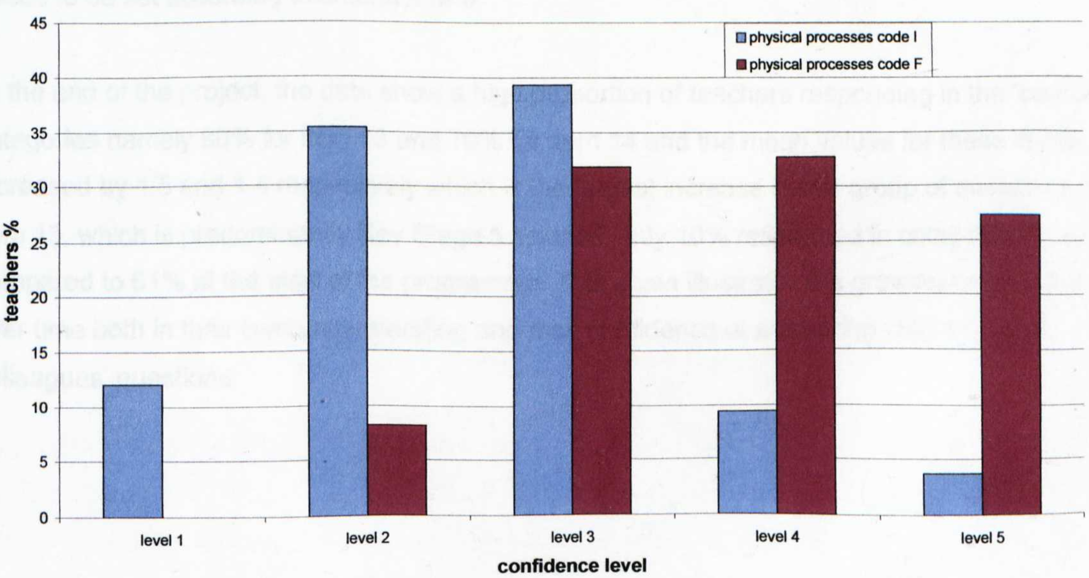

Figure 6.13 Teacher confidence about physical processes

Initially, more than 50% of teachers classified themselves as categories 1 or 2 in most of the items, which gives a clear indication that teachers perceive they lack knowledge and confidence in Physical Processes. This is supported by the mean value response for questions about Physical Processes was 2.6 initially. In items 15, 16 and 18, the maximum number of teachers describing themselves as confident is 10%. Item 15 involves explaining how and why varying the numbers of batteries or bulbs in a circuit will affect the flow of electricity. This illustrates that the teachers can "do" the activity that is change the batteries or bulbs, but do not understand why the effect is produced so they are very limited in the way they can support children in their understanding. If children do ask why the brightness of a bulb changes (as they often do), the teacher would not be able to deal with those children's questions effectively and would be more likely to give them incomplete, or even incorrect reasoning. This is supported by a quote from one of the teachers at the electricity workshop *"I just give them the stuff and let them play"*, this teacher, in conversation, did not understand electricity and could not answer children's questions.

In addition to the findings in the data, it also needs to be considered that in responding to the questionnaire, the teachers were limiting their ideas about for example, electricity to those as stated in the National Curriculum. In discussions with teachers at the workshops, it became clear that many of questions raised by children in investigative situations with circuits, challenge their knowledge, for example, opposing batteries in a circuit, using non-identical bulbs of different brightness, for the same voltage applied. For instance, teachers generally (but not always) knew that electricity goes round a circuit, (as opposed to a 'clashing current' model favoured by the majority of primary school children) but had not considered why electrical phenomena such as the ones above could be better explained by a 'circulating current' model. This again supports the premise that to be effective, teachers' assessment of their own knowledge and understanding needs to be set according to criteria 4 or 5.

At the end of the project, the data show a high proportion of teachers responding in the 'confident' categories namely 80% for item 13 and 70% for item 14 and the mean values for these items increased by 1.5 and 1.4 respectively which is the largest increase in this group of questions. For item 15, which is predominantly Key Stage 3 science, only 10% responded in categories 1 and 2 compared to 61% at the start of the programme. This again illustrates the growing confidence over time both in their own understanding and their confidence at answering children's and colleagues' questions.

6.3.5 Experimental and investigative science

Table 6.6 and Figure 6.14 show teacher confidence for the investigative strand of the National Curriculum.

Table 6.6 Teacher confidence experimental and investigative science

Experimental and Investigative Science	Level 1		Level 2		Level 3		Level 4		Level 5	
	I	F	I	F	I	F	I	F	I	F
24 generating closed, open and productive questions	8	0	32	0	41	20	16	70	3	10
25 relating science to everyday life	6	0	21	0	53	20	15	70	5	10
26 planning an investigation	7	0	32	0	42	20	14	70	5	10
27 recognising factors to change or not change	7	0	24	0	53	20	10	50	6	30
28 accuracy of measurement	7	0	21	0	56	10	10	70	7	20
29 use of tables and graphs	10	0	14	0	57	0	14	60	5	40
30 evaluating results or data	8	0	23	0	50	0	11	70	7	30
31 use of IT to store, interpret and present data	26	0	49	0	19	30	3	50	3	20
32 safety issues, risk assessment	10	0	17	0	53	30	14	50	6	20

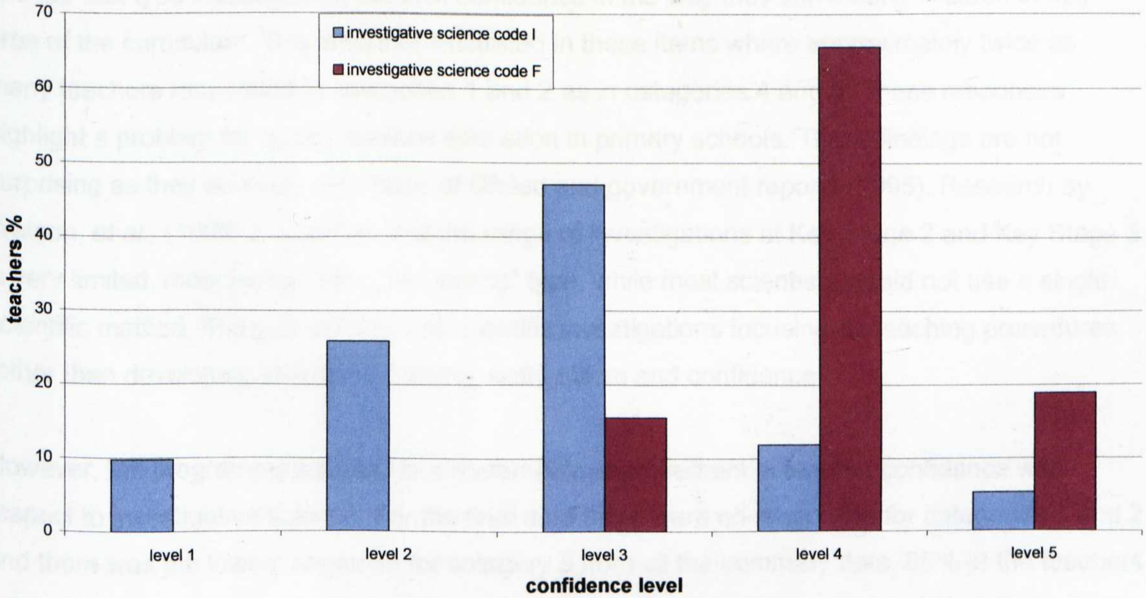

Figure 6.14 Teacher confidence about investigative science

This set of data produced the largest increase in mean value namely 1.4 with the lowest value in the final responses being 3.9 and a mean greater than 4 which translated into a statement is: *Confident in the subject and can answer most children's questions. Can think of curriculum ideas.* In considering aspects of experimental and investigative science, the data in Table 6.6 demonstrate that generally teachers feel less confident in asking scientific questions (item 24) and planning an investigation (item 26) than in relating science to everyday life (item 25). The data indicate that teachers are less comfortable at generating new ideas that can be investigated. This is supported by items 27 – 29 where there is a more positive response to items that involve the performing of an investigation. In addition, a large group of teachers fall into categories 1 and 2 for item 30 concerned with evaluating and interpreting data. These findings are supported by the Ofsted review 1994-8 (Ofsted, 1999) that teachers are more inclined to simply "do" standard investigations rather than use them to provide the evidence for challenging children's ideas. "Of the schools visited, those with the highest or most rapidly improving standards ensured that scientific enquiry was at the core of their work in science" (Ofsted, 2008). Teachers perceive science as a 'doing activity' and they believe in a hands on approach, but then they will see the set of results and possibly a brief conclusion as an end in itself. They will rarely see this as the start of the process and a gathering of evidence which will then lead to an informed discussion, even though it is this discussion of their ideas that will highlight for the teacher limited conceptual development in the children and will provide opportunities for the enhancement of the children's scientific ideas. Ofsted reports, continually cite good science teaching as being characterised by interpreting, evaluating and discussing children's ideas.

Experimental and investigative science in items 24-30 provides the largest response from teachers for category 3 (reasonably secure).Teachers are now quite familiar with the mechanics of a fair test type investigation, but lack confidence in the way they can extend children in this area of the curriculum. This is further illustrated in these items where approximately twice as many teachers responded in categories 1 and 2 as in categories 4 and 5. These responses highlight a problem for quality science education in primary schools. These findings are not surprising as they coincide with those of Ofsted and government reports (1995). Research by Watson, *et al.*, (1998) has shown that the range of investigations at Key Stage 2 and Key Stage 3 is very limited, most being of the "fair testing" type, while most scientists would not use a single scientific method. There is a danger of scientific investigations focusing on teaching procedures rather than developing children's thinking, enthusiasm and confidence.

However, the programme resulted in a remarkable improvement in teacher confidence with respect to investigative science. For the final data there were no responses for categories 1 and 2 and there was the lowest response for category 3 from all the summary data. 85% of the teachers felt confident (categories 4 and 5) at the end of the programme as opposed to 17% initially. This was the most significant improvement of any area and this out of any aspect of science study is the most likely to develop a constructivist approach with the teachers.

The initial data show there is a clear need for professional development of information and communications technology applications in science education. The response of 94% of teachers lacking confidence was the highest single response in all the items in the questionnaire. Many teachers did not feel computer literate in displaying and analysing results from investigative work and none of the teachers had experience of data logging which has recently become a matter of priority. Teachers have expressed an opinion that data logging is important because it appears on National Tests rather than for the scientific reasons of more effective ways of enhancing children's understanding. At the end of the programme none of the teachers felt they lacked confidence in using ICT. Even with recent developments in ICT, for example interactive whiteboards are installed in many primary classrooms, these are still being used as an extra resource for providing information, or assessing children's progress. There continues to be little evidence of teachers using ICT to develop children's understanding of scientific ideas. Working with the teachers in the classroom and showing how useful techniques such as data logging were in gathering evidence certainly had a pronounced effect on their confidence. They reported their confidence level between initial and final as increasing by 1.8 levels – the largest, single increase.

6.3.6 Problematic topics

In examining Tables 6.3 to 6.6 there are certain items where large numbers of teachers indicated a lack of confidence in teaching the topic or a lack of scientific knowledge about that topic. For example, the items selected which have a minimum of 55% of respondents selecting categories 1 or 2 for confidence include:

Table 6.7 Problematic topics

Item No	Item Description	Responses/%. I	Responses/% F
6	micro-organisms	55	0
11	particle model	64	20
12	separating mixtures	56	10
15	explaining electricity	61	10
16	gravity	59	10
18	balanced forces	58	10
29	density	63	20
31	information technologies	75	0

Teachers are often reluctant to teach these topics, many workers in the field of primary science research including Kruger and Summers (1988), Kruger *et al.* (1990) and Ginns and Watters (1995) would acknowledge that teachers feel the most insecure in these areas. They tend to feel more confident in biological topics and children's attainment overall has been shown to be limited by this (Osborne and Simon, 1996; Harlen and Holroyd, 1997). Historically there have been INSET courses specifically for these topics, but the demise of local authority INSET provision means that there is very little academic training for them. Teachers may be able to increase their 'contextual knowledge' that is 'the right answer' in those circumstances, but they will not develop their understanding. This has been illustrated in lessons and INSET sessions where if the teachers are presented with out of context situations, they cannot use their acquired knowledge to make correct deductions and so they predict intuitively and could easily make a wrong prediction.

The questionnaire data show improved levels of confidence mean 61% in levels 1 and 2 initially and 10% finally, also no teachers responded with category 1 at the end of the programme and the responses in category 2 were significantly reduced. The fact that the data do show some responses for level 2 illustrates further the need to consider teacher professional development as a long-term issue.

6.3.7 Changes in teacher confidence over time

The trend in teacher confidence is highlighted by Figure 6.15 which shows how teacher confidence increased with involvement in the project

The teachers' involvement was varied and ranged from teachers who were at the start of the project to those who had 2 years close involvement with the project. For the purposes of the graphs these were allocated codes.

code 0/0 start of project
code 1/0 school one year of project but not directly involved
code 1/1 school one year of project and teacher one year involvement in the project
code 2/0 school two years of project but not directly involved
code 2/1 school two years of project and teacher one year involvement in the project
code 2/2 school two years of project and teacher two years involvement in the project

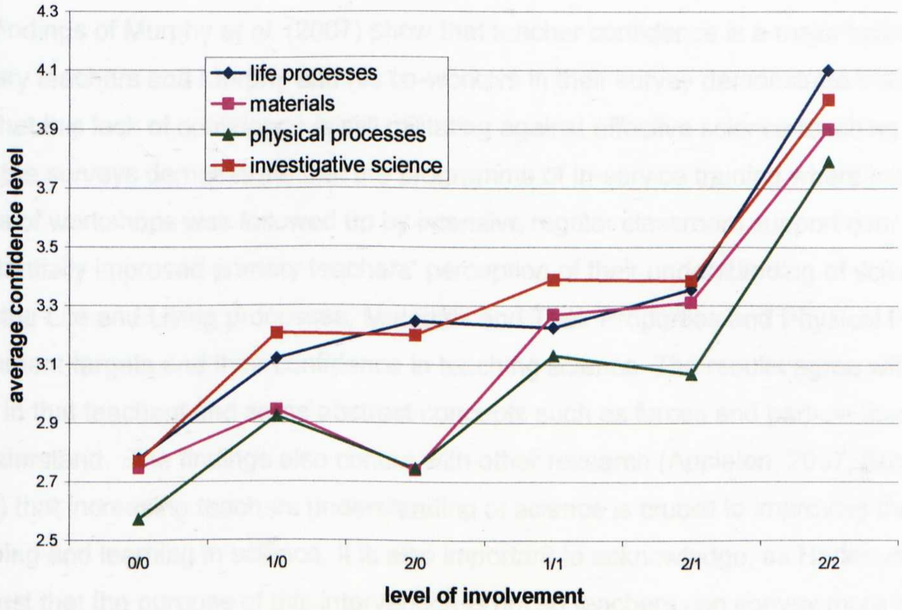

Figure 6.15 Changes in teacher confidence related to involvement

Figure 6.15 shows that confidence has increased considerably over time and they indicate particularly that there is a dramatic increase with the second year of involvement. Although this is obviously not conclusive it does correlate, for instance, with the views of Joyce and Showers (1995), that the continued professional development of teachers takes time. The whole of the research demonstrates that a considerable investment both of personnel and resources will produce a considerable effect. In the second year of involvement the teachers have increased their view of their own self-efficacy by almost 1 level, changing them from being teachers who are:

reasonably secure in the subject and can deal with simple children's questions and *prepared to look for ideas* to teachers who can now be *confident in the subject, can answer most children's questions and can think of curriculum ideas.*

A further interpretation these data might show a relatively low increase in confidence in the first year followed by a large increase in confidence, if the first year of involvement involves assimilating the issues and the second year involves implementing new practices and changing epistemology. The impact of developing confidence of teachers is also illustrated by a comment from an Ofsted inspector: *"They have a good grasp of scientific language to explain their work. In other work the children showed they could carry out investigations and effectively use information technology to create a range of graphs to record their findings".*

6.3.8 Conclusions

The findings of Murphy *et al.* (2007) show that teacher confidence is a major factor of concern to primary teachers and Murphy and his co-workers in their survey demonstrate that the teachers feel that this lack of confidence is still militating against effective science teaching. The results from the surveys demonstrate that the programme of in-service training where initial work at a series of workshops was followed up by intensive regular classroom support over a long period substantially improved primary teachers' perception of their understanding of science concepts from the Life and Living processes, Materials and Their Properties and Physical Processes attainment targets and their confidence in teaching science. The results agree with the previous work in that teachers find some abstract concepts such as forces and particle theory more difficult to understand. The findings also concur with other research (Appleton, 2007; Schwartz, *et al.*, 2000) that increasing teachers understanding of science is crucial to improving the standards of teaching and learning in science. It is also important to acknowledge, as Harlen and Jelly (1997), suggest that the purpose of this intervention is not so teachers can convey more facts to children, but they can become more confident in asking questions, in allowing children time to discuss and reflect on evidence generated from practical work and other sources and be able to move the children on to build the bigger ideas of science. The data from Figure 6.15 show that the length of time of the support was also crucial, which agrees with the findings of Corcoran (1995), Darling-Hammond (1995), Hargreaves and Fullan (1992), Little (1993), Stiles, *et al.* (1996). The data show initially that there is a minimum level of involvement, to produce a dramatic rise in confidence, but this is based on a very small sample and there may well be other factors such as teacher capability that are equally important.

The researcher had a clear vision of effective learning and teaching approach based on constructivism. The workshops were structured to challenge and question teachers' own initial conceptions and move their scientific thinking forward using the same constructivist approaches that were modelled and adopted in their own classrooms. Regular evaluations of the workshops were carried out and the discussions held regularly with teachers in school monitored their professional development in the classroom.

The support of the researcher in the classroom was a crucial element of the professional development programme: it relied on building trust and empathy between the researcher and the teacher so the teacher was able to admit their lack of understanding to a competent fellow professional, in a supportive and non-threatening environment. As a teacher explains:
"*I wasn't secure in my own understanding and having someone there ....initially, I would say to the children I'm not sure about that .... Now Mr. X, what happens at that stage? ...can you explain that because I am not sure ... but I became much more secure in my knowledge and understanding of the science curriculum. I was able to allow the children to explore ideas with me*

because I was exploring it too ... I had the security of knowing I had someone there who could explain to me how things worked."

An important issue then is how teachers can be offered this type of support, when there is now little local authority INSET in primary science. Surely, it places demands on the key role of the science co-ordinator, assuming their science background is strong, in having time to monitor and develop the subject and conceptual knowledge of colleagues. In these schools, time was made available so many of the teachers originally involved worked with other teachers and extended the approaches throughout their school, so they are developing a life long learning culture within their schools. The objective of the professional development of teachers was ultimately to improve the attainment and attitude of the children in their schools: in many of the schools involved, there was a significant increase in the Key Stage 2 SATs results in science. Analysis of the children's performance in the tests against national averages indicated that the improvement in answering questions, which demanded greater application of knowledge, was higher than that in questions demanding simple factual explanations.

6.4 Developing the theory into practice (a case study)

6.4.1 Introduction

This case study illustrates a constructivist approach to children and teachers in a problematic area within the science programme of study, namely the teaching and understanding of forces. This was following observations and discussions with teachers and their difficulty of teaching forces, observation of children using the elicitation exercises and considering the implications from a range of sources including Driver (1985), Miller *et al.* (2000), Shayer and Adey (1981) and the SPACE project (Russell *et al.*, 1998) also on trying the elicitation activities with children and then revising these activities, I thought this was a justifiable topic for both research on teacher confidence and children's understanding about forces. The researcher and the teachers involved held as *a priori* not telling the children that what they are saying is wrong, because what they say is based on their personal experiences, but also not what the right answers are. The ideas they have will be as a consequence of the evidence obtained.

There were two questions that needed addressing:

- What are some of the underlying difficulties that children have in learning forces?
- What aspects of learning pertain to this study?

A lot of the difficulties that many children in a wide range of ages and indeed many adults experience, is that when they attempt an explanation of a particular phenomenon related to forces, they tend to give a context specific explanation. This leads to several inter-related needs associated with this topic and discussions with teachers and observations of classroom activities. A list of essential attributes for effective teaching and learning was devised.
These typify considerations in other curriculum areas and they are the:

- need to develop a coherent theory;
- need to take account of what children say;
- need to change teachers' knowledge and attitudes and strategies;
- need to set the right environment, and
- need to develop the language/vocabulary.

The topic of forces has received interest from a wide range of researchers over many years (Stead and Osborne, 1981; Watts, 1983; Brown, 1989) and continues to be a topic of debate (Singh and Rosengrant, 2003; Schofield, 2008; Bug, 2008). There are numerous publications dealing with children's ideas in science and invariably these contain a section on forces and motion and the difficulties that children have in understanding this topic. The purpose of this section is to attempt to demonstrate that the problems children encounter when learning about forces are not insurmountable, provided that the teacher takes into account how children learn science and provides learning activities which challenge or confirm children's intuitive ideas and promote the development of new or more complete ideas.

Following a survey of these primary teachers' opinions of their confidence in teaching science, forces was mentioned most frequently as being problematic. In order to address the perceived lack of understanding from both children and teachers, the researcher adopted a constructivist approach, believing that if the epistemology of constructivism is valid, it should be possible to explore the traditionally difficult topic of forces in a way that the children and teachers can understand.

6.4.2 Building learning

There are underlying issues with respect to how children learn which will apply to a variety of science topics and these are much more likely to manifest themselves when the children have to apply reasoning and use concepts, rather than simply recall factual information. Informal discussions with children, supported the work by Kuiper (1994) that the views held by children are often context-specific and this idea has been well documented by others (Donaldson, 1978; Hennessy, 1993; Lave and Wenger, 1991). It is not surprising that children find more difficulty in dealing with forces in different contexts if they cannot see any commonality in the underlying principles for each situation where forces operate. Reif (1987) has suggested that children tend to invoke 'knowledge fragments' to explain natural phenomena rather than to use a generalised understanding. The different contexts for forces will lead children to use different 'knowledge fragments' to explain them, even if two explanations appear contradictory. Some of the discussion of the nature of children's thinking revolves around the terminology used by researchers. The ideas expressed by children which do not conform precisely to the accepted scientific views have been referred to as *'misconceptions'*, for example by Johnstone *et al.* (1977). Driver (1985) has referred to the idea of *'schemes'*, a collection of elements of knowledge, supporting Reif's notion of knowledge fragments. Osborne and Freyberg (1985) refer to *'children's ideas'* to describe the intuitive ideas that children have to explain their observations. Other authors have referred to *'alternative frameworks'* held by children. Kuiper (1994) challenged this implying that his understanding of an *'alternative framework'* is a coherent but different theory to the accepted scientific explanation; he supports the notion that children's ideas are a loose set of incoherent ideas. diSessa (1983) uses the term 'phenomenological primitives' to describe children's developing ideas. This latter term is more consistent with what will be referred to as, *'limited frameworks'* in this study, in that some evidence is available to children, but this is less than that which is available, or has been considered, by the experienced scientist. This lack of available evidence will influence the way that children make sense of what they see, the children are unable to develop a complete, coherent and rational explanation for the phenomena they observe, becoming inclined to use different sets of ideas that they have within their learning framework, to explain different natural phenomena, thus presenting arguments which are context-specific.

Whilst not contradicting the published terminology, the researcher thinks it is more enlightening to use the term *'limited frameworks'*, to categorise children's ideas. This is because this allows for explanations which are based on children's observations and experiences, where they give a reasoned, scientific view, yet by the very nature of the children's limited experience and knowledge, they have limited evidence on which to build their reasoning. These frameworks explain their own observations so far, but may not explain new situations, or those which they have not yet considered. *'Limited frameworks'* is proposed in preference to *'alternative frameworks'* and not *'misconceptions'*, because the ideas that children have, on discussion, are reasonable, based on what they have observed, but these by their very nature will be based on limited experience and knowledge of natural phenomena. This is an important change of emphasis for teachers thinking about children's responses, because by doing this they are not considering the children's answers as wrong – but limited. Also they will have insufficiently developed powers of deduction and modelling to produce a complete scientific explanation of some phenomena.

'Limited frameworks' are not restricted to children's ideas. Throughout scientific study and thought there have been many such examples of *'limited frameworks'* dating back to the Aristotelian idea that force is maintained if an object is moving and the Buridan notion that when a ball is thrown upwards it is given an 'impetus' the 'impetus' is gradually used up as the ball moved upwards and the impetus decreases to zero. There is an instant at the top of the flight when no force is acting and then the *natural* downward forces take over and the ball falls. Watts and Zylbersztajn (1981) in their survey of 13 year olds in a London school found this to be typical of children's ideas. The Aristotelian idea of no movement means no force has been found to be a commonly held view. Some children do not think this requires an explanation: "It's like that because it is". When asked, "is gravity still acting on the brick?", at least 75% of these 10-11 year olds answered "No." These ideas and ways of reasoning were also found by Driver (1983). Ideas about forces have developed throughout the history of science and are still developing, even Newtonian mechanics, which is used in schools as the theory which explains how forces operate and was the underpinning science for these strategies, is used to launch objects into space, yet cannot explain some parts of Relativity Theory or Quantum Theory, or does not take into account what holds the Sun in place. The notion that scientific ideas develop over time in the light of new evidence is only now beginning to be emphasised in school science education.

6.4.3 Classroom implications

6.4.3.1 Constructivism

It is a basic tenet of constructivist theory, that children carry with them experiences from everyday life and that they will make reasoned conclusions based on these. Therefore it is necessary to find out the ideas that the children have so that they can be addressed. This is the elicitation phase and this was achieved by using the bowling ball paper activity (appendix10.4). The issue of conflict, to challenge the pupil ideas was a feature of the classroom work undertaken in this study, an example was to drop two balls of the same size but differing masses, asking the children which they thought would land first – if any. Clement (1982), Osborne and Bell (1983) and Posner, *et al.* (1982) have all advocated providing experiences which are aimed at challenging children's views. In addition, with primary children, they must be given evidence and experiences that clearly demonstrate and confirm their opinions and the accepted scientific view, a simple discussion and exposition of new ideas (to the children) will be inadequate, so simply telling the children that both masses land at the same time would not be sufficient, the children need to have the evidence. Children can be very reluctant to let go of some of their opinions on scientific phenomena and Hewson (1981) and Posner *et al.* (1982) have further argued that in addition to the need for conflict, any new ideas put forward need to *intelligible, plausible and fruitful.* He maintains the new arguments must be *intelligible* to the recipient; that is the primary children must understand what is being covered and the examples must be within the realms of their experiences. The arguments put forward must be *plausible;* there has to be a matching between the new ideas being put forward and their previous experiences. There must be a rationalising of the ideas, the new concept, which explains both the old and the new with one coherent theory. This is what Hewson (1981) and Posner *et al.* (1982) refer to as being *fruitful.* The child is now better equipped to explain new phenomena, so is more likely to find them acceptable. This discussion with the children to explore various ideas they proposed, would take place after the provision of the evidence.

6.4.3.2 Learning environment

A classroom atmosphere was needed whereby all the children's ideas were valued and contributed to the debate. The importance of classroom atmosphere has been highlighted by Minstrell (1982). As part of the classroom discussion firstly observation was used so that all the children could be involved. Then the debating format was used so that different ideas formulated by different children can be justified and sided with by their classmates. This is the dialogic process recommended by Mortimer and Scott (2003) and the children should be encouraged to reflect on ideas put forward and use them if they made more sense than their own ideas.

It takes time to change the children's previously very strongly held views and the teacher needs to be patient and nurture the class with the new ideas. Repetition and confirmation of understanding the ideas developed was essential before a new idea could be broached and old ideas challenged. This is an important feature of the studies carried out by Viennot (1979) and Gunstone, *et al.* (1981). These ideas are encompassed by the term 'non-threatening learning environment' (now the term positive learning environment is often used) and this was an important feature of this study.

6.4.3.3 Language

The issue of language was important and complex. Children have an idiosyncratic way of describing events which is dependent on their age and conceptual development, as well as the environment in which they live. The teacher needs to have empathy with this so that the method of describing events can conform to the way that scientists have developed. The researcher and the teacher were developing in the children the Cognitive Academic Language Proficiency as advocated by Cummins (1979). It was important that the children developed their language to describe events as well as using the correct vocabulary.

This is another long-term issue and should be tackled at early years translating a child's language to the accepted scientific format. Barnes (1976) said 'that the more a learner controls his own language strategies, the more he is enabled to think aloud, the more he can take responsibility for formulating explanatory hypotheses and evaluating them'. The extent to which children can explain their hypotheses is limited, but the issue of ownership of the language is a valid one. He maintains that this is more likely to happen when the teacher is not part of the discussion, however the researcher would maintain that the children need guidance and support in the debating process and although children-children interaction was encouraged whenever possible, active intervention by the teachers and the researcher was used to both challenge and summarise the children's ideas. However, empathy with the children, their ideas and the way they express them was important if success was to be achieved within the debating format. Also a comment by Prestt (1980) was relevant to this work where she compares some language to wrapping paper. The study has found that a significant number of children could use the technical vocabulary but had minimal understanding of the processes operating. The researcher would concur wholeheartedly with her opinions and it applies no more so than in the teaching of forces. An example would be the use of the word "power" which the children often equated to strength or size of force, as opposed to the scientific definition of "power".

6.4.3.4 Developing the Knowledge Framework

The children have a lack of evidence, which means they are unable to develop a complete, coherent and rational explanation for the phenomena they observe, so they have to use different sets of ideas to explain what they see, thus presenting arguments which are context-specific. An example from the study which illustrates contextual learning is a bouncing ball, which eventually stops bouncing and comes to rest on the floor. The children's explanations for why the ball bounced back up after hitting the floor were of the type *"it is bouncy", "the floor is hard", "the ball is squashy", "it can't go through the floor"* etc. The children have no empirical evidence that there is a reaction force from the floor to the ball so the Newtonian explanation is not available to them. Also in the discussion they were asked why does the ball bounce lower and lower each time and eventually stop? One child's response was *"because the air runs out"*. On further questioning she was referring to the air that she said was inside the ball and some of this "runs out" each time it bounces and when all the air has run out it stops bouncing. The illogicality of this argument is not uncommon in children's responses and was similar to the contextualisation and use of *knowledge fragments* as found by Reif (1987). Since the focus of the study was to develop children's own ideas, this response was used actively at a later stage, whereas a typical comment from a teacher: *"Before I would not have done that, I would have counted that as a 'wrong answer' and just told them the correct one"* (if they had known it!) but this would probably not have changed the child's strongly held ideas. This child's explanation is strongly context-specific (in addition to other inadequacies) since it could only be applied to hollow bouncing balls. Other natural phenomena will need alternative explanations not involving air. However, why should a child of 10 –11 years old be expected to know that there are three unifying laws of motion and why can she not have different explanations for each phenomenon she observes. When the idea has been put forward (from an idea developed about the direction of movement) for the bouncing, by at least one of the children then the idea can be investigated. This example illustrates an important change in emphasis on the teaching skills required for the children learning science. Many of the teachers in the initial phases of the study saw their prime purpose as being the provider of knowledge and many instances and much research has shown that the teacher knowledge is incorrect, or inadequate. The prime skill of the teacher now becomes one of devising activities that will challenge or confirm the ideas put forward, so in this example the teacher would challenge 'the air runs out' by then testing a solid ball, with no air in.

A constructivist approach will require evidence so this is developed and confirmed by bouncing the ball on a surface that will vibrate obviously, for example a bowling ball on a floor, or a hockey ball on a table, so they can agree that a vibration is a movement of the surface and that this movement can exert a force on the ball thus moving it back in the opposite direction. The action of a trampoline was often mentioned by the children at this point. This example can then be used to further develop the idea of transfer of momentum between the ball and the floor first mentioned with the ball and the skittles for introduction of 'momentum' (see appendix 5 Forces Strategies). Why does the ball bounce? How is momentum being transferred between the ball and the floor and back to the ball again? And why does the ball eventually stop? The concept of a transfer of part of the momentum to the floor at each bounce and therefore a gradual decease in momentum of the ball was readily accepted by the teachers and children.

The ideas were applied to all abilities. Most of the lower ability children could make complete observations and demonstrate coherent understanding within limited sentences that were built up by the teacher's questioning. The teacher knew the correct logical sequence for an explanation, so elicited the knowledge by a series of graded questions. The brighter child could independently construct an holistic explanation using the correct scientific terminology. Really, the children were hypothesising, not explaining, since the latter demands some degree of certainty which was probably not justified. These children had the conceptual development to be able to assimilate a new model and rationally use it to explain a new experience. This has important implications for teachers because it has been shown that Year 4 children can observe and will accept new terminology and develop their scientific vocabulary but most of them are not at the stage where they can rationalise and apply the complex conceptual ideas. For these reasons, the initial development of the ideas took place with Year 5/Year 6 children, but research has been carried out with all year groups to determine what skills and knowledge can be assimilated at each stage to prepare for a fuller understanding in later years.
Thus the development of children's ideas demands two allied features:

- the examples that are used must be those to which the children can relate and must confirm some of the existing ideas that they have before they can be introduced to new ones, and
- the level of conceptual thinking must start with their own level of reasoning and using it to explain their own ideas before any development of this to a higher level.

6.4.3.5 Effect on Teachers

Palmer (1997) studied context related understanding of 15-16 year olds and none of the teachers in this study had followed a physics based course beyond the age of 16 and some had not followed a physics based course at all. It was probable therefore, that they had not developed their ideas since that time and indeed discussions with these teachers confirmed this. The consequence of this situation is that they are less likely to attempt, or be able to modify, the context based ideas of the children and this was noticed with these primary teachers as most failed to perceive commonalities, or coherence in some differing contexts. These teachers had experienced difficulty in understanding forces but could not necessarily explain why they found it so, hence they felt uneasy in their teaching of forces. Although the idea was to find a way of making the concepts of forces acting more accessible to children, it also had the far more significant effect of making the ideas more accessible and understandable to teachers. They had the added advantage of maturity and above average cognitive abilities so they could appreciate the strength of the scientific arguments because they knew they had not previously understood forces, or found it a difficult topic. One of the contributory factors is that there does not appear to be this unifying idea which explains all the different circumstances where forces operate. Hence the teachers think that many examples of forces operating as mentioned in National Curriculum Science are in effect unrelated and compartmentalised – in effect context-specific. If the vast majority of a typical adult population hold Buridan's views, then how will primary teachers with no scientific training demonstrate otherwise?

The new format of addressing and developing understanding using the revised ideas was seen as being particularly *fruitful* because they could understand forces for the first time (in most cases). There is also evidence on the effect on teachers involved with this approach in that they have maintained the use of this approach and have stated "*it's the only way to do it, it makes so much sense"!* Or a quote from a different teacher, *"I thought it would be really hard (because I am not a scientist) and boring, but it's not, it's really easy and there's lots* (activities and explanations) *you can do".* Also the teacher's role is changing from that of a provider of information to one who devises activities and resources to address understanding.

6.4.4 Children's Performance in Strategies

6.4.4.1 Elicitation activities

The elicitation at the start of the sessions was normally by an ad hoc discussion with each class group to reflect on how they expressed their ideas and simply confirm that the ideas they held were typical. They were sometimes given a picture of a girl bowling (appendix 10.4) with the bowling ball half way down the lane and they could label the diagram and/or write in a box what forces they considered to be acting – the same activity as used in the teachers' INSET. Their responses were used mainly for elicitation and there was no formal attempt to decide the extent to which commonly held views were held, it was assumed that they would be there. In addition the exercise gave some background about terminology and scientific knowledge. This was the constructivist starting point for the development of their ideas. The responses to the elicitation exercise are given in Figure 6.16 which show the responses from children at four different schools. These data show a vast difference in the initial knowledge about forces; note that for school 3 only 13% of the children identified that gravity was acting on the ball could correctly label this. This school also had the most children incorrectly labelling friction and that the ball had a push acting on it. Figure 6.17, shows the same responses combined. The total number of children was 164. (They referred to the reaction from the floor as upthrust).

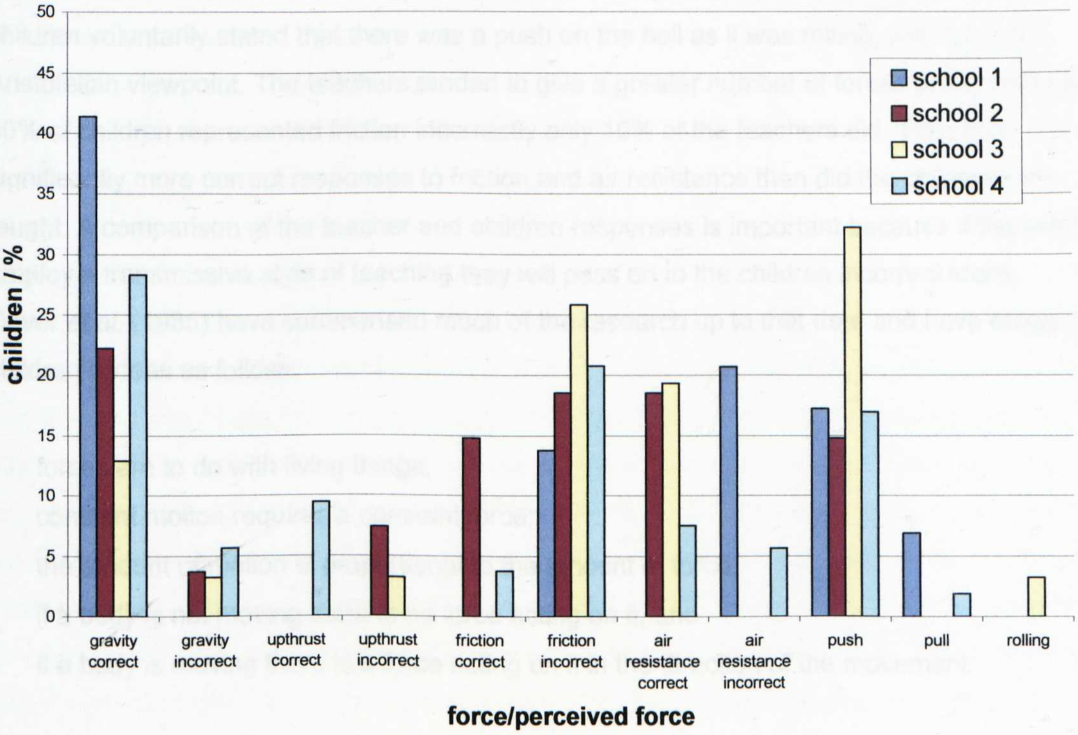

Figure 6.16 Children's perceptions of the forces acting on a rolling ball (by school).

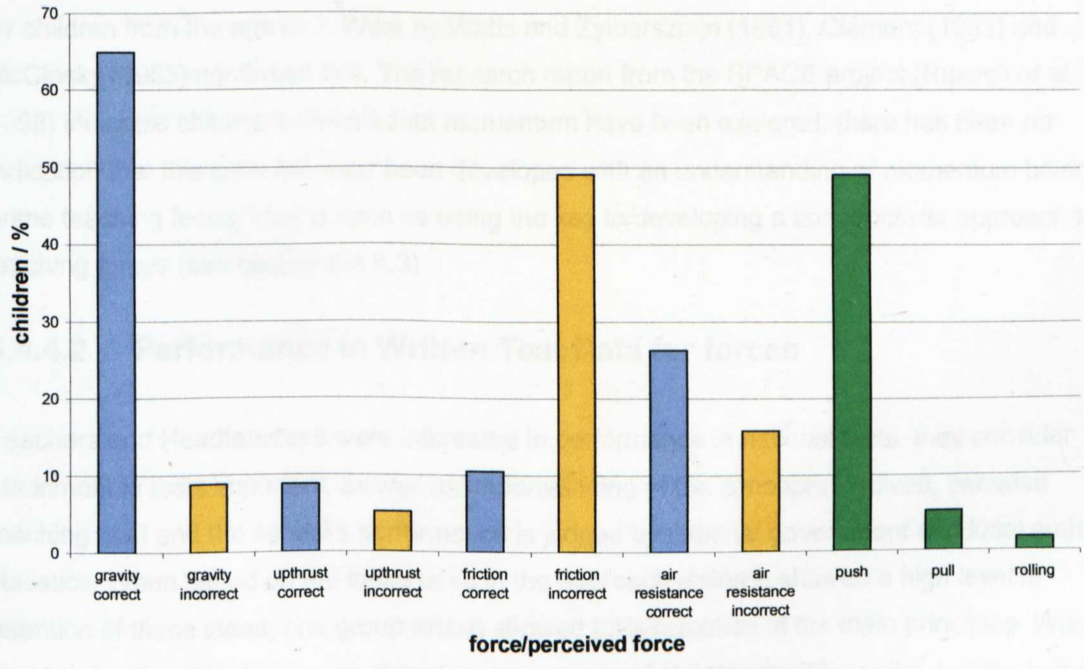

Figure 6.17 Children's perceptions of the forces acting on a rolling ball.

During the initial elicitation, discussion stage, virtually all the children held the Aristotelian (that a force is needed to maintain movement) views of forces, even if they did not put it on their diagram. These views were considered because they contrast directly with the ideas formulated

in Newtonian mechanics. As a comparison approximately 50% of teachers and 50% of the children voluntarily stated that there was a push on the ball as it was rolling, endorsing the Aristotelian viewpoint. The teachers tended to give a greater number of forces present and while 50% of children represented friction incorrectly only 10% of the teachers did. They had significantly more correct responses to friction and air resistance than did the children they taught. A comparison of the teacher and children responses is important because if the teachers employ a transmissive style of teaching they will pass on to the children incorrect ideas.
Driver *et al.* (1985) have summarised much of the research up to that date and have categorised children's ideas as follows:

- forces are to do with living things;
- constant motion requires a constant force;
- the amount of motion is proportional to the amount of force;
- if a body is not moving there is no force acting on it, and
- if a body is moving there is a force acting on it in the direction of the movement.

These ideas are well documented and the main purpose of this research was to adopt a constructivist approach to deal with these ideas and transform them into the more accepted scientific view as described in Newtonian mechanics. Osborne (1980) has proposed that the children are confusing the idea of force with the concept of momentum and these ideas are held by children from the age of 7. Work by Watts and Zylbersztajn (1981), Clement (1982) and McClosky (1983) confirmed this. The research report from the SPACE project (Russell *et al.*, 1998) indicates children's ideas about momentum have been explored, there has been no indication that this work has ever been developed with an understanding of momentum being the prime teaching focus. This is seen as being the key to developing a constructivist approach to teaching forces (see section 6.4.4.3).

6.4.4.2 Performance in Written Test Data for forces

Teachers and Headteachers were interested in performance in national tests, they consider attainment in tests important, as well as understanding of the concepts involved, because teaching staff and the school's performance is judged by national government and local authority statistics. When tested on the ideas used in the approach children showed a high level of retention of these ideas, one group tested showed 93% retention of the main principles. When the results of national tests were analysed for two groups of children (n=72) twelve months before and after using this approach, they scored as below (Table 6.8) compared to national data facility values for test items.

Table 6.8 Differences in attainment for different types of questions

% Difference between facility value score and group score

	Without intervention				With intervention			
Question type	Recall	graphs	application	patterns	recall	graphs	application	patterns
% difference	-3	-7	-20	+5	+15	+7	+15	+25

These figures show that these children generally scored better than the national average on forces topics after the intervention. The significance is hidden slightly for these children had an average CAT score of 88 compared to the national average, so should have scored significantly below the national data throughout, as they did before the intervention. The data show not only a highly significant change in the overall scores, they also show on closer examination of the question types, that they performed particularly well on questions which required them to apply their knowledge in new situations and to seek out patterns. These demonstrate that children who have undergone this type of approach are more secure in their understanding of forces, have more coherent ideas which are based on general principles. If the children do not understand Newtonian mechanics it is reasonable to assume that children will find questions on forces difficult – all the scientific information is not available to them and they have a '*limited framework*'. In many cases children are not comfortable with the ideas and in most cases have learned the answers by rote, which has a dual disadvantage, the children are more prone to errors and they will find it difficult to apply their learning to new contexts. The more able children can cope with this method of learning, but children who are less so are less capable of remembering exactly <u>when</u> to apply the learnt responses and are more prone to random errors. Many of the written test questions available at Key Stage 2 test recall and don't understand ideas thus allowing the '*limited frameworks*' to persist into Key Stage 3 and beyond.

6.4.4.3 Constructivist considerations when teaching forces

The problem was to teach primary school children the concept of momentum – interestingly this is a topic not dealt with until Key Stage 4 in higher level GCSE papers, however it is not tested from a conceptual point of view, but in a mathematical format, namely momentum = mv. This could lead to rote learning and use of the formula since the number of Key Stage 4 children who can translate a mathematical formula into a physical model of an event must be very limited. Clearly also, if children's ideas at primary school are to be developed, then a mathematical treatment is inappropriate (because the majority of key stage 4 children find this difficult) and the examples have to be ones that are within their everyday experiences and indeed *intelligible, plausible and fruitful* offering a more powerful and coherent explanation to the children than their own previously held views.

Although Constructivism promotes the philosophy of building on the children's own experiences, they have to be taught that and they have to accept that a moving ball has momentum as opposed to a force and to distinguish between and yet relate, the two concepts. We are telling them that a moving ball does not have a forward force acting on it, (and calling this a misconception), but we are not giving them the correct terminology to describe the ball! This distinguishing of the two needed to be done carefully and the ideas built up logically and their existing ideas and experiences had to be the foundation of all that followed. There was a considerable amount of reinforcement, they were being told something new and the topic dealt with things that were new to them; but in accepting new ideas more phenomena can be understood and explained.

The children were being asked to use science to describe the events that took place and would demonstrate quite clearly that they knew of many examples of where forces were operating, as well as the effect of those forces in terms of:

- the amount of motion being proportional to the amount of force;
- a body moves in the direction force acting on it, and
- That often two forces are operating for example action/reaction (though you might not be able to see one.

When the children were comfortable with the concept of transfer of momentum, these ideas were particularly rich when explaining new phenomena where pairs of forces were operating such as friction and air resistance. Friction and air resistance and drag could be explained equally in terms of transfer of momentum from the object to its surroundings and by this stage the more able children could do this without any prompting. Most of the children were using Newton's three laws of motion to explain a wide range of phenomena. One boy explained the complete flight of a paper aeroplane as one coherent passage, "the plane moves forward because there is a push from your hand, this gives the plane some momentum. Then the plane has air resistance acting against the plane so the plane slows down and some momentum is transferred to the air particles in moving them out of the way. The air particles push against the flaps on the plane, this gives an up force and this makes the plane go up until it stops. Then the plane is pulled down by gravity and when it lands on the carpet the forces are balanced". A similar example to this level of detail has been given as exemplar material for level 7 (Dcsf, 2009). This was not typical of the vast majority of children, but does show the capabilities of the teaching strategies.

The teaching strategies had to be such so as to engage the children; since by its very nature this was a class group experience and there was a need to ensure that all the children were actively engaged in the discussion according to their level of conceptual development. There was an important feature of trust here towards the research and a need to work with the teacher due to the researcher's lack of knowledge of individual children. This is a shared learning experience in which the opinions of all children are valid and valued. The children were encouraged to express their ideas so that limited frameworks could be noted and dealt with at the appropriate stage in the sequence of teaching sessions. There is a need to put in various practical activities with associated individual work to confirm an individual level of understanding and the level of sophistication in their ability to express their ideas scientifically. Their existing ideas which are correctly held would form the basis and means of predicting new situations. Any new idea was only developed using their own firmly held views of forces and the nature of movement. Thus new ideas were not contradicting their own ideas, but were situations they had not previously thought of in as much depth.

A summary of the strategies used is given in appendix 5.

6.5 Promoting constructivist approaches in primary science: impact on teacher effectiveness

While the use of forces as a topic attempted to demonstrate the effectiveness of constructivism as an epistemology, this was used on a wide range of topics, especially in the physical sciences, to demonstrate a wide range of applications as this comment from an Ofsted inspection at one school shows *"As a result of this intervention the school has been able to provide effective opportunities for children to be involved in activities that develop the investigative skills of making evaluations and conclusions based on prior scientific knowledge". The school is keen to further develop these skills to further raise standards"*. With constructivism as with other epistemologies, there are some basic principles. The development of a constructivist school environment does not depend solely on the teacher understanding the nature of science and nature of constructivism. There are other social conditions, which must be satisfied and these must be developed to produce the 'constructivist classroom'. In order to achieve a constructivist approach, there must be a supportive environment where an individual's comments are valued (Claxton, 1984). Lorsbach and Tobin(1992) and Pereira (1996) have both emphasised the social environment and this is supported by Watts and Bentley (1987) who use the term Non-Threatening Learning Environment. They highlighted the enthusiasm of the teacher as being a key factor whereas Driver *et al.* (1994) seem to address effectiveness in terms of well thought out strategies. Watts and Bentley (1987) state that youngsters seem to be asking for enthusiasm on the part of the teacher and above all teachers who make their lessons fun by being enthusiastic, moreover these teachers show humility when things go wrong. They argue that the learning environment is dependent on what the teacher says as well as the important aspect of how the teacher behaves - the hidden messages that the teacher gives out, for instance is the teacher trustworthy, engaging the children, friendly and most of all developing an environment where it is permissible to speculate?

If a constructivist approach is to be adopted and conceptual change is going to take place there will inevitably be challenge to children's existing ideas and this could be very intimidating and may be counter productive. Minstrell (1982) suggests that for conceptual development to take place there needs to be an engaging, free thinking, free speaking, social context; again emphasising the social nature of conceptual development. Gurney (1989) holds similar views where "a safe environment in which children are free to ask questions... to wonder out loud...voice agreements or disagreements....with the expectation that justification will be given". This is true at the primary level where it is important to build the children's confidence, by letting them wonder about what the evidence they are presented with, means. The Science Processes and Concepts Exploration (SPACE) project allowed this to happen across a range of topics. The emphasis was not on whether the child was right or wrong but enabling the children to test their own ideas against the evidence presented which was in agreement with what Harlen (1992) stated. To develop this ethos within the classroom, the researcher phrased these values as "tell me what you think and if it is what you think, you have got to be doing the right thing – so you can never be wrong! This served two purposes, it generated the relaxed, secure environment that was wanted and it elicited what the children were actually thinking. Both of these are essential for a constructivist learning environment. Driver (Driver *et al.*, 1994) sees the teacher as pivotal in these debates as "intervention and negotiation with an authority figure, usually the teacher, is essential," whereas Lorsbach (1992) seems to recognise peer discussion much more as a means of formulating new constructs. Both these viewpoints were used in the setting of a supportive environment.

There is another aspect, the need for the knowledge to be contextual and within their realm of experience. The examples that were used were from their own everyday experiences for example water, ice pops, toast, shiny (drawn) cats. The children did not see these examples as posing further challenges thus eliminating the argument *"I do not understand the science because I do not understand what you were on about"*.

6.5.1 Changing Teachers' practice

Before the project, many of the teachers operated a transmission style of teaching, as this quote demonstrates:

"As a year 6 teacher, my primary concern when teaching science was to ensure that the children had enough information, across a range of topics, to be able to tackle a variety of Key Stage 2 SATs questions. This was achieved simply by "chalk and talk teaching", where I gave the children the information they required and they learnt it in rote fashion."

The teacher would ask one or two of the children to put forward their ideas, but generally closed questions were used, which were expected to generate the correct factual response. Teachers admitted that they used this approach because they lacked confidence in their own scientific knowledge and were afraid of opening up class discussions, which might reveal their shortcomings.

"We were reminded that children need time to consider and discus". I felt pressurised in terms of content and delivery....I wanted to get to the outcome. You are sometimes narrowed by your own objectives".

During and after the intervention, teachers demonstrated that they had changed the climate in their classrooms: they thought they had an open classroom, but there was always the spectre of 'the right answer'.

"For example, so although I do think I always employed an element of open questioning ... that was exploded in my classroom in terms of really opening up lessons ... not feeling that I had to have everything written down and recorded ... that I could give the children real time to think about things ... to share their own concepts, their own understanding so the children always had the opportunity to say what do we now ... what do we think will happen ... to comment on things that we learnt... to observe things, then bring things together in a conclusion".

After the intervention the teachers encouraged all children to make predictions and join in discussions. This extract shows how the teachers developed their lessons from a transmissive type to a dialogic type.

A year 6 teacher describes how she created such an atmosphere in her classroom:

"We established a climate where all were expected to contribute, it wasn't OK to sit back and we employed strategies the children enjoyed. All contributions were welcomed.... all contributions.... and that was understood, it took time but that's the way of working, the ethos of the classroom anyway.... And the questions I used, whilst being open, were also differentiated in terms of where people were. Ideas were never dismissed. In the beginning, when we looked at something new, we would write down every single idea that people had on the white board, so everything was valued. To examine their ideas later, when we had looked at the evidence, we used pictures of light bulbs, if they agreed with the idea – they held the light bulb up — and if they did not agree, they did not hold it up"

6.5.2 Creating a positive classroom climate

The teacher was planning to hold a discussion about where the water has gone from each group's beaker, culminating in the evaporation process and the conditions which favour this. So the teacher had a clear idea of what science would be the outcome, but no idea what the children would say. This is summarised by *'they drive, you steer'*, which means that the children will come up with the ideas, so will have ownership of the lesson, and the teacher will steer towards the scientific outcome related to a learning objective. In the activity the children had filtered off sand from a salt/sand mixture and had then left the salt solutions in various points of the room for several days.

Teacher: I want you to tell me what you think has happened to the beakers with the salt dissolved in water which we left round the room. Kayley, what would you expect to happen, (then, to the class) this is what you think there are no rights or wrongs, it's what you think would happen
Kayley: It would have evaporated

Teacher: What's it, the salt

Kayley: Miss, the water

Teacher: Who agrees with Kayley, that that's what will happen (show of hands). Are you not sure, Sarah?

Sarah: I think it will evaporate, Miss

Many teachers would halt the discussion at this point as some children have used the correct terminology. However, other children in the class have not contributed to the discussion and this may hide a lack of understanding on another part. Other researchers have found similar instances where the child says the water has evaporated, but not necessarily understood what is happening during the process for example, from the SPACE project,

*I think the water gets dried up with the sun and the water dries into the sun (*SPACE,1990*).*

Or the child may give a long explanation which contains a combination of scientifically correct and incorrect ideas, with a high degree of complexity. They are trying to sort out their ideas as well as communicating them.

I think that the water has gone into the air because when the sun shines on it, it disappears because the heat of the sun dries it up, but it doesn't go away, it stays in the sun and the sun goes in so the water has gone from here but this when the sun comes out is a different place. The water has gone because when the sun goes behind a cloud I think the water stays in the cloud and that is what is makes the rain.(SPACE,1990).

Over a period of time, the teacher has established a non-threatening learning environment in the classroom, an essential feature of the constructivist approach if children are going to reveal their own ideas in front of the teacher and their peers (Watts and Bentley, 1987). As Fisher (1990) explains, "The creative climate is maintained by communication, and communication is rarely neutral – either it helps to create an atmosphere where it is safe to share thinking and speculation or it damages that climate". She has provided an atmosphere of warmth and trust, which has removed the necessity for children to give "the right answer" and created a climate conducive to making hypotheses, to testing hypotheses against the available evidence, to supporting scientific discussion and aiding conceptual development. Previously the teacher would have considered science as a subject where there are right and wrong answers, not allowing the children to explore their own ideas and ways of thinking. Kayley says "it" and the teacher immediately picked up on this and guided the child towards a more unambiguous expression of her ideas. Through open discussion the teacher goes from child to child to probe their scientific ideas and to move the conversation forward. This is illustrated by the next extract, which is part of the same discussion.

Teacher: Where has the water gone?

Tony: It's gone into the other beaker (points to another groups' beaker)

Teacher: So where has the water out of the other beaker gone, have you lost some, lads?

Teacher checks with the other group's results: You've lost 20mls so where's their water gone Tony (Tony shakes his head)

Teacher: OK, that's fine, Tony

In this supportive atmosphere, even the weaker children such as Tony feel able to express their ideas.

"all contributions were welcomed ... all contributions ... and that was understood and took time but that's in the ethos of the classroom anyway ...".

Tony has revealed, surprisingly, that he thinks the water has moved from his beaker into another group's beaker. His alternative idea demonstrates the difficulty children have in understanding the process of evaporation: previous research has shown that children have even suggested holes or cracks in beakers/trough to explain where the water has gone (Russell and Watt, 1989) and a common response is that there is less water because it has been spilled. The teacher tries to help Tony consider the evidence, if his group's water has gone into the other beaker, why has the level of water in the other beaker also gone down? Before involvement in the project, the teacher would have considered this idea as simply wrong, or even bizarre, but she makes no judgemental comments and accepts what Tony has said. However she has stored Tony's idea, so it could be dealt with at a later point in the discussion.

Asking about what would happen to the salt children hypothesise:

Jenny: it would still be in that the beaker because it is a solid.

Teacher: So we all agree that water would evaporate. If Jenny is saying that salt can't evaporate because it is a solid, can we say why the water does evaporate?

Kyle: Turns into water vapour

Teacher: So we think the salt will be left in the beaker as a solid who agrees? (many hands) *We think we know what happens to the water we think the water will evaporate, but we need to see it.*

Child: (unsolicited) *if you put the beaker near the radiator it will evaporate*

*Teacher: who had the beaker by the heater? Right (*to Terry) *how much water have you got left*

Terry: 24 mls

Teacher: and you started with 100 mls

If we take this as an example what difference would it make, Dale, if Kerry and Daniel put their beaker away from the radiator

Dale: it would still evaporate
Teacher: what would change
Dale: the level of the water
Teacher: why would have that changed, the level of the water
Dale: because it's being heated and that would make the water evaporate.

The teacher praised the child for mentioning the heater, but is not entirely happy with the statement, she has spotted an opportunity to develop the discussion further. There is more that can be done to link hypothesis to di da di di dah. [the mnemonic rhythm used with the children to provide them with a limiting scaffold on which to build their answers (see section 6.8.4.6). The teacher was looking for a statement such as "the higher the temp(erature), the faster the evap(oration)].

Teacher: Can anyone help Dale out. Emma.
Emma: It wouldn't evaporate as quickly away from the radiator as it would near the radiator.
Excellent so it say about the <u>speed</u> at which it evaporate so I think we can now make one of our di dah di di dah sentences out of this
Emma: The higher the temperature the faster the water evaporates
Teacher: Dale, the opposite?
Dale: The lower the temperature the slower the water evaporates

The teacher was confident not only in her own ability, but in the class' ability through time allowed for the discussion to progress to a scientific statement which would fit the evidence.
There was another example, in the same discussion, of the teacher developing and making more precise the children's ideas about condensation. There is a tendency for children to just use scientific vocabulary without first of all being able to explain the concept – "verbal wrapping paper" (Prestt, 1980). It is important for the words only to be used after they can explain the process precisely. Sean thought that when the water condensed, it froze. Here the teacher was supporting the children to clarify their ideas using the correct scientific terminology in the correct way. She realised that Sean knew what he wanted to say but he was not quite correct in the way he stated his ideas. The teacher is displaying the Vysgotsky principle that progress can be made more rapidly with the help of a significant other. Prior to the intervention the teacher would simply have corrected this, but in this instance she used the ideas with the class to clarify the process of condensation – she managed the discussion using authoritative/dialogic techniques, (see Table 4.3) illustrating a complete change in purpose for the activity, but using exactly the same activity.

6.5.3 Activities to elicit and explore children's ideas

The activity above was commonly used but there were instances where it was sometimes necessary to adapt activities to develop a constructivist and Non-Threatening Learning Environment. Before their involvement in the project, some teachers found it difficult to devise ideas for teaching activities. They often relied on material from a published resource, reflecting their lack of knowledge and confidence (Asoko, 1996) but did not realise why the activity was important, how it fitted in with the overall learning objectives for a unit of work, or how it could be used to develop children's understanding. Teachers after the intervention were able to present children with experiences which find out and challenge their existing ideas as illustrated by the following extract. The children had been able to observe shiny and dull materials and classify these. This was a year 2 class illustrating that the same principles apply to every age group but with a younger group, we were challenging their ideas about 'shininess' and providing them with an activity which clarified their ideas and allowed them to move on with an important scientific concept about reflection. A significant number of the class were unable to explain why some materials were shiny (because they reflected the light). In order to explore 'shininess', the children were taken in small groups to examine three identical cardboard cats (one white, one black and one covered with aluminium foil) on a black background, in a completely dark store cupboard.

Teacher: Will you be able to see the cats if we close the door and put the light out?
Jane: Yes, we will be able to see the shiny cat.
Teacher: (to group): Do you agree?
Group: Yes, miss.
Teacher: Why will you be able to see the shiny cat?
Tony: The light from our eyes will help us to see the shiny cat best.
Leanne: It is shiny
Tom: It gives out light
Teacher: Does that mean light comes from your eyes, then what?
Tony: It bounces off the shiny cat and comes back into our eyes.

Here the teacher was clarifying for herself and summarising what the children thought. Prior to the intervention the teachers would have felt 'guilty' that either she or the children were somehow inadequate because the children did not know the 'right answer'. The children's ideas show that from their experiences, they know that if you close your eyes the light stops, a simplistic notion of seeing which is consistent with many children's misconceptions, or alternative frameworks (Driver, *et al.,* 1994). Ramadas and Driver (1989) reported that children often held the notion that you did not need light in order to see. Andersson and Karrqvist (1981) referred to a 'visual ray' accounting for these children's ideas about how we see. Although the children had successfully completed a number of activities on light sources and shiny/dull surfaces, they were unable to apply their knowledge to a new situation. Part of the INSET and in-class support was to highlight how the ideas that the teachers' children held were generally the same as any other population. This example illustrates how teachers were choosing activities and putting them in contexts which are appropriate for engaging children in genuine discourse (Watt, 2002). An approach that encouraged the children to put forward ideas, test them against evidence and allow their present knowledge structures to be made public, are important elements of an effective learning environment. Previously the teachers would not have seen 'shininess' and reflection as key learning outcomes for this unit of work. (This led to the development of Key Learning Outcomes, developed with the science coordinators as a principle for planning a curriculum).

6.5.4 Children's discussion and reflection: limited frameworks.

Initially, many teachers felt that they must limit the time available for classroom discussion because of the need to cover all aspects of the National Curriculum in preparation for SATs. After the intervention, they recognised that as children become older, "their ideas may be constructed by social and educational interactions as well as their own thinking" (Harlen, 2000). Opportunities for children and teachers to share ideas and to reflect on these were created.
Context: Continuation of activity in store cupboard -light switched off

Teacher: *Can you see any cats?*
Group: No, miss.
A small amount of light, through a slightly open door, was now allowed to enter the cupboard.
Teacher: *Can you see any cats now?*
Group: Yes, the shiny one.
Teacher: *Can you explain why you can see the shiny one?*
Tony: The light comes in from the door, reflects off the shiny cat into our eyes.
Teacher: *Do you agree with that Jane...*
Jane: Yes, it comes in the door and bounces off the shiny cat into our eyes so we can see it.

Some children in the class worked out this explanation themselves, others were happy to accept their interpretation. After the activity, only one child in the class of 28 was not able to respond with the idea, "light enters through the door, reflects best off the shiny cat and enters our eyes - that is why we can see the shiny cat". The teacher has allowed the children to consider the new evidence, to listen to each others' thoughts and so has extended their existing framework so their ideas are developing towards a more scientific view. They are content with the explanation because it fits with the evidence. The children had changed their explanations not because the teacher had told them the 'right answer', but because the evidence was presented to them in a way they could assimilate it. This showed the strength of evidence-based learning, nobody told them what to say as they simply used the evidence presented to them and gave an explanation which fitted in with that evidence. The children in the initial phase had a limited framework in that they thought that light came out of their eyes and that is how we see (a classic misconception!) but when they considered the evidence they completely changed their opinions and explanations of how we could see the cats . This shows that children will completely change their explanations in the light of new and framework expanding evidence. So this research is saying they do not have misconceptions who according to Cumming (1998) are traditionally difficult to change, they have limited frameworks because they have changed their explanation by simply exposing them to appropriate evidence.

6.5.5 Developing the discussion.

This is a continuation of the discussion in section 6.5.2. In the previous discussion the children have been working on reversible changes, dissolving salt in water and evaporating off the water - and discussing other reversible changes, such as melting, freezing, boiling and condensing. One boy made a fortuitous statement, again unsolicited:

Terry: Miss

Teacher: Yes Terry

Terry: Miss- if you heat... If you heat a solid it will turn into a liquid and if you heat the liquid it will evaporates into a gas and if you cool a gas it'll turn back to will liquid and if you cool the liquid it'll turn back to a solid.

The teacher then used this fortuitous statement. One of the things that was found, was that if the children were allowed to express their ideas many fruitful ideas for discussion arose. It was not possible to predict who, or when, but a child always gave something. This completely unplanned statement gave the link between reversible and non-reversible changes. The teacher was about to challenge their ideas by burning toast.

Teacher: *Professor O'Neill* (Terry, but the teacher often used 'professor' in her science discussions), *what did you say would happen to a solid when it was heated?*

Terry: It'll melt.

Teacher: *Now, I am going to make some toast to go with my cup of tea this morning. So, I will put this solid into the toaster and wait for it to melt.*

Liam: It'll burn.

Teacher: *Terry, do you still apply that principle?*

Terry: Not with all solids

Teacher: But you said that solids will melt if you heat them to form a liquid - I know that is not exactly what you meant .... Would you like to change your conclusions or predict what will happen to the toast.

Terry: The heat will make it go hard.

The teacher used a different style of conversation here with Terry than with Tony earlier. With Terry it was much more challenging because she knew the class and who could cope with challenge (Terry) and who needed support (Tony). This was an advantage of working in the classroom, where the teacher's knowledge of the children was much greater than that of the researcher.

(The teacher then asks other children for their ideas about toasting the bread)

Children: It will change colour. It will get smaller: It will get crispy

(The toast is allowed to burn)

Teacher: Let us think it scientifically, has there been a change?

Children: Yes

Teacher: Has it changed from a solid to a liquid?

Children: No

Teacher: Has it changed at all, how has it changed?

Dale: Shape, it's gone smaller

Teacher: I haven't got any evidence of that. I'd need evidence - you would have to suggest how I could find out it's gone smaller?

(Dale says to measure it before and after)

Kevin: Colour

Teacher: Colour has changed, why has the colour changed and what's that horrible smell

Kevin: You burnt it

Teacher: Put that in science terms, what does that mean I burnt it

Steve: You've heated it too much

Teacher: The bread has been heated and something new has been produced.

The teacher was developing the scientific story, by mentioning the 'new material', which was highlighted as key in distinguishing between reversible and non-reversible changes.

Terry: Miss it's changed it to a different solid.

Teacher: Do you know what it is that has been produced?

Carl: Toast

Teacher: Toast OK. The bread is burnt on top, something new has been produced

(discussion about the properties have changed due to the new material being formed)

Teacher: Can I just tell you that this is carbon that's been produced on the bread. That's the black stuff, the burnt bread produces a new material called Carbon.

Here the teacher is rounding off the discussion by giving them some extra information (in terms of the Key Stage 2 Programme of Study) about the bread changing into carbon.

The child, Terry, over-generalised in his initial statement, so the teacher used this to make the point that scientific ideas need to be precise and then used the incident to highlight the introduction of a second type of change, an irreversible change. She was widening the learning framework for the class by providing them with an extending, but still very familiar, activity. Reversible changes are not always possible, so the teacher needs this counter example to take the learning process further. The teacher has reinforced the children's understanding of reversible changes, and now has challenged them with an example that does not fit with the previous examples of water (or chocolate), generating cognitive conflict. The teacher intervened here because that was needed to help them with their discussion about irreversible changes. They could not hypothesise what the science was because they were entering a new area of science. Their existing scientific knowledge was limited and needed to be extended by the teacher. They had a limited framework, since they could not express the new ideas in terms of their existing knowledge about change. This is an example of where the teacher does have to be the provider of knowledge, but it is presented in a way that it is 'fruitful' to the learner. The knowledge is presented in stages so she scaffolds the children's thinking until they become secure with the new idea. The next extract shows how the process is extended with the consideration of more evidence.

The teacher was allowing the children to give qualitative observations, but impressing on them the need for quantitative data when possible. She was also clarifying terminology, *"we can say the toast has burnt but not been on fire"*, the children were very ready to accept these criticisms because they felt they were becoming better at communicating their ideas.

Teacher: We've looked at all the properties of the bread, is there anything else that we could test if we were doing this again to look at the changes that have occurred? Any ideas? Dale you mention measuring it before any other ideas. As scientists, if we were doing this investigation again and we wanted to see as many changes as possible any other ideas as what you could do?
Sean: Miss weigh it.
(weighing, as a source of evidence, had been a recurrent theme throughout this topic)
Teacher: Why weigh it Sean?
Sean: It might have lost weight

The teacher did this investigation, the bread is weighed and the children were asked to predict the weight of the slice after toasting. The teacher accepted all answers and returned to children to ask for reasons. She asked them to explain their predictions, whereas previously she would certainly not have done this activity and would not have asked for predictions. Because all children could make a prediction, so they were all involved and then she was able to elicit a range of ideas to test against the evidence.

Dale: Miss, it's like more stuck together so it's heavier.

This response illustrated stages of development – the child had not grasped the concept of mass only changing when something is added or taken away. He did not appreciate that mass remains the same if something is simply squashed together. This is a common limited framework which would not be dealt with here but the children would be encouraged to think how this hypothesis could be tested out. Prior to the intervention the teacher would not have known the best way to deal with this response, whether to deal with it there and then or simply treat it as a wrong answer. Another thing that was emphasised was that the teacher decided whether the response would help the discussion, so deal with it then, or whether it was a sidelining issue which would be saved for later – but would still be dealt with.

"One of the things that helped me was it was ok to save questions till later, because you knew you were going to deal with the idea. Before, I would have been in a quandary what to do".

The previous example was dealt with at a later stage, but this next example was relevant to what the teacher wanted.

Teacher: Who else, Louise
Louise: It's heavier because of the burnt stuff
Teacher: That's an interesting idea isn't it? Because of the burnt stuff, the new thing that's produced it might weigh heavier because there's something new there that's an interesting idea – that's a sensible idea.

This was a valid statement because in some irreversible changes, for example in secondary school, mass will increase. It illustrates the importance of valuing the children's ideas when supported by reasoning which is testable. This again was the child's limited framework, how could she know yet whether the mass was lower because something was lost or higher because something has been added. It also has illustrated that the teacher has completely changed her epistemology from that of right and wrong answers, to that of holding a discussion and relating hypotheses to the evidence obtained.

Terry: Miss I thought it would be lighter because you need water to mix it with and if you put it in the toaster and water might evaporate so some of its weight will be gone.
Kayley: Something else has been added
Teacher: Added or made?
Kayley: Made

(At this point Sean announced the weight of the toast to the class and the teacher asked what the evidence was saying to the class.)

Teacher: Josh, did you hear anybody else's reason that made sense to you?
Josh: Terry's (Water in bread evaporates)

Teacher: Louise, because something new was made so maybe that could have made it weigh heavier, although yours was a logical explanation, did it fit the evidence?
Louise: no.

(Teacher recaps the evaporation idea for the whole class.)

Teacher: who agrees with Josh that Terry's idea of evaporation was the most likely,

Note that the teacher here did not say the 'Terry's right answer' she has changed her view of science as a process of gathering of evidence which supports or challenges a particular idea.

Teacher: Where has the black stuff come from? Any ideas?
Children: The rust from the grill inside / the heat from the toaster / the crumbs
Dale: No water to keep it moist and stay white so it forms black because there's no water left in it
Penny: Miss- the water is lost and there is a chemical reaction in the flour because you've heated it.
Teacher: What clue is there that there has been the chemical reaction
Penny: Miss the Carbon has been added to the bread
Teacher: so there's been a...
Penny: ...change

Teacher then discusses the change using this term and then asks is this a reversible change. Three children say yes. Teacher asks for how it could be reversed.

Children: Cool it, Scrape off the black stuff, put water onto it.

The teacher was using evidence from observation and evidence from investigation to move the discussion forward. She also presents challenge to the children by asking them to think about things they had not thought of considering, for example where does the black stuff come from? This illustrated how the ideas started to flow because they were putting forward various hypotheses to explain the initial piece of evidence. Then she invited other children who had not come up with ideas to choose their preferred options from all the given hypotheses. The teacher has given the children the opportunity to explore their ideas, to build on experience and to re-structure their knowledge. Their existing ideas worked for the reversible changes that they have experienced but not for this change. The teacher had an essential input here as a new term was needed for the changes that cannot be reversed, irreversible or non-reversible. The children were now able to explain their new ideas more effectively.

This again confirms the change in practice because teachers after the intervention reported,

" I give the children real time to think about things, to share their own concepts, their own understanding so the children always have the opportunity to say what do we do now... what do we think will happen ... to comment on what they observe"

These examples demonstrate that the teacher is aware of the essential role of language in science. The "talk of science" provides the conceptual tools for "thinking about science" (Leach and Scott, 2002). In listening to the responses put forward by other members of the class and to the teacher, each individual learner starts to relate the talk to their existing ideas, their previous experiences and reflect on their thinking.

6.5.6 Children developing their learning framework.

This is also from the discussion on evaporation. Harlen (2000, p13) has described children's learning in science: "start from the 'small' ideas and build upwards so that at each point the ideas are understood in terms of real experience". Primary science can then begin to enable children to make links between their experiences and build bigger ideas. Now that teachers are encouraging children to discuss and reflect on their experiences and evidence, this is beginning to happen.

A child, without prompting, demonstrates an advance in his conceptual understanding, from the processes being discussed related to evaporation of salt/water mixtures, to the water cycle:

Teacher: Yes Darren

Darren: Miss you know when the sea evaporates miss the water vapour goes into the air and the higher it gets the colder it gets, it forms clouds and. and the salt, it can't evaporate so it stays down in the sea and when there is too much... water vapour it'll turn back into water and form a cloud so it rains.

Praise from teacher for Darren linking knowledge of water cycle to the investigation in the classroom.

The child related the class work to the world of science outside the classroom, and also transferred knowledge from one scientific topic to another. This application to another topic, or to a situation outside the classroom, demonstrates a good understanding of the scientific constructs underpinning the topic under discussion. In discussing the water cycle what happens to the salt in the sea is not normally considered but Darren has inferred this from the investigation and subsequent discussion and has restructured his knowledge to contain a wider and more coherent set of ideas. The teacher congratulated the child on making this link, and in doing so reinforces an important goal and sets a high expectation for all children in the class. Encouraging the children to question, debate and relate ideas was now seen as very important in developing their conceptual understanding.

6.6 Nature of Classroom Discussion

It was considered important that children were able to communicate their ideas in a scientific format and the children's deficiencies in doing this were found as a result of serendipity. The researcher had to find out what the children actually thought, not the researcher's interpretation of their ideas and this reinforced the epistemology of constructivism both in eliciting the children's ideas and in them being able to communicate their ideas to others. The children overwhelmingly used the word *'it'* in their explanations, which was too vague for the scientific community, so the researcher insisted that they use the correct scientific word in their explanation. According to Bakhtin (1981) (translated by Holquist) a social language is "a discourse peculiar to a specific stratum of society". The language of science, is the "social language" of the scientific community that has to be developed from and out of the classroom social language. It was considered important that each child should develop this scientific social language and in order to do this they had to think and talk scientifically. To achieve this, the focus of the lessons, the learning environment both had to be conducive to the development of the scientific social language. In order to change the epistemology of teachers from that of a transmissive style to an interactive style, we focussed on how the lessons were organised and most importantly the discussion that took place, both teacher with children and children with children.

The structure of the lesson and the subsequent discussion was analysed using the tool set out by Mortimer and Scott (2003). Although this was devised in secondary classrooms, the principles apply equally well to any science discussion. They have set out an analytical framework based on five aspects contained within three strands of Focus, Approach and Action (Table 4.2 and 4.3).

In planning the lesson, the teacher needed to have a clear idea on what s/he was trying to achieve and this was decided in the first aspect, The Teaching Focus. This has been extensively subdivided and Mortimer and Scott have identified the following stages in the lesson:

- opening up the problem;
- exploring and working on students' views;
- introducing and developing the scientific story;
- guiding students to work with the scientific ideas and supporting internalisation;
- guiding students to apply, and expand on the use of the scientific view and handing over responsibility for its use, and
- maintaining the development of the scientific story.

6.6.1 Examples of classroom discussion

There are many examples of classroom discussion conducted during the gathering of research data and during the course of the intervention Ofsted inspections were carried out. This illustration is from a highly capable teacher who completely changed her epistemology. *"In a science lesson of the highest possible quality, delivered with the help of a lecturer from Liverpool John Moores University (the researcher), very motivating and imaginative teaching which was very effective in developing children's scientific knowledge, understanding and skills was shown".* After the lesson the teacher involved also made the comment *"It went well didn't it ....but that's no different than how they are week in week out, he could have come into any lesson and seen that".*

These three case studies have been selected to illustrate the principles involved.

6.6.1.1 Solubility 1: An open discussion

The teacher in this example was investigating solubility in water. The teacher demonstrated he had a clear focus on what he was trying to achieve by the nature of the solids he used, the structure of the lesson and the layout of the classroom. The teacher had set up a 90 minute activity and he had prepared a blank sheet to assist the children in recording of predictions and results. He had a selection of soluble and insoluble, coloured and colourless solids. Previously he would have chosen a pair of soluble and insoluble solids picked at random without prior thought of what he was trying to achieve. He used a joint class activity (an under-used method according to HMI reports) so that he had more control over the discussion and he could highlight what the children should notice to provide them with evidence. By adopting this style he made for himself a central role in managing (but not dictating) the discussion. Previously he may have used a class practical, for example, using sand and sugar as contrasting materials. This would have led simply to him "doing science". An activity of this style would possibly have led to closed outcomes such as: was the material soluble or insoluble?

By using a range of powders he was opening up the problem and providing the full range of experiences for Key Stage 2 and widening the children's learning framework to encompass all scenarios. This would allow him in the discussion to develop the scientific story and encourage the children to express their predictions using the appropriate scientific language.

The activities showed all the facets of dissolving that the children needed to know and he did not tell them any answers. He used their previous knowledge and the evidence from the activities to reinforce and develop and clarify ideas, both for themselves and others. In this he was maintaining the scientific story and supporting the children in consolidating what they already knew about dissolving, encouraging them to be more precise in their explanations so that they and others in the group were clear about their ideas. He was achieving all the points on the checklist for Teaching Purpose, as this episode demonstrates:

Adding the sugar to the water
Alan: I think it will sink
Teacher: and stay there?
Alan: yes some will
Donna: I think it will disappear
Teacher: what do you mean by disappear?
Donna: it dissolves

There are many examples of children using words to explain phenomena and they might not understand the concept involved. Does the child understand what happens to the sugar and the water when dissolving takes place. Previously the teacher would have left it at this stage, but this time he pursued the matter.

Teacher: what happens to the sugar when it dissolves?
Donna: it disappears
Teacher: has it gone or is it still in the water
Donna: it is still in the water

(This is following up the idea and checking some aspects of understanding. Donna is quite confident in this discussion)

Teacher: (returning to the activity) – Donna you think all the sugar will disappear, but Alan you don't
Alan: you need to stir it, then the sugar will disappear
Teacher: why can't you see the sugar
Alan: its gone and mixed in with the water

Again the teacher was allowing the discussion to progress so that he could check any conflict between two different predictions of the same activity. Previously he would not have done this and this conflict would have only been resolved at the experimental stage. The discussion showed that both children had the same understanding and experience and they agreed with each other's predictions, even though they might have appeared different initially, because they were phrased differently.
Then one child, Alisha, had a way of explaining and giving scientific reasoning for the disappearance of the solid during dissolving.

Teacher: Alisha you want to say something
Alisha: when the sugar dissolves it goes smaller, so you can't see it
Teacher: Say that again Alisha so everybody can hear because that might help us all.
Alisha repeats
Teacher: so you are saying that as the solid dissolves it goes smaller
Alisha: yes
Teacher: and smaller and smaller and smaller until when . . .. ?
Alisha: it's so small you can't see it.
Teacher: excellent well done Alisha

Previously the interjection by Alisha would not have happened because the discussion would have been much more closed - authoritative and predominantly non-dialogic, so there would not have been the classroom environment where thinking about why things happen the way they do was encouraged and the time for this consolidation of ideas was allowed.

His teaching purpose throughout this was fulfilled because the children moved from sharing their ideas with teacher support, to the children being able to express their ideas using the correct scientific vocabulary in a logical scientific sentence. Whenever he got to a point where the children needed to think, he asked just the right question to take them on.

The communicative approach was categorised using Mortimer and Scott's grid to ascertain the type of communicative approach used by the teacher. These are generally one of four types but as may be realised the boundaries between each type may be blurred. The dialogic dimension examines whether there is an interaction or exploration of ideas between the teacher and child or child and child (Table 4.3).

This discussion quoted above can be categorised as interactive and dialogic because the teacher did not state an opinion and through the dialogue of the two children involved, he reached an end point of the discussion that dissolving involves:

- A solid in water;
- The solid disappears;
- The word 'disappears' in this context was clarified for the teacher and all the children;
- The solid is still present, and
- The solid (particles) are going smaller so cannot be seen.

The episode also illustrates the Patterns of Discourse. Previously the teacher would have used a triadic I - R - E pattern (Mortimer and Scott, 2003) where the teacher asks the question (I) "Is the material soluble?" Then the child responds (R) "Yes" or "No" with a right or wrong answer –

decided by the teacher as the authoritative arbiter. Then the teacher would evaluate (E) the correctness of the response. Here the teacher has entered into an extended dialogue with three different children, in the form of an I - R - F - R - F pattern of discourse. Here the teacher gave feedback or asked for elaboration after the response, encouraging the child to think more carefully about the response they have given. Within this continuous dialogue of more than twenty steps the teacher only asks for elaboration or clarification and the children were all involved in either a contribution or listening to the responses and the dialogue. A conscious effort was made to involve all the children in the discussion, which was done in two ways; he asked for volunteers to test for solubility and give observations and explanations, he selected various children who might be reluctant to contribute and (he had not done this previously) he allowed all the children who wanted to respond and add to the observations and explanations, the chance to do so. This produced a wide-ranging class discussion throughout. He questioned them in just the right way, he involved all the children, he allowed them to put forward all their ideas. Previously he would let one or two make comments and always was looking towards "the correct answer". Here he did not make comments about the "correctness" of the response, but more about the "validity" of the argument.

The final part, where Alisha interjected, was an example of a teacher intervention. He saw this as a really powerful idea which would help the class understand the scientific story even better. In this episode his tone of voice changes from non-authoritative to authoritative, signalling that this was something of which everybody had to take note. This interjection was not planned, nor could it be, but has happened often throughout the project. As the researcher often said to teachers "You don't know when, you don't know who, but somebody will". The teacher was now very aware that these opportunities will arise and was ready to use them to help the remainder of the class. Rather than simply stating the scientific point of view "the particles become too small to see" he used the child's reasoning to make the point for everybody.
Throughout the short episode, the teacher has:

- acknowledged all the contributions to the story;
- he has emphasised the key scientific words, and
- he has checked their understanding through the explanations they give,

And in the final part:

- he breaks down Alisha's explanation with her;
- then repeats the explanation, and
- he emphasises the importance of the explanation to the whole class.

In the discussion, being an open one, where all contributions were valued and valuable, there was also an example of where the children brought in other areas of the science curriculum. The powder paint did not all sink immediately.

Dean volunteered that there was gravity pulling down on the powder and upthrust acting up

Teacher: and what can you tell me about those two forces

Dean: They are equal and opposite

This is an example of the techniques and strategies that the researcher has developed leading to an embedding and reformulating knowledge by applying knowledge learnt in one context being used in another one.

On the flour and water sample the flour floated but in addition little bits kept falling off and sinking:

Sarah: (offered, without being asked) *the gravity force was becoming greater so it was sinking. Sir is that because the water is getting into it (the flour) and making it heavier*

Teacher: why does that make it sink?

Sarah: because the force acting down is getting bigger and then it will be bigger than the force acting up

Teacher: and what if the force acting up was greater than the force acting down

Sarah: it would move up.

This illustrates a good grasp of the concept because she has learnt about gravity and upthrust in one context then applying the knowledge in another and she is justifying her observations confidently.

Teaching interventions have been observed and classified by Scott (1997, 1998) and similarly by Edwards and Mercer (1987) and Lemke (1990). Scott (1997) defines six forms of teacher intervention as set out in Table 4.4 and shows how this is used to develop the scientific story and make it available to all the students.

The final aspect can only be reviewed after all the solids had been tested. The teacher was going from observation, to explanation, to generalisation, which was important because it mirrored conceptually more demanding tasks. We were trying to go from observations which at a basic level is a task with low demand, to explanation using the correct scientific terminology which is the level expected for year 5 and year 6 groups, to the higher level of making generalisations, where the statements are not limited to specific examples and can be applied to a wide range of materials.

There were examples of the teachers subconsciously retaining a tighter control of the discussion rather than opening it out. This was particularly typical of teachers when they were unsure of their science and they do not want to venture into unknown territory where their science knowledge might be lacking. This was a contrasting occasion where all children were allowed to respond and he was able to use the variety of their responses to promote the discussion.

6.6.1.2 Solubility 2: A more closed discussion

The previous example illustrated how the teacher elicited from the children what their observations and explanations were but conversely there were many instances initially of an essentially transmissive epistemology. In the initial stages of the project, many teachers saw the purpose of the lesson as making sure that the children could recall the facts. Other teachers were typified by comments such as *"I want to make science exciting and interesting and I do investigations, but somehow it is not just…..right. Help!"*. With both these examples the teacher needed to consider the purpose of teaching and choose a purpose which led to an open-ended discussion and which elicited what the children thought, so that these ideas could be addressed. The purpose of the teaching from the teacher was to convey or reinforce the scientific facts. In this contrasting example of a class practical activity also about solubility, the teaching focus was simply to define substances as soluble (if they had dissolved), or insoluble (if they had not). This was essentially a closed activity and in terms of classroom interactions this would be classed by Mortimer and Scott (2003) as non-interactive/authoritative, the substance would be classed as soluble, or insoluble, according to the teacher's list, so there was a right answer and no dialogue. There was an additional problem with this mode of teaching highlighted in this example, and that was teacher error, the teacher had incorrectly assumed that Polyfilla was soluble. The quality of the teacher's questions has been related to the teacher's knowledge of the subject-matter. Carlsen (1987) showed that teachers with high content knowledge ask fewer questions and encourage more questions from the children. Low levels of teacher understanding of the subject matter were related to asking low-level questions designed to serve the purposes of classroom management. Carlsen also showed that teachers are more likely to use whole class teaching for topics where they have greater knowledge of the subject matter. Also Harlen *et al.* (1995) found that primary teachers, whose understanding and confidence in teaching science is low, tend to avoid whole class discussions and many research studies have found that primary teachers' knowledge of science is similar to that of secondary school students. This was not the case here, the teacher had a good understanding of solubility (apart from one example illustrated) and he was quite confident about doing class practicals. In the activity the teacher only used a range of white powders, because "those were the ones I thought of" and he did not have a focus on what children's lack of understanding might be.

Checking against Mortimer and Scott's criteria for teaching purpose given above, the teacher would not be able to open up a problem, would not elicit children's views and could not develop a scientific story. After discussion with the researcher the focus of the lesson and the nature of the interactions was changed completely by a simple change of phrase from choose either "soluble or insoluble" to "what do you think will happen if I add this solid to water?" If we use Mortimer and Scott's list for Teaching Purpose then there are possibilities to:

- open up the children's understanding about solubility,
- find out the children's views;
- introduce and develop a scientific story about what solubility is;
- discuss the children's ideas to work with the scientific ideas and support internalisation;
- allow the children to apply, and expand on the use of the scientific view, and
- maintain the development of the scientific story throughout the discussion.

These match the stages that are possible, but with a closed question such as classify as soluble or insoluble, they are not. By making this subtle change in the nature of the question, a far reaching change to the Teaching Purpose was achieved, the child-teacher relationship changed and the interactions became non-authoritative and dialogic. This again illustrates the importance of a constructivist approach. The teacher only needed a prompt in the right direction at an appropriate juncture and did not need a major INSET input and this happened in his class with his children, so would have a major impact on his epistemology. He could take this change of emphasis and apply it to a wide range of activities using a non-authoritative and dialogic approach to many of, if not all, his lessons. As the Ofsted report "Success in Science" states, (Ofsted, 2008), "Teachers tell us that some of the most valuable professional development takes place in their own schools when they have the opportunity to learn from and with other teachers".

However this illustrates one of the difficulties of research in that the researcher was not in a position where he could analyse rigorously before and after scenarios and carry out a comparative study, because the teacher was supported at that instant and changed his practice. The researcher has to make assumptions and interpret from the discussion with the teacher what his practice would have been.

For the practical activity, the children were surprised and interested by observations, they could observe the rate at which the powders sank and different ways the powders sank. They were refining their investigative skills and observing much finer detail, rather than the simple soluble or insoluble observations that would have happened previously. The children were also doing the investigation in white plastic pots which could not be changed at this stage, but the researcher suggested doing these sorts of investigations in clear, colourless, plastic pots so the children can see better what happens to the solid and the liquid. This again illustrates the benefit of planning for differentiation in the skills you want the children to develop and having the different teacher focus of how you can use good quality observations to develop their understanding and with that their ability to communicate and engage in dialogue with each other and the teacher. The teacher was not going to highlight the difference between white, colourless and transparent. There was evidence from children that they did not know how to distinguish between the properties of clear and colourless, which has been found in many classes. These children suggested using a dictionary. This was done and the dictionary defined colourless as without colour. The teachers do not see the significance of this observation or its relevance to studying solubility. To demonstrate this it was discussed that white, soluble powder giving a colourless solution, shows the powder has dissolved and a white powder in water giving a cloudy or milky solution shows it had not dissolved.

The researcher prompted the teacher to ask the class *"how could you tell if only some of the powder had dissolved?"*
A girl responded *"If you put one teaspoon in and only half a teaspoon is left then half has dissolved"*. The teacher impressed by the response and admitted he would not have thought of asking that question. *"This shows the benefit of working together,"* he said *"because next time I would do basically the same activity but with a different focus, I would be looking for them to say much more challenging things"*.

6.6.1.3 Solubility 3: Developing teacher skills

This is an example of where the teacher was very much at the initial phase of changing her epistemology from a transmissive type to a more open type. It illustrates how support and intervention in the classroom can lead to a greater development of her expertise.

The teacher started the question and answer session and said she was happy with the earlier questions but then she said *"I don't know what question to ask next"*. She had reached a point where she struggled for the next question. This was not a science content related issue it was a science pedagogical issue, she was focussing on content and closing the questions down instead of opening up the children's ideas. The teacher was asking factually orientated questions and did not address understanding, the problems ensued when recalled knowledge came to an end, as constrained by the Programme of Study, and explanations from the children, had to start. This was another illustration where the teacher adopted an authoritative, non-dialogic approach. If the interactions could be changed to non-authoritative and dialogic, then the teacher would be able to continue with the questioning. This required a different style of question and the teacher had to focus on finding out what the children *thought* which was at least as important as finding out what the children *knew*.

A range of children could recall words such as soluble, insoluble, dissolve, disintegrate, particle, absorb, disappear, evaporate, which was done as part of the initial thought-gathering process and these words demonstrated a reasonably high level of scientific and general vocabulary, but this only illustrated what the children said, not what they thought. In making judgements about understanding, the teacher needed to ask open questions which would require a greater level of confidence. When we discussed with the children what would happen if sugar was put into the water, the children could make predictions about the outcomes which would be suitable for National Test questions and illustrated the previous style of questioning. However this would not necessarily address the understanding of what was happening and it was this gap between knowledge and understanding that the teacher could not bridge. The teacher had taken them to this point and did not know what to ask next. Throughout the information gathering, the teacher only used an I-R-E pattern of discourse, there were no I-R-F-R-F patterns of discourse. In order to develop the I-R-F-R-F patterns the teacher needed to know, or find out, the sort of things that children are likely to say so they can check their own class's ideas against what children say generally.

The researcher demonstrated for the teacher how to modify the questioning and the type of discussion that was possible from this point. The children were asked to expand on their ideas by describing and explaining their observations and this led to the opportunity to hold a discussion about what would happen if the sugar solution was left for several days. This eventually led to statements about where the water and sugar would be. Questions such as where has the water gone produced answers such as "it soaks into the sugar", "the sun sucks it up", "it goes into the air", "it disappears", also one child said "the sugar evaporates with the water so nothing will be left". The researcher pointed out to the teacher, that these children's ideas were entirely typical of the population as a whole. This illustrated to the teacher how the discussion could be opened out, but that is the initial part of the discussion, then the teacher must provide concrete examples usually in the form of practical activities to confirm or challenge those ideas. Previously a response such as "the sugar evaporates with the water" would have been evaluated by the teacher as an incorrect response and with many children this would have led to a loss in confidence. If, however, the response is approached as an idea having merit, which could be tested, many children would have been quite happy to accept this evidence even if it contradicts their initial idea.

These ideas could be used to develop the scientific story and there were many other activities that could be used to provide evidence for this. Using the example, to check the validity of the hypothesis "the sugar evaporates with the water so nothing will be left", the sugar solution was left to evaporate over several days, but the researcher warned the teacher that the best she could hope for would be a syrupy solution. We tested the idea (in the lesson) of nothing being left using a solution of alum in water and put on a filter paper to dry out. This technique had been suggested by a child in a different school and complete evaporation happens quite quickly, leaving crystals on the filter paper and evaporated water. This could then be referred back to the sugar solution and all were happy with the idea that the sugar was still in the water but it was very small and too small to be seen. You could tell the sugar was there if you tasted it. Or you could weigh the water, sugar and solution as with other groups to test whether anything remained. Also striations and coloured solids were other activities which could be used to demonstrate this and were suggested to the teacher and the fact that these had been used in other classes gave credence to their effectiveness. They now saw science as a process where ideas are given and then tested.

6.6.1.4 Teacher's capability deficiency

This study was from a teacher who was not as good at developing her skills and that of the children, she could follow the instructions but she did not always know what she was looking for. She did not always know what to do with their comments and how to develop the children's ideas, for example, she emphasises the child's use of the word "it" but then allows this style of response right through the initial discussion and does not develop the children's ways of discussing their ideas to make them more specific. The following dialogue illustrates that the children hold a mixture of ideas and some were contradictory, but the teacher did not get the children to discuss with each other, in an attempt to keep the discussion dialogic, she just accepted what they said without comment. This meant that the scientific story was not progressing.

Teacher: This morning we are going to find out what happens when we add sugar to water. But before we do that, before we find out let's make some predictions when we add sugar and water together. What will happen if we add sugar and water together
Dean: Miss it will dissolve.
Teacher: The sugar will dissolve
Teacher: Right what else Gavin
Children: It will evaporate
Teacher: Evaporate? Is "it" the same thing
Children: No
Gabbie: it will stay at the bottom
Teacher: Right any others
Bobbie: It will go round in bubbles.
Kirsty: It will go but it is still there it will be in tiny pieces. The sugar will float around then down to the bottom then it will dissolve.
Children: I don't think it will dissolve
Dean: It's still be there but you can't see it
Children: It'll go to the top and evaporate

Children: Float at the top and stay at the top

The children are saying random things and the teacher is asking for children's ideas, but the scientific story is not developing. Then the teacher compared this solution with one she has left overnight with sugar crystals in the bottom which had dissolved but leaving a concentrated solution at the bottom and water (or a dilute solution) at the top. The researcher providing the support modelled the discussion with a small group and the teacher observing, to show how you could interact with what the children say. Instances of the children using 'it' were highlighted and corrected.

The researcher tips the plastic cup so they can see the sugar solution moving:

Researcher: Why do you think this in the bottom is going from side to side?
Children: It's the sugar
Researcher: Can you see any sugar
Children: Yes it's like a tornado going from side to side
Researcher: Does this water (concentrated solution) look different from that water (dilute solution)?
Children: Yes
Researcher: And why do you think that is?
Children: Because you can see sugar in the water
Researcher: But can you see grains of sugar. Any crystals in the liquid.
Children: No. no
Researcher: But you think there is sugar in there
Children: Yes
Researcher: So what happened to the sugar we put in the bottom
Children: The sugar's like….

This was an illustration of where the children are beginning to question how they communicate, they are developing their ideas, but have not quite reached a level of confidence that they can develop ultimately. The teacher at this point has to be able to judge when to support and give more ideas for them to work with and when to allow them to struggle to an outcome on their own. This was a judgement skill which the teacher needed to develop and illustrates a change necessary in her epistemology from the teacher adopting a transmissive approach and knowing all the answers to a more open approach where the teacher uses the evidence obtained in the investigation and from the children's experiences to make progress in the scientific story.

So the researcher starting from the point where the sugar had dissolved….

Researcher: And where has it dissolved

Child: In the air

Researcher: You think the sugar has dissolved in the air

Children: No No (others)

The child may be guessing here, but the sharing of ideas in a non-threatening learning environment allows this discussion to progress without the child losing confidence.

Child: It dissolved in the bubbles in it. (this had been one of the observations when the sugar had dissolved during stirring).

Researcher: You think it's dissolved into little bubble things. What makes you think that?

Child: Because it wasn't there before so it's dissolved into them.

Here the child has seen the bubbles (accurate observation) but thinks the sugar dissolves in the bubbles. The children will have their own ideas based on their own experiences, both inside and outside the classroom. These are examples of limited frameworks, children have a range of experiences and some apply to this situation and some not. They have to use the evidence from their observations to explain what is happening. It is important for the teacher to know what they are thinking in order to change the ideas to a more scientifically acceptable explanation. Some of these ideas may appear bizarre to the teacher, but it is what they are saying (and thinking) and therefore has to be dealt with. The researcher summarised ideas and asked for children's opinions, then had to deal with the ideas using examples. The children must have evidence on which to base their ideas, because these year 4 children were only at the concrete operational phase of their development.

Researcher: I will put some sugar in the cup and you will tell me if you see any bubbles. (Does this and the children see bubbles)

Researcher: have the bubbles finished now

Children: chorus yes

Researcher: and has all the sugar dissolved

Children: no

The researcher then had a discussion about whether all the sugar had dissolved in the bubbles and what the mixture would be like the day after. This needed to be done so the children were content with the evidence. However if the bubbles do not dissolve the sugar the bubbles still need an explanation.

Researcher: Right we have agreed that the bubbles do not dissolve the sugar, but is there an explanation for the bubbles being there, where have the bubbles come from? They appear when we put the sugar in then rise to the top and disappear.
Dean: is it something to do with the sugar
Researcher: yes the sugar has air around it and when the crystals go in the water the air in the spoonful of sugar makes those bubbles.

Here the learning framework of the children (and the teacher) has been widened, which illustrates a completely new skill for the teacher. It is not about the teacher knowing all the answers but about using the evidence to explain the observations and what evidence to use to challenge or confirm the children's ideas. The children were observing and coming up with ideas and the actual explanation is quite complex but they were giving the teacher their ideas so the teacher could tell how they were thinking and the sorts of ideas they came up with. The evidence showed that they know there is sugar there but you could not see the actual sugar grains in a solution. This contributed to their understanding of what dissolving is. There is a need to develop the children's language, so they can communicate effectively with other members of the scientific community using the language of science. Lemke (1992) argues that Personalised Narrative has a vital role in developing any specialised language because it presents a view of the world in their own everyday language, which is how they will initially think and make sense of what they experience and this is where all of us begin. This is particularly important with younger children. Then this has to be developed by the teacher into the language of science, which has its own specialised linguistics, which at this level is limited to correct vocabulary and sentence structure. This teacher was not as capable as she needed to be and continued to receive support tailored to her most pressing needs, namely in questioning for developing children's ideas in a way that would lead to a discussion and providing evidence for children's observations. Again by only attending a course she would not have been able to develop her skills, she would have learnt the answers for those situations covered on the course but would not have been able to practise them in the new situations, which arose as a result of her doing the investigation in class.

6.7 Developing investigative practice

This was an example of a teacher who needed support and was working in a school that had been placed in special measures by Ofsted as a result of poor leadership, unsatisfactory teaching and poor attainment in SATs. One of the issues in science highlighted by Ofsted was the lack of formal investigative work so this is where the intervention was started. Before the intervention the teacher had little or no structure evident in his investigations that he did with the class and these were often investigations where volunteers did one part of each of the steps in the investigation, so the skills of the whole class were not being developed. The researcher had modelled Investigative Planning Boards (appendix 6) which provided a scaffolding process to help the children work through the potentially complex process of planning an investigation.

This discussion shows how the teacher supported their learning, allowed the children to take much more control of the planning of the investigation and how he used small groups working together so he could assess and develop the skills of each child. The change in practice illustrates how a constructivist approach influenced in-class support and provided highly effective continuing professional development.

At the start of the investigation the teacher did some discussion demonstrating dissolving sugar in water. The children could think of a range of things to vary and the teacher was non-judgmental, whereas previously he would have had one idea and organised the investigation around this one idea. The children suggested measure the sugar, use sugar cubes, use different sugars, time the sugar, stir the sugar, warm the water and this led to the idea of "put it in a microwave". This was an example of a variable that would not have been suggested prior to the intervention, because the teacher would have had tight control over what was being suggested. All the children knew you kept fixed variables the same to make a "fair test". From this one child mentioned temperature - again the teacher would have not allowed the discussion to progress to this or possibly he would have fed the word *temperature* into the discussion. The children had random ideas for an investigation as illustrated here, but they need support from planning boards to put their ideas into a logical format. Using the planning boards the teacher started with what we are going to change and what we are going to measure. Everything follows on from these two decisions:

Teacher: Right. So we need to agree on one thing we will change so what would you like?
Children: The temperature (this was the majority decision)
Teacher: I am trying to find out ... what will I measure. Yes Terri Ann
Terri Ann: Dissolving
Teacher: And what about the dissolving, what am I measuring to do with dissolving

Terri Ann: How long it will take the time
Teacher: so I am changing the....
Children: temperature (written on a sticky note and placed on the Planning Board)
Teacher: and measuring the .....
Children: time (written on a sticky note and placed on the Planning Board)

(the words on the sticky note can be written by the teacher, classroom assistant or child depending on the stage they are at). Here the teacher was facilitating the children's ideas, supporting the class rather than controlling the investigation. A class discussion followed about the effect on dissolving rate of changing temperature.

Teacher: So we can fit our question in now.
The question is scaffolded as well and is phrased

"How does the ...... affect ...."?

This is another example of the scaffolding being present which supports the children in the way they express their question. If the children are allowed to express their question most children will produce a long sentence which may or may not have covered the variables.

Teacher: So Kyle can you give me the question? How does the ....
Kyle: temperature
Teacher: affect the ......
Kyle: time to dissolve.
Teacher: excellent

then the teacher summarised and consolidated what the children have decided.

Teacher: So we are trying to find out how the temperature affects the time to dissolve the sugar in water.

This teacher by using a summary is collating in a logical way, the children's ideas so is using a dialogic yet authoritative approach. The class and teacher decided to use hot, warm and cold as the three variables so as not to introduce another level of difficulty, because these children and the teacher were only at the initial stages of developing the skills needed for planning and carrying out an investigation.

The discussion process was an example of the social nature of learning, where the learning was taking place in a social environment. Here the children were not only reinforcing their own learning but the group were supporting each other and helping each other learn. This is akin to 'communal constructivism,' a term first used by Holmes *et al.* (2001), who described communal constructivism as "an approach to learning in which children not only construct their own knowledge (Constructivism) as a result of interacting with their environment (Social Constructivism), but are also actively engaged in the process of constructing knowledge **for** their learning community". The teacher was consciously or subconsciously employing these techniques here. He saw this as good practice because the children were actively involved in the learning and the emphasis is different from the teacher simply asking questions. Here the children were all part of the learning community.

Teacher: Now we need to make our test fair what will we need to keep the same
Children: Equal water
Children: Equal sugar
Children: Speed of stirring

Here the teacher was not telling them the answer, but sometimes giving them a clue, so they still think they are deciding, the teacher was being patient and waiting for the ideas to come from the children. The teacher allowed plenty of time for this part, whereas previously he would only have allowed one or two to answer and then completed the list. He now realised the importance of allowing time for their understanding to be consolidated in their framework, and the expertise of the teacher was the judgement of whether the outcome is within their conceptual capability.

Teacher: So we need to agree how long we are going to stir the mixture

(The teacher got slightly confused here and referred to the dependent variable and needed support). This was an example of a constructivist approach being used in the intervention. The teacher was conducting the lesson, but when he needed support the researcher sympathetically helped at the point in the investigation where it was needed – here the teacher's mistake was going to lead to problems with the number of variables in the investigation. We agreed to keep stirring at a steady pace until sugar has dissolved. The discussion between teacher and researcher about how to manage the investigation was important and different from a workshop approach since the teacher would only be told how to do the investigation and the course providers would not be available to provide this detailed advice. This was a constructivist approach because it built upon the teacher's expertise framework, then extended the framework at the point he needed it, making the teacher more enabled.

The children and teacher discussed the rate of stirring which illustrates that you do not tell the children things they can work out for themselves. The onus is on the children to think so that they are engaging with the learning process. This gives an opportunity for the teacher to check that confusion has not persisted and the teacher can assess the level of understanding from the children.

The children were reminded about the safety issue of being careful with hot water. The teacher allocated roles in each group and the children carried out the investigation.

However, as they are starting Rachel asks *"how much sugar should we use?"*

Teacher: Rachel's just asked a good question sensible question-please Rachel

Rachel: How much sugar should we use?

Here the teacher discussed all the fair testing and practical issues surrounding this point in a dialogic manner.

The teacher circulated and checked they could all do this and were following other correct procedures. This was exciting to them and all the children were engaged. At the same time the teacher was able to check their understanding of the procedures and the correctness of their explanations of the scientific ideas. As part of the investigation, the teacher was questioning the children about their techniques measuring a volume of liquid. What's that reading and why do we do this? (a child was reading at eye level on a flat surface). The children could say why reading at eye level gives you a correct answer and reading from above does not. This is an example of where the teacher can learn for future investigations, by watching what the investigative capabilities are and they can then share their ideas with the class, thus developing the skills of more children.

Teacher: Right we have all got our results. How could we record that so people can see right away your information and make it nice and clear for them?

Children: A graph

Teacher: Good

The teacher then held another discussion confirming which type of graph to use. The children decided *words and numbers* so a bar graph was appropriate. The teacher worked through the graph scales with the children and worked through one table's results to demonstrate how to plot a bar graph.

This is another example of the scaffolding used with the planning boards. The children could learn, with support, the type of graph to be used for different categories of results.

Teacher: Yes Zac

Zac: when the graph goes down the temperature goes up.

Teacher: That's really good Zac can you say that again Zac see if everyone agrees with you. Everybody look at this graph while Zac tells us what he means.

Zac: The first one the temperature is going down the temperature when it's going down

The teacher helped because the child was trying but needed a little bit of support, but the teacher needed to be sure he did not answer for the child.

Teacher: As the temperature goes....
Zac: Up
Teacher: As the temperature goes up the time goes...
Zac: Down
Teacher: So the higher the temperature ----
Children The quicker the time
Researcher: Have we done di da di-di dah, di da di-di dah?

(The little rhyme we did which we could fit the findings to). The class repeated until confident with the rhythm. This was another example of the scaffolding which was similar to that for composing the question (see section 6.8.4.6 for a discussion). Younger children often had a long winded way of expressing their ideas and they found it difficult to do this succinctly. Quite often they would lose track of their argument. Placing a restriction on the way they communicated their ideas, they could express relationships between variables in a more concise manner. This episode demonstrates that a light touch approach to investigation, allowing the children to demonstrate what they know or can do, leads to a much more open discussion and the children having much more ownership of the investigation.

6.8 Assessment of children's attainment

Assessing the impact of constructivist teaching strategies on the children necessitated the assessment of children's science abilities before and after teaching. It was not possible to use a control group to compare the data before and after the intervention, because of the nature of how the intervention was being carried out;

- all schools were being supported, so none of these could be used as a control;
- there were differences between schools, as most schools were single form entry therefore there would be differences between these groups, and
- schools with more than one form of entry would have differences between the teachers taking the classes.

Contrasting intervention schools with other schools would ignore the differences between schools, hence the limitations of the link. So the inability to assign schools randomly limited the methods available and other strategies were tried.

6.8.1 Examples of Assessment of children's work

The assessment of children's work was happening as a day to day experience, the children were making progress throughout the intervention and it is not possible to quantify this fully considering the nature of this research. Here are two examples of how the children's ideas and explanations progressed through the sequence of lessons. The sequence of lessons were recorded and transcribed and here are two examples which demonstrate progress in learning.

6.8.1.1 Electricity

This was a combined activity of them having ideas making suggestions and then testing out the ideas with evidence from the circuits – a Socratic discussion. The discussion usually started with red and black leads as to what would happen with two red leads. Usually about half the class would predict the bulb would not light (their initial assertion *"it won't work"* was changed to the bulb will/will not light up). This was then tested out and from this discussion the key terminology: conductor, insulator, metal and the realisation that the colour of the lead was immaterial, was decided. This then led on to a discussion about how the electricity moves through the leads. Typically about 80% of the class would favour the 'clashing current' model. Though a series of activities and discussions over more than one session which involved more than one bulb and a motor which will reverse its direction of spin and a buzzer, they would realise that the 'circulating current' model satisfies all the evidence but the 'clashing current' model does not. Again through a series of activities the children would be able to explain the effect of more than one bulb, more than one cell, the orientation of the cell, the purpose of the cell quite confidently. They could use the concept of energy to explain that electricity is not used up by the bulb and they would be able to draw neat circuit diagrams. This shows the power of evidence based learning because the children are gradually building their knowledge and understanding of electricity, which is in line with Fosnot's view "learning is an interpretive, recursive, building process by active learners interacting with the physical world" (Fosnot, 1996:29). This is confirmed by an incident in one class where all the children could draw circuit diagrams and they all concurred with the circulating model but several children, when presented with a different context, reverted to a 'clashing current' explanation. Pine *et al.* (2001) discuss how children hold on to their beliefs unless the teaching supports changing of these to more fruitful ones.

6.8.1.2 Filtering

The activity was linked to sieving and here they developed their language about which particles would pass through culminating in the statement that 'if the particles are smaller than the holes they will pass through'. This then extended to the elicitation exercise showing the children's ideas of what would happen if the mixture was poured into the filter paper. These are shown in Figure 6.18.

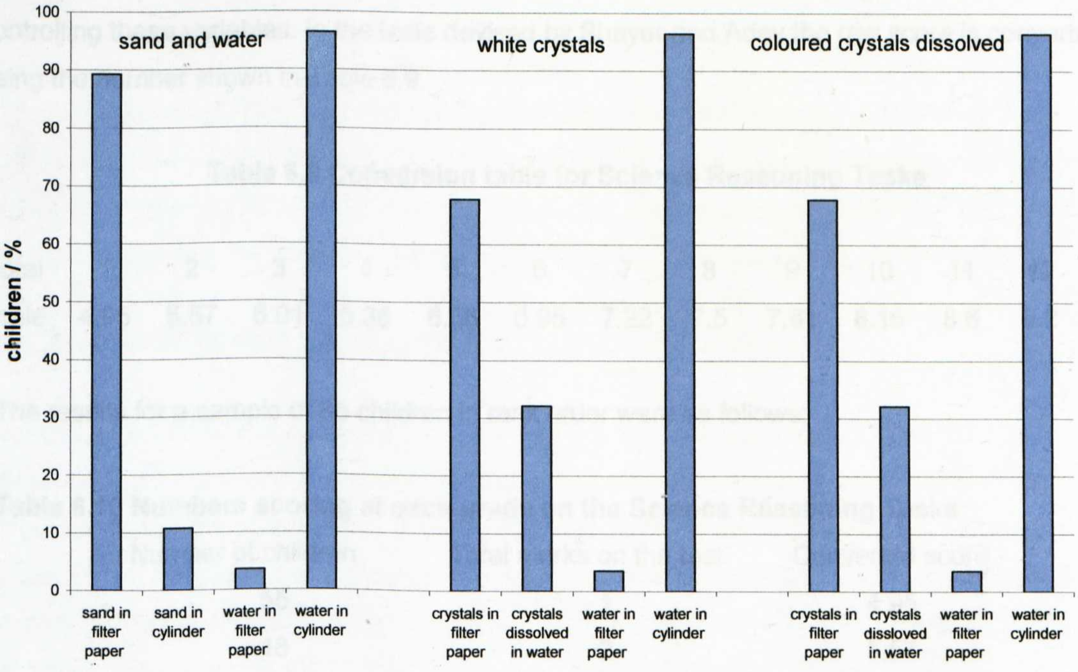

Figure 6.18 Children's responses to filtering soluble and insoluble materials

First they had to demonstrate to one another that the filter paper had holes in for example breath, water, light passing through, then the activity was carried using filtering equipment for filtering sand and water, white crystals dissolved in water and coloured crystals dissolved in water. These data show quite clearly that they are confident about insoluble materials, but they have 'limited frameworks' for soluble materials. The activity demonstrated the evidence of what actually happened and this led to explanations about why the dissolved solids passed though the filter paper. When they had the evidence they could explain quite confidently (usually using particle theory) the results using the correct scientific language. They developed their filtering skills, their language skills and their understanding of the process of dissolving in the one activity.

6.8.2 Assessment using Science Reasoning Tasks

In an attempt to assess the children's abilities more quantitatively, in particular, the reasoning powers of the children as opposed to purely factual recall, they were tested using Science Reasoning Tasks developed by Kings College (Shayer and Adey, 1981). These tasks were developed on Piagetian principles, so should fit in with the constructivist principles involved in this intervention. It is well documented using evidence from developmental psychology and from brain MRI research that there is a major brain growth spurt around the age of 11 after a plateau around the age of 8-10 years. In the opinion of Shayer and Adey,(1981) these changes in children's brains make it possible for the development of concrete operational thinking at the age five to six, and for formal operational thinking at age ten to eleven. The Science Reasoning Tests were trialled on groups of eleven year old children to measure the effectiveness of these tasks at assessing the children's ability to control variables and make reasoned judgements as a result of controlling these variables. In the tests devised by Shayer and Adey the raw score is converted using the number shown in Table 6.9.

Table 6.9 Conversion table for Science Reasoning Tasks

Total	1	2	3	4	5	6	7	8	9	10	11	12	13
Scale	4.95	5.57	6.01	6.36	6.66	6.95	7.22	7.5	7.81	8.16	8.6	9.2	10

The results for a sample of 85 children in rank order were as follows:

Table 6.10 Numbers scoring at each grade on the Science Reasoning Tasks

Number of children	Total marks on the test	Converted score
55	1	4.95
18	2	5.57
5	3	6.01
1	4	6.36
1	5	6.66
1	6	6.95
1	7	7.22
4	9	7.81

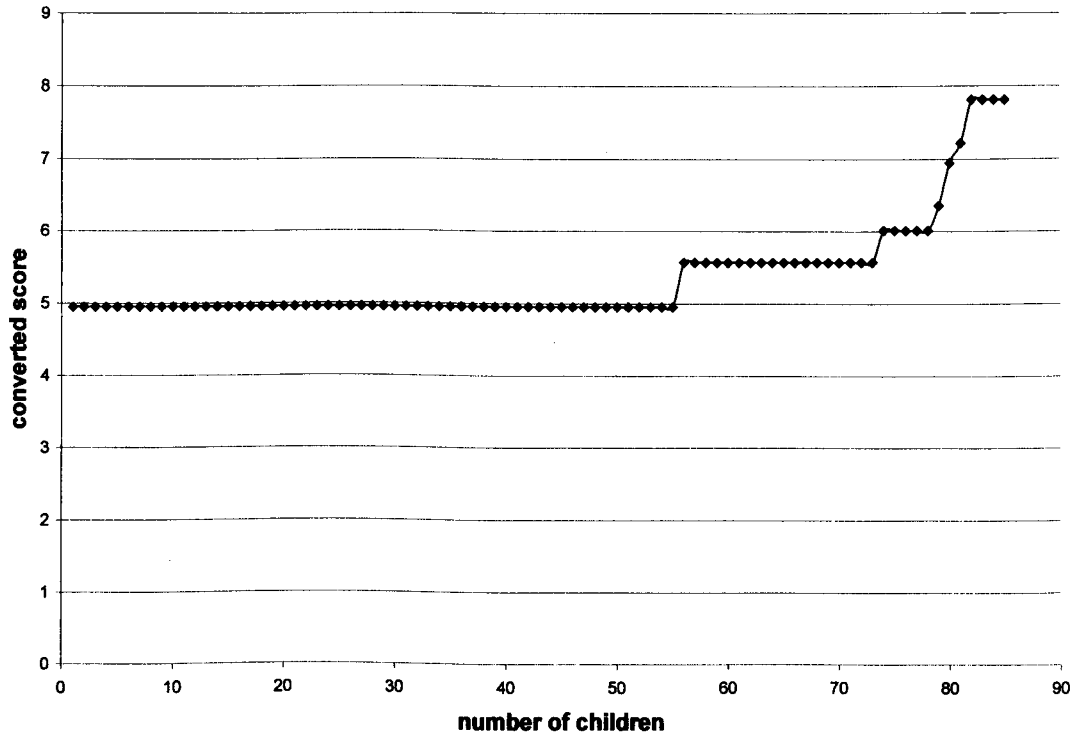

Figure 6.19 Children's performance in Science Reasoning Tasks

The data proved of little value in finely discriminating between children, they tended to score either well, which was less than 10% of the children, or very poorly (65% of the children only gained one mark). The results for the pendulum test are given fully in Table 6.10 and they demonstrated that the Science Reasoning Tasks did not fulfil the needs of the research.

6.8.3 Assessment using pre and post test data

Following the lack of discrimination provided by the Science Reasoning Tasks, the children were assessed using pre- and post-tests devised by the researcher. They were designed using some National Test parts of questions, particularly those involving investigative skills, some from QCA assessment tasks and some diagnostic questions based on aspects of the topics that previous research has shown children had confusion about. The key terms in a topic were also tested. Pre-tests were given at the start of the topic. The post-tests were different questions but based on the same principles. Mark schemes were provided for the questions so there would be a standardisation within the marking and the teachers could use them in the future. The tests used in this part of the intervention were checked for consistency by the researcher, who was an experienced examiner. The numbers sitting each test varied from 56 children to 127 children so the results in the tables have been displayed as percentage of correct answers obtained for each question part. The abilities more specifically demonstrated by the Science Reasoning Tasks were elicited in the lessons and other children's work.

9 pre-tests and post-tests were used on some major science topics from the National Curriculum for Science. The topics were very similar but not identical for pre- and post-tests since as a result of teaching, more detail needed to be covered in some topics and less in others.

Table 6.11 List of pre-tests and post-tests

The topics for pre-tests were:	The topics for post-tests were:
Plants	Plants
Living things	Living things
	Human Body
Grouping materials	Grouping Materials
Changing materials	Changing Materials
Rocks and soils	
Sound	Sound
Forces	Forces
Electricity	Electricity
Light	Light

There was increased level of difficulty from pre and post-tests. Examples of the forces pre-test and post- test are given in appendix 7 and 8.

The children's performance in all the pre-tests and post-tests is shown Table 6.12. Since there was no attempt to coerce the teachers to use the tests the number varied for each test, but the minimum was one class (n=24) and the maximum was 4 classes (n=107), the average attainment has been used.

Table 6.12 Performance in the pre-tests and post tests

Test	Average attainment	Test	Average attainment
pre-test plants	56	post-test plants	73
pre-test living things	85	post-test living things	74
		post-test human body	72
pre-test grouping materials	80	post-test grouping materials	84
pre-test changing materials	71	post-test changing materials	79
pre-test rocks and soil	35		
pre-test sound	38	post-test sound	80
pre-test forces	47	post-test forces	80
pre-test electricity	63	post-test electricity	78
pre-test light	60	post-test light	75

The average scores for pre- test data and post- test data were compiled and analysed using a *t*-test to examine whether there was a statistically significant difference between pre- test and post-test data. This analysis showed that the difference in the data was statistically very significant (t = 2.975 and p = 0.009) which demonstrate that significant changes were taking place as a result of the interventions. The summary analysis does not show, but viewing of the individual tests did show, that children's ideas were becoming more sophisticated in the language and scientific vocabulary they were using and were less prone to those 'wrong' scientific ideas highlighted by the summary reports for national tests. These were found to be of value in this investigation because the teachers wanted to base line their children and demonstrate progress using a simple easy to administer assessment, but the tests also addressed some aspects of understanding which were not found in national tests. The teacher may need to know these in order to provide a constructivist learning environment.

6.8.4 Assessment using national test data

6.8.4.1 General discussion

The children still had to demonstrate progress in National Tests because this was how the school would be judged by outside agencies. In attempting to find ways of obtaining meaningful comparative data from national tests, published facility values gave a level of standardisation and comparison. The facility value shows the performance of a very large number of children, from a range of schools on individual items, so this provides a national measure of achievement, and facilitates a way of comparing an individual school with the national average on each particular test item. Such a comparison would involve examining SATs data, and for each item in the test comparing the intervention classes with the national average in terms of the percentage of children who answered the item correctly. From a governmental perspective it is the number of children at or above level 4 that demonstrate acceptable standards in teaching science. In order to achieve level 4 in science National Tests, the children are required recall the accepted scientific ideas correctly using correct scientific terminology in their explanations. Level 5 in National Curriculum science requires children to demonstrate application of scientific principles. They have to interpret and process the information so the kinds of questions they are asked cannot be answered simply by recall. Children have to analyse a given situation, identify the scientific concept being focused on and explain what has happened using appropriate scientific language. Here they are developing a more formal operational mode of thinking and mental processing has been used as an indicator of understanding as opposed to recall, because the children have to mentally process the information before responding. The number of children who achieved level 5 in the Year 6 science SATs in the year preceding the school's involvement with the intervention was calculated for 9 schools (these are the schools for which data is available initially and finally) and this gave a mean of 5.9%. This figure was then compared with the number of children who achieved level 5 in science in the SATs examination after the intervention and found for the same schools a mean of 27.2%, so an increase in the percentage of Year 6 children achieving level 5 from 5.9% to 26.9%. A *t*-test on school's percentage scores demonstrated a very statistically significant improvement in level 5 scores, with $t = 4.207$ and $p = 0.003$. These data indicated that the changes cannot have occurred through chance, and must be the result of some intervention. However for national tests the scores obtained can place the children at level 5 by obtaining a particularly high score on the level 4 questions. The schools may get the children in year 6 to practise and practise past paper questions and concentrate on content and recall until the children perform well. This is in line with the Ofsted comment in their summary report 2004 - 2007 "In too many primary (and secondary) schools, teachers were mainly concerned with meeting narrow test and examination requirements and course specifications. This led them to adopt methodologies which did not meet the needs of all children or promote independent learning." (Ofsted, 2008). This was not the approach in the intervention, although the children were prepared for the exam, the focus was on applying scientific principles, as a demonstration of understanding, rather than recall. A headteacher from a school not involved in the intervention stated *"Our children can recall the answers to all the questions, but your children understand the science they are talking about"* or from an Ofsted inspection at one of the intervention schools *"The inspector was amazed to see such quality of explanation and thought about science activities".* The analysis later compares the performance on individual items to which can be assigned level 4 or level 5.

In examining the data from schools involved in the intervention there were many examples where schools used to have fewer than 70% of children achieving level 4 or better, and whose children have now achieved at a higher level. For example, a school where 38% of children gained level 4 or 5 prior to their involvement in the intervention had 79% of its children gain level 4 or 5 after two years, one school increased the percentage of children from 65% to 93%, another from 68% to 81%. The trend for involvement in the intervention across 9 schools and its impact on SATs performance is shown in Figure 6.20. (n=245)

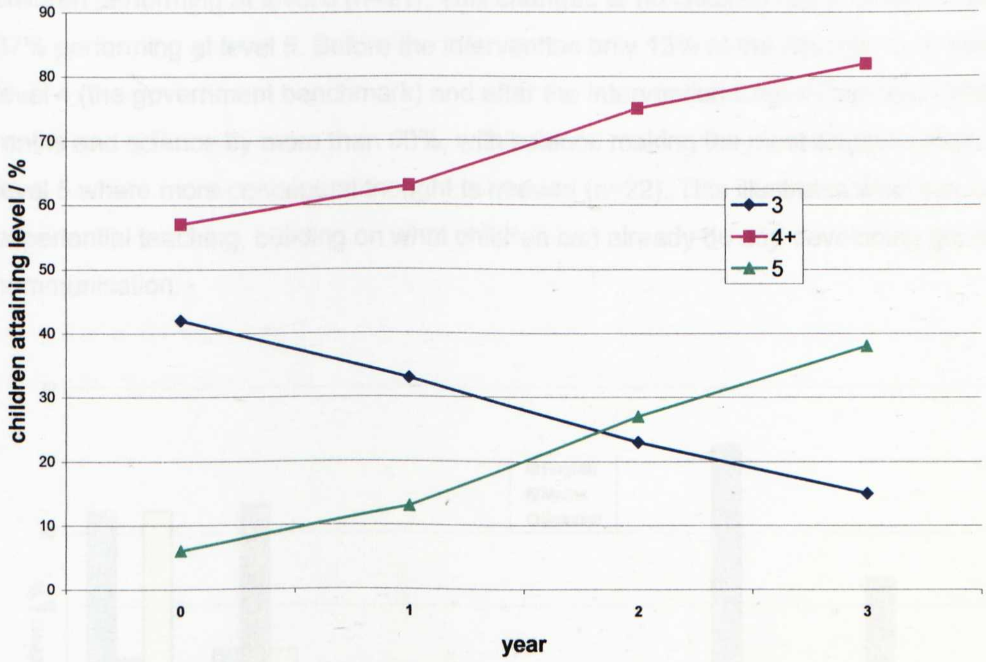

Figure 6.20 Children's increased attainment in National Tests

A comparison was made of performance in national tests over a period of 4 years for three schools with a higher level of involvement and this is given in Figure 6.21.

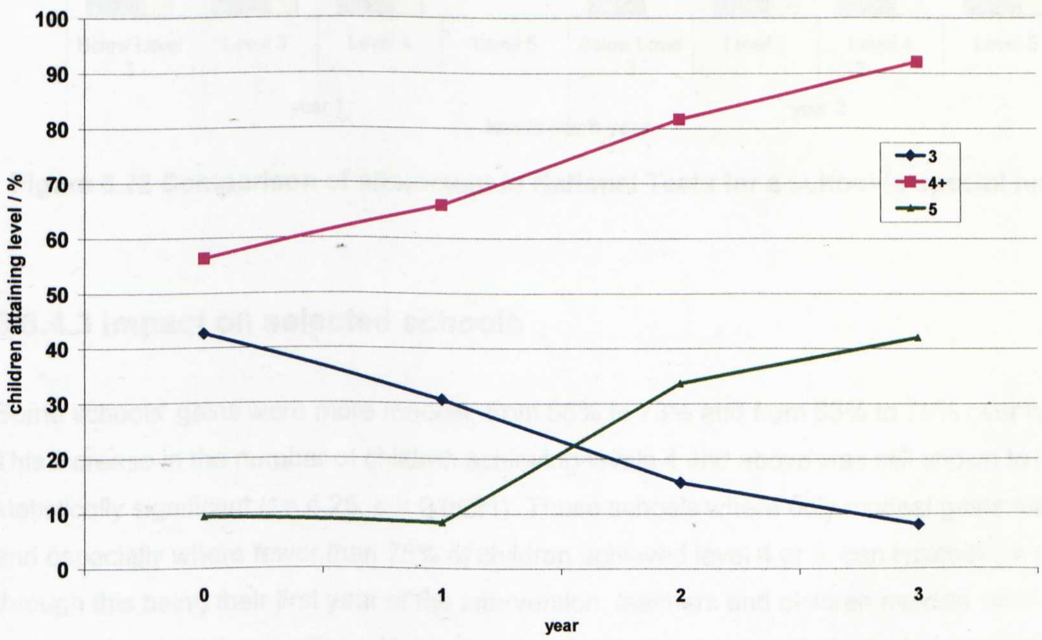

Figure 6.21 Children's increased attainment in National Tests in 3 selected schools

6.8.4.2 Impact on a school in Ofsted 'Special Measures'

Figure 6.22 illustrates the impact in one year for a school that had been placed in 'Special Measures' by Ofsted. The school was starting from a low baseline, but did make dramatic improvements. More than half the children were performing at below level 3 on their SATs with no children performing at level 5 (n=21). This changed to no children below level 3 in science and 37% performing at level 5. Before the intervention only 13% of the children were performing at level 4 (the government benchmark) and after the intervention English had improved by 18% and maths and science by more than 50%, with science making the most dramatic improvement at level 5 where more conceptual thought is needed (n=22). This illustrates what can be achieved by experiential teaching, building on what children can already do and developing good scientific communication.

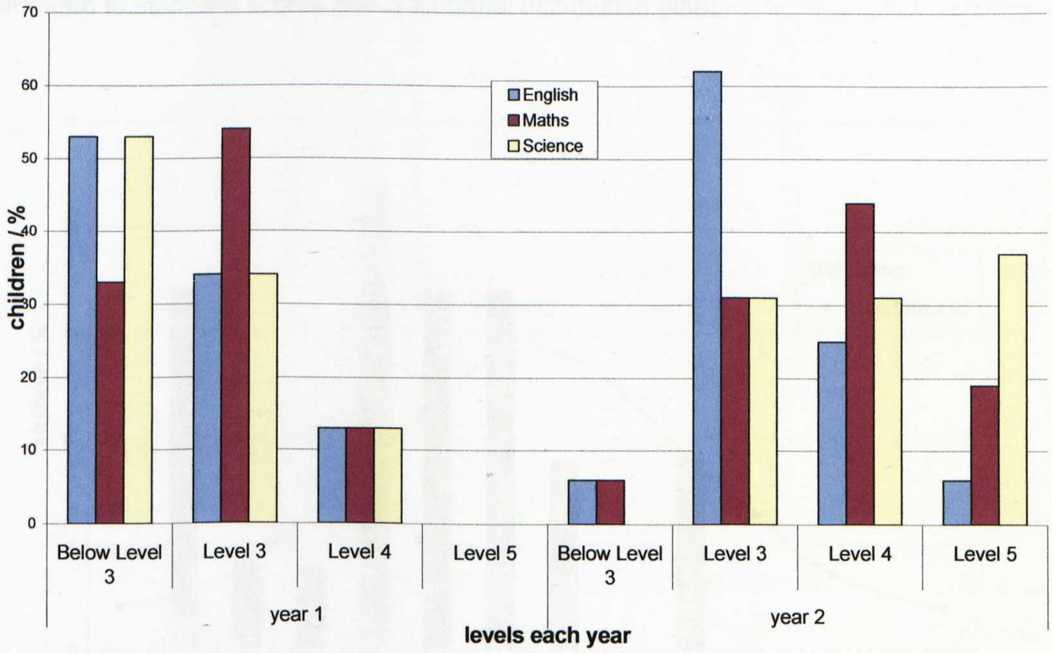

Figure 6.22 Comparison of attainment in National Tests for a school in special measures

6.8.4.3 Impact on selected schools

Some schools' gains were more modest, from 66% to 73% and from 63% to 75% over one year. This increase in the number of children achieving levels 4 and above was still shown to be statistically significant ($t = 4.25$, $p = 0.0021$). Those schools where only modest gains were made, and especially where fewer than 75% of children achieved level 4 or 5, can typically be explained through this being their first year of the intervention: teachers and children needed more time to adopt and embed the practices. However, there is another important element that explains schools making only modest gains, which is that typically in these schools the headteacher or class teachers tended to adopt only minimal ideas from the intervention, and did not alter their policies and practices to the extent suggested through the intervention. This illustrates the concept of capability within the teaching staff which has been referred to in section 3.6.5.

In order to demonstrate one of the ways in which some of the intervention schools differ from one another, and from schools generally, the researcher obtained data on Cognitive Ability Scores (CAT scores) devised by NFER. These are Non Verbal Reasoning (NVR) scores and are measures of children's cognitive ability. They provide a measure of natural intellectual ability. They are used by some schools to provide a way of predicting likely learning outcomes. CAT scores are normally distributed, with a mean of 100. The distribution of CAT scores in three schools is shown in Figures 6.23 (n=41), 6.26 (n=28) and 6.25 (n=30), together with the CAT scores of a normally distributed population. The charts show CAT scores from the schools (bars) compared to standard scores giving a normal distribution (line).

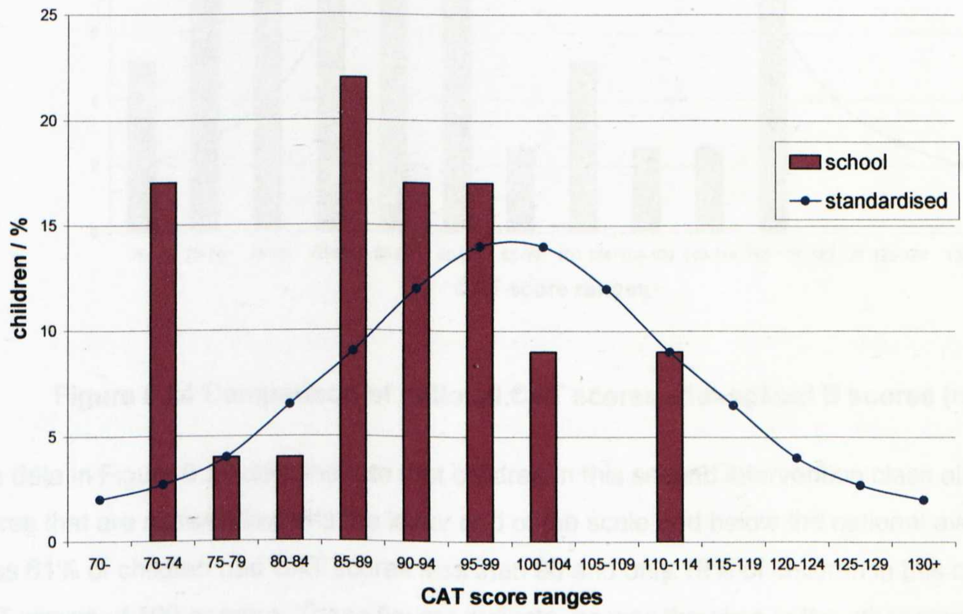

Figure 6.23 Comparison of national CAT scores with school A scores (n=41)

The data in Figure 6.23 demonstrated that children in this intervention class have CAT scores skewed towards the lower end of the scale and are below the national average. In a normally distributed population about 24% of people would have a CAT score of less than 90, but in this class 47% of children had CAT scores less than 90. Further, in a normally distributed population 50% of the population would have CAT scores of 100 or more, but only 18% of children in this class have CAT scores of 100 or more. These figures indicate that the cognitive abilities of children in this class are well below average. We would expect children's scores on tests in all subject areas to reflect these CAT scores: in such circumstances we would expect them to be below average in english, mathematics and science.

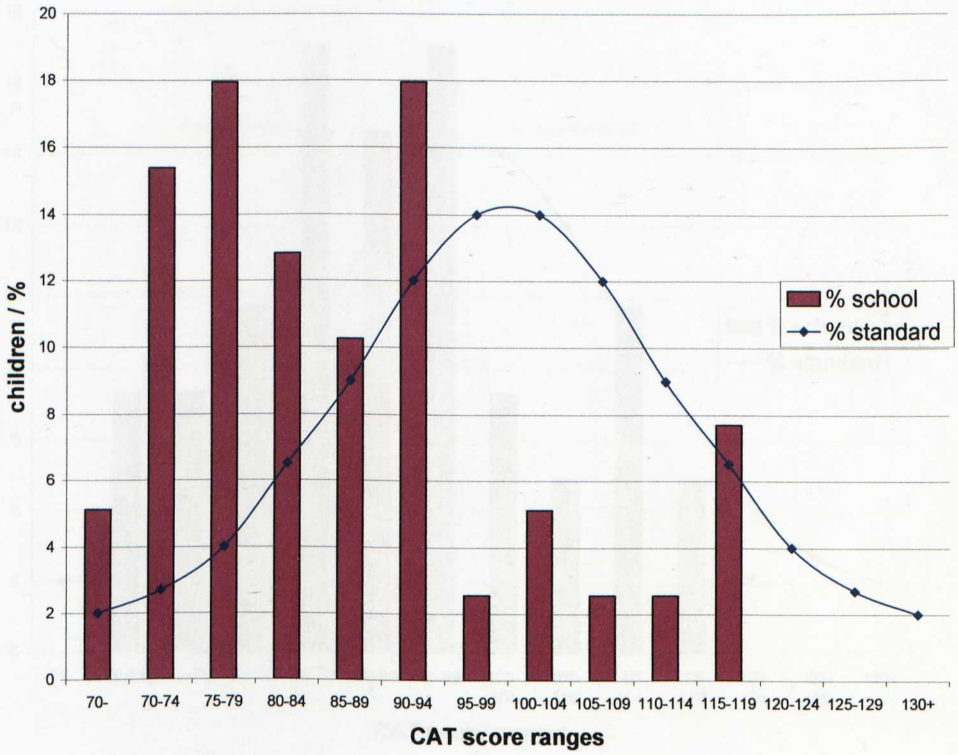

Figure 6.24 Comparison of national CAT scores with school B scores (n=28)

The data in Figure 6.24 demonstrate that children in this second intervention class also have CAT scores that are skewed towards the lower end of the scale and below the national average. In this class 61% of children had CAT scores less than 90 and only 18% of children in this class have CAT scores of 100 or more. These figures indicate, as was the case in the other class, that the cognitive abilities of these children were well below average. In this class about 50% of children are more than one standard deviation below the CAT national average. We would expect children's scores on tests in all subject areas to reflect these CAT scores. In such circumstances we would expect them not only to be below average in english, mathematics and science, but we could reasonably expect their scores to be very much below average.

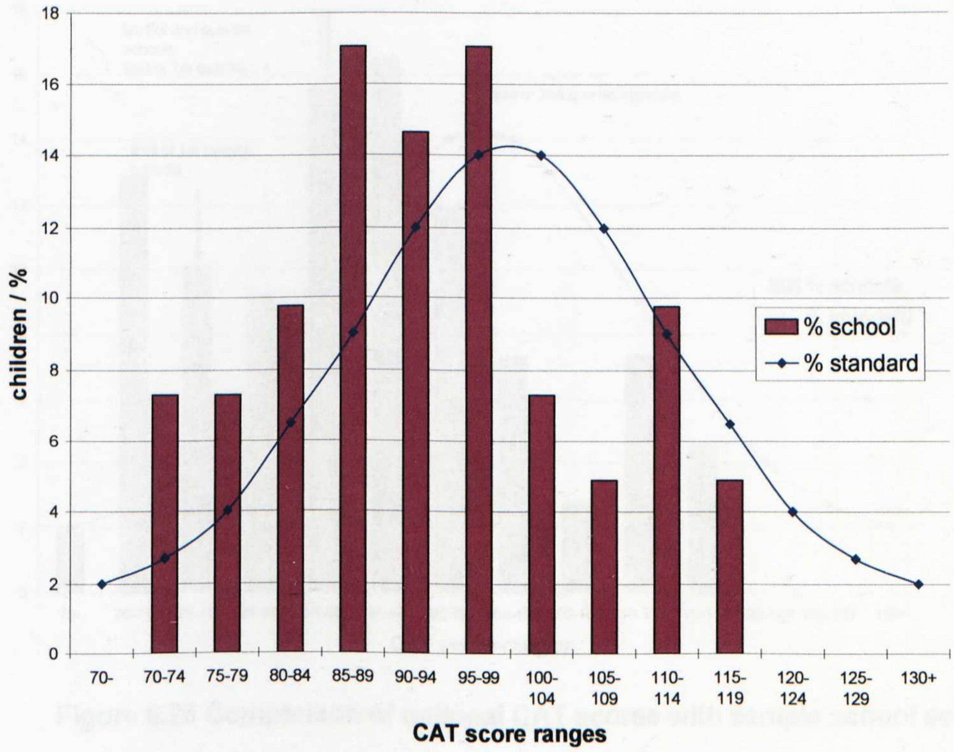

Figure 6.25 Comparison of national CAT scores with school C scores (n=30)

The data in Figure 6.25 demonstrate that children in this third intervention class have CAT scores that are also skewed towards the lower end of the scale and are below the national average. In this class 41% of children had CAT scores less than 90 and only 27% of children in this class have CAT scores of 100 or more. These figures indicate, as was the case in the other classes, the cognitive abilities of these children again were well below average and we would expect the children's scores on tests in all subject areas to be considerably below average. In all three schools the CAT scores are well below average and combining the data from these schools gives an average picture for a sample of 109 children in Figure 6.26. For all schools 50% of the children score below 90 and only 22% of children scored above average. For all schools the first quartile (25% of children) score below 80 and the second quartile (50% of the children) score below 90. The mean value for CAT scores for these schools is 88 which is very low. However Figure 2.26 shows that even within this group there are some highly intelligent children.

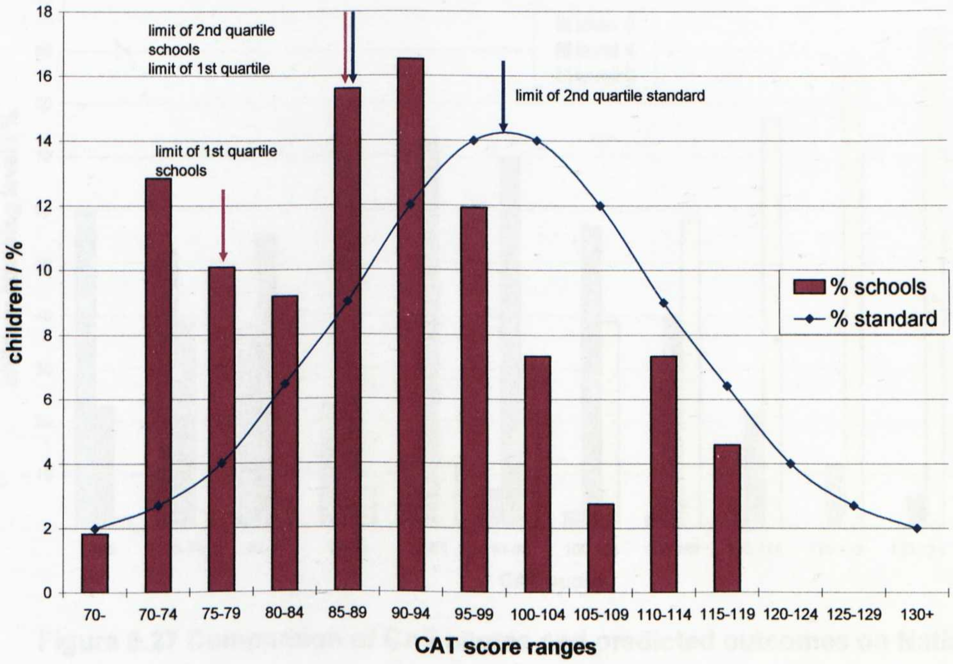

Figure 6.26 Comparison of national CAT scores with sample school scores

However all these data provide an indication of what is possible when children such as these are taught effectively. These data demonstrate that children who are categorised as below average and in many cases, much more than one standard deviation below average, are able to achieve learning outcomes that are at least as good as those from the normal population when effective teaching techniques are applied in their science classroom. The children are better able to understand and apply their knowledge and this motivates them so they respond in a more positive way.

Figure 6.27 shows the predicted outcomes on National Test performance for ranges of CAT scores.

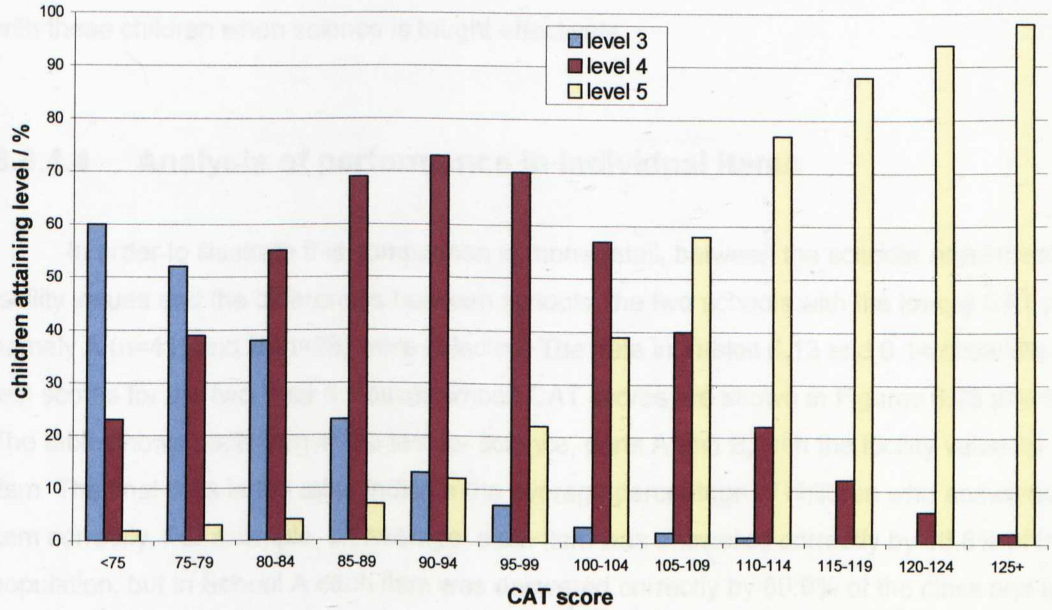

Figure 6.27 Comparison of CAT scores and predicted outcomes on National Tests

Figure 6.28 compares the predicted outcomes according to CAT scores and the actual outcomes for this sample of children.

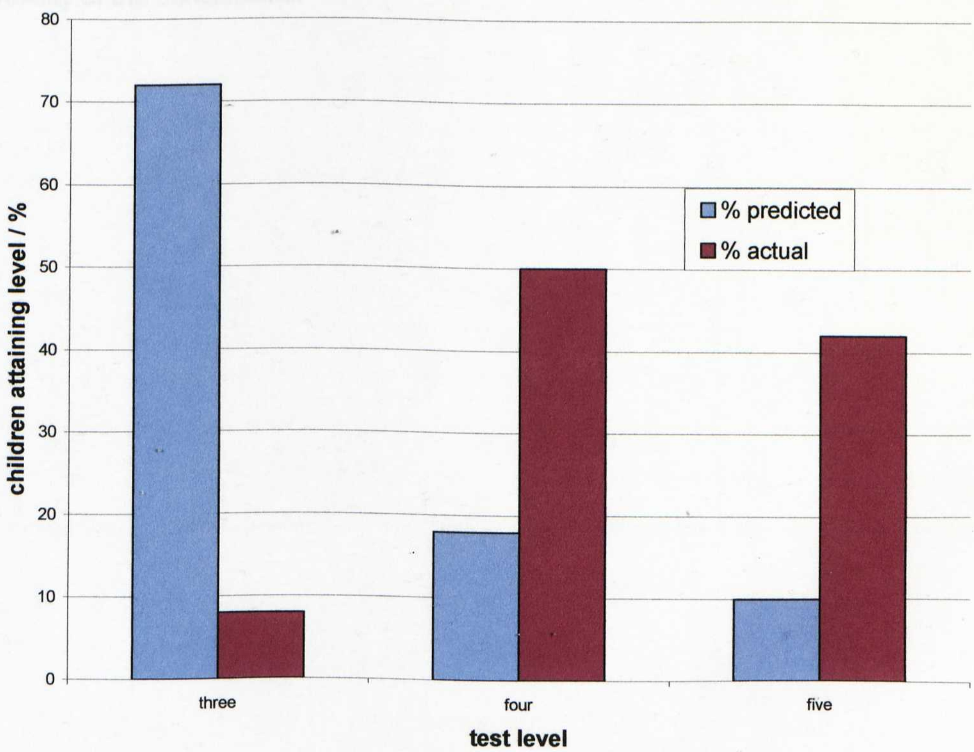

Figure 6.28 Comparison of CATs predicted performance with actual performance

Figure 6.28 is showing that according to CAT scores more than 70% of the children should be attaining level 3 and 10% level 5. whereas less than 10% of the children attained level 3 in that year and more than 90% are attaining levels 4 or 5. All the comparisons show what is possible with these children when science is taught effectively.

6.8.4.4 Analysis of performance in individual items

In order to illustrate this comparison in more detail, between the schools' attainment and facility values and the differences between schools, the two schools with the lowest CAT profile namely A (n=41) and B (n=28) were selected. The data in Tables 6.13 and 6.14 show the SAT test scores for the two Year 6 classes whose CAT scores are shown in Figures 6.23 and 6.24. The table shows each item in the test for science, parts A and B, with the facility value for each item. The final cells in the table indicate the average percentage of children who answered each item correctly. For example, on average, each item was answered correctly by 66.8% of the population, but in School A each item was answered correctly by 69.9% of the class and in School B by 67.9%.

This is simply a comparison of two classes in one year's test and questions have been selected to illustrate the points to be made. However throughout the intervention, in numerous classrooms with a variety of teachers, similar responses were made from the children, which support the validity of the conclusions.

Table 6.13 Comparison of schools' performance in National Tests with national data (Test A)

School values compared with national facility values

Test A question	Facility value %	School A children %	School B children %	Test A question	Facility value %	School A children %	School B children %
1ai	92	75	83	6a	47	11	40
1aii	74	86	70	6b	91	86	75
1bi	98	100	100	6ci	95	89	88
1bii	92	96	95	6cii	82	93	78
2ai	86	86	88	6d	72	89	70
2aii	93	96	90	7a	61	79	38
2aiii	79	82	68	7b	96	86	93
2bi	85	86	90	7c	58	18	58
2bii	60	36	65	7d	36	61	75
2biii	65	32	50	8a	79	71	75
3a	91	89	83	8b	58	61	63
3bi	57	64	68	8c	60	61	58
3bii	40	61	63	8d	42	54	45
3c	39	86	70	8e	80	75	73
3d	60	89	63	9ai	45	43	55
4a	65	57	55	9aii	38	21	58
4bi	64	64	65	9aiii	33	18	55
4bii	44	61	58	9b	73	61	75
5a	78	82	80	9c	52	36	70
5b	61	64	65				
5c	75	89	73				
5d	73	93	63				

Table 6.14 Comparison of schools' performance in National Tests with national data (Test B)

School values compared with national facility values

Test B question	Facility value %	School A children %	School B children %	Test B question	Facility value %	School A children %	School B children %
1ai	87	89	88	6ai	92	100	90
1aii	77	71	85	6aii	93	96	93
2a	66	71	58	6b	78	89	55
2b	44	61	70	6c	22	54	20
2c	63	75	60	6di	46	61	48
2d	31	61	40	6dii	39	61	48
2e	26	36	28	7ai	94	100	90
2f	86	93	78	7aii	93	93	93
3a	79	100	73	7aiii	94	96	93
3b	64	93	80	7b	81	86	60
3ci	63	36	68	7ci	55	54	62
3cii	66	50	63	7cii	50	50	60
3ciii	55	32	68	8a	62	82	63
4ai	86	96	80	8b	61	68	43
4aii	81	93	70	8ci	47	32	45
4b	54	54	55	8cii	48	36	35
4c	60	68	75	9a	82	82	80
4d	78	89	95	9b	85	75	70
5a	95	100	90				
5b	47	61	68				
5c	49	57	45				
				Mean (tests A+B)	66.8	69.9	67.9

In comparing the children's scores with the national scores, on many items the percentage of intervention children's correct answers is higher than the national average. This demonstrates the effectiveness of the intervention unequivocally: children of less than average cognitive ability are able to score above the national average as a result of their involvement in the intervention. A statistical analysis comparing the intervention children scores with the national average scores, involving a *t*-test, showed that for School A the children's scores (mean = 69.9) were higher than the national average (mean = 66.8). This difference was not statistically significant, however combining the higher performance and the lower CAT scores for this school and the school's proximity to the significance value of 0.05 suggest the intervention is having an effect (n=41, $t = 1.72$, $p = 0.0896$). In the case of School B the children (mean = 67.9) scored slightly higher than the national average (mean = 66.8), but in a statistical sense there was no difference between the groups (n=28, $t = 0.77$, $p = 0.444$).

However, this lack of statistically significant difference between the scores from the two schools and the national average scores needs to be placed in the context of the CAT scores of the intervention children. That the intervention children, with CAT scores highly skewed towards the lower levels, could score anywhere near the national average is exceptional. The scores of Year 6 children in each school exceeded the national average, and in School A their higher scores were very nearly statistically significant. The children had achieved a remarkable outcome in SAT scores given their CAT scores. This outcome demonstrated, with certainty, that involvement in the intervention has increased the learning outcomes of these children.

Tables 6.16 and 6.17 show that the overall trend for those questions which are recall based is random in their distribution of marks, but those which are testing application of scientific knowledge and understanding, intervention schools tended to perform better than the national average, again stating that this is with children whose CAT scores are well below the national average. A particular feature of the intervention was to develop understanding and the ability to communicate science effectively rather than rote learning of scientific facts. If this is so the SATs answers should illustrate this. In order to illustrate this analysis certain questions have been selected and are analysed in more detail in appendix 9. A sample of the commentary is shown below.

Context: photograph which shows some children hitting a kettle drum.

Question:

(b) Nuala uses the drum-stick to hit the skin of the drum in different ways.
Describe how the loudness of the sound is affected by the force of the stick hitting the drum.

Category: Application question:

Performance

Item	Facility value	School A	School B
A3bi	57	89	83
A3bii	40	64	68

Discussion:

(b) This type of question, where the children have to summarise data or make a generalisation, occur at various stages in the papers and indicate a level 5 response. A general fault is that children either quote results that are given in the question, or only make a statement for one scenario. This is a question type we have specially targeted to develop their ability to express their knowledge in the required format. An indication of this is that children who do not make a generalisation only gain one mark as is shown here, but it may be complicated by the children not realising that they have to make a comparative statement. The children were supported by using a mnemonic scaffold. This is discussed in more detail in section 6.8.4.6. The data show that both school A and school B have scored higher than national marks.

Question:

(c) The children turn the screws on the side of the drum to make the skin less tight.
What effect does this have on the pitch of the sound the drum makes when Nuala hits it?

Category: Application question:

Performance

Item	Facility value	School A	School B
A3c	39	86	70

Discussion:

(c) Questions like this are phrased as 'reverse items' so that the children have to use the science to work out the answer and the guessed response of the pitch goes higher is wrong. Both sets of children were given lots of opportunities to look at the effects of changing sounds and always to make a trend statement so they are used to interrogating the data and then giving a response. Again the children have scored higher than national marks, demonstrating that they can apply the information in different contexts. This is an indication of their understanding as opposed to simple recall.

Question:

(d) The children in the class listen to the sound the drum makes.
What does the sound travel through to get from the drum to their ears?

Category: recall question

Performance

Item	Facility value	School A	School B
A3d	60	89	63

Discussion:

(d) As part of the teaching the children had experiences of sound travelling through different media and this was extended into the scientific model of solids liquids and gases using the particle idea. The use of simple models is not strictly speaking part of the Key Stage 2 programme of study, but was found on many occasions to be useful and helped their linking of scientific ideas to the evidence they obtained.

6.8.4.5 Summary data of individual items

Doing summary analyses of these particular questions illustrates the differences in these children's performance on recall and application questions.
For recall questions the marks were as in Table 6.15

Table 6.15 Performance in recall questions, nationally and for schools

Test question	Facility value %	School A children %	School B children %
A1ai	92	75	83
A1aii	74	86	70
A2bi	85	86	90
A2bii	60	36	65
A2biii	65	32	50
A3c	39	86	70
A3d	60	89	63
A7a	61	79	38
A7c	58	18	58
B2a	66	71	58
B2c	63	75	60
B2d	31	61	40
B3b	64	93	80
B3ci	63	36	68
B3cii	66	50	63
B3ciii	55	32	68
B4b	54	54	55
B4c	60	68	75
B4d	78	89	95
B6b	78	89	55
B6c	22	54	20
B7b	81	86	60
B7ai	94	100	90
B7aii	93	93	93
B7aiii	94	96	93
average	66.24	69.36	66.4

The analysis shows that the averages for recall questions, each school shows no statistical difference from the facility value. For school A (n=41, $t = 0.5147$, $p = 0.6091$), for school B (n=28, *t* = 0.0304, *p* = 0.9759) so the null hypothesis that there was a significant difference was not proved. The data for application questions is given in Table 6.16.

Table 6.16 Performance in application questions, nationally and for schools

Test question	Facility value %	School A children %	School B children %
A3bi	57	64	68
A3bii	40	61	63
A4bi	64	64	65
A4bii	44	61	58
A7d	36	61	75
B2b	44	61	70
B6di	46	61	48
B6dii	39	61	48
B7ci	55	54	62
B7cii	50	50	60
average	47.5	59.8	61.7

Here, for the application questions, the results are very statistically significant (n=41, *t* = 3.9200, *p* = 0.0010), and for school B (n=28, *t* = 3.5970, *p* = 0.0021). The very low value for *p* shows that there is a very significant difference between the national figures and these schools.

Table 6.17 Performance in 'trends' questions, nationally and for schools

Test question	Facility value %	School A children %	School B children %
3bii	40	61	63
4bii	44	61	58
6dii	39	61	48
7cii	50	50	60
average	43.25	58.25	57.25

For those questions that involve summarising the data and highlighting a trend as a summary statement (the second parts), the results were again statistically significant, School A (n=41, *t* = 4.0391, *p* = 0.0068), school B (n=28, *t* = 3.4165, *p* = 0.0142).

These data strengthen the view that these children who were in groups that were below average compared to national data, performed extremely well in items where application of knowledge and intellectual activity were required, again showing that the classroom experiences related to evidence based learning were highly effective.

6.8.4.6 The use of scaffolding to facilitate the making of comparative statements.

Scaffolding was used to help the children with scientific communication and to help them in answering comparative questions. In an attempt to develop the children's ability to respond to scientific questions in the 'accepted scientific format', the researcher found that they needed support to do this. Much of language development took place in classroom discussion, but this section focuses particularly on the use of a scaffolding mnemonic to facilitate responses in an acceptable way. The task was to develop children's responses by providing them with a sentence structure demonstrating the children's 'understanding' of the science in an unambiguous communication. This is also necessary for external assessment processes and many of these children were under-performing in 'snapshot' tests because they did not respond, in the accepted scientific way, particularly with comparative questions where children were being asked to analyse data for trends. This was another example of where the researcher working alongside the teacher in the classroom, could perceive the difficulties the children were having, then supporting the teacher to solve the problem.

For instance when using a forcemeter, a typical item would be: *Describe how the size of the force affects the length of the spring in the forcemeter.*

There were three typical types of response to this question.
A very common response was:

It increases.
It gets longer

There are two issues with this type of response:

'It' is not defined - is 'it' the length of the spring or the size of the force? Also there is no linking of the independent and dependent variables, the force applied and the length of the spring. The children must compare the effect on the spring when the force is changed, by including a reference to both the force and the spring in their response.

An alternative response commonly encountered was that they would use a sentence which simply quoted from the data.

"When the force is 1N, the length is 2cm and when the force is 5N the length is 10cm".

They would not get credit for this response, because they were merely repeating the information given in the question and they were not demonstrating unequivocally, they have interpreted the trend.

A third type of response was one where the children composed a long, convoluting sentence which never really got to the point or answered the question. They might have quoted relevant points (which gain marks) or they might not. This type of response relied to a certain extent, on chance.

An example of this type of response would be:

"when the force is big, so for a big force the spring would stretch and the stretching is caused by the force on the spring, so it is long. So when the force is big the spring is 5 and when it is small it is 2".

In this example the child initially, is only discussing a large force and he may be assuming the comparative answer for the smaller force and the child will not get credit for assumptions. In the second part where he compares the larger and smaller force he has actually mixed up the size of the force (5N) and the distance (2cm) and this may be because he has forgotten what he said the first time and cannot hold everything together.

The accepted scientific response to this item would be of the style:

The bigger the force, the greater is the stretch of the spring
The bigger the force, the more the spring stretches.

Or the converse:
The smaller the force, the smaller is the stretch of the spring
The smaller the force, the less the spring stretches.

The class responses to comparative questions were analysed before and after the intervention process. Firstly, the class were helped to adopt a sentence structure by the use of fun verbal activities. Here the teacher, in an animated way, promoted and used a mnemonic to put over the idea of a simple, comparative sentence structure. The mnemonic was in the form of a two part train rhythm running over rails, di da di di dah, di da di di dah. They practised the rhythm till they could say it themselves. Secondly, the class needed to be taught which variable (force or spring) was put first - by simply asking them the question - in the investigation, which one did you change? (force), this goes first and the third part was to identify the trend illustrated in the data.

This fragmented the problem. The approach taken allowed the children to juggle the two statements mentally and come up with the correct order. This would only support those children who could do this but were struggling to put the ideas into some semblance of a simple scientific format. The use of the mnemonic here was not another form of rote learning, it was an example of scaffolding. In that it supported the children in what could be for them a complex task. They still had to:

- identify the two variables;
- identify the trend in the data, and
- construct a sentence using an appropriate scientific format.

Scaffolding helped the children cope with the complexity of a task, process how they could accomplish the task, and actually complete the given task, independently. The term scaffolding was first used, in an instructional context, by Wood, Bruner, and Ross in their 1976 article, "The Role of Tutoring in Problem Solving" (Wood, *et al.,* 1976). They used the term "scaffolding" as a metaphor to describe a "process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts" (p. 90), which is exactly describes the situation here. The concept of scaffolding has taken root from Vygotsky's theoretical concept, the Zone of Proximal Development. The Zone of Proximal Development is the "area between what children can do independently and what they can do with assistance" (Clark and Graves, 2005, p. 571). These children were at the Zone of Proximal Development because they could identify the variables and interpret the trend. The mnemonic was not simply to aid memory by affecting neural paths, it was a fun activity which provided them with a framework for their response. In order to complete the mnemonic the children had to identify the variables and trends in a set of data, then use the mnemonic to provide a simple rhythm, limiting the number of words they could use to fit their response into. This was an example of operational thinking.

Comparisons were made using SATs questions before and after the use of a mnemonic to scaffold the children's communication skills on comparative/generalising questions. Figure 6.27 shows the improvement in performance by using the intervention strategy which increases the success rate from below 40% to 80%. These questions are rated at level 5 by QCA because they involve more than simply recalling scientific reasons for phenomena: they involve intellectual processing of the data into a given format.

A comparison has also been made between national facility data and the performance of three schools. There are two issues that are illustrated here, one is the improved performance of the three schools generally over national attainment on this type of question (Figure 6.27) and the second was the closeness of the second mark to the first with the these schools compared to the fall off from an average of 56% to 43% in the national figures. In this type of item the first mark is for identifying a trend and the second is for making a comparison. This illustrates that these children are making statements which include variables, trends and accepted scientific communication of a comparison.

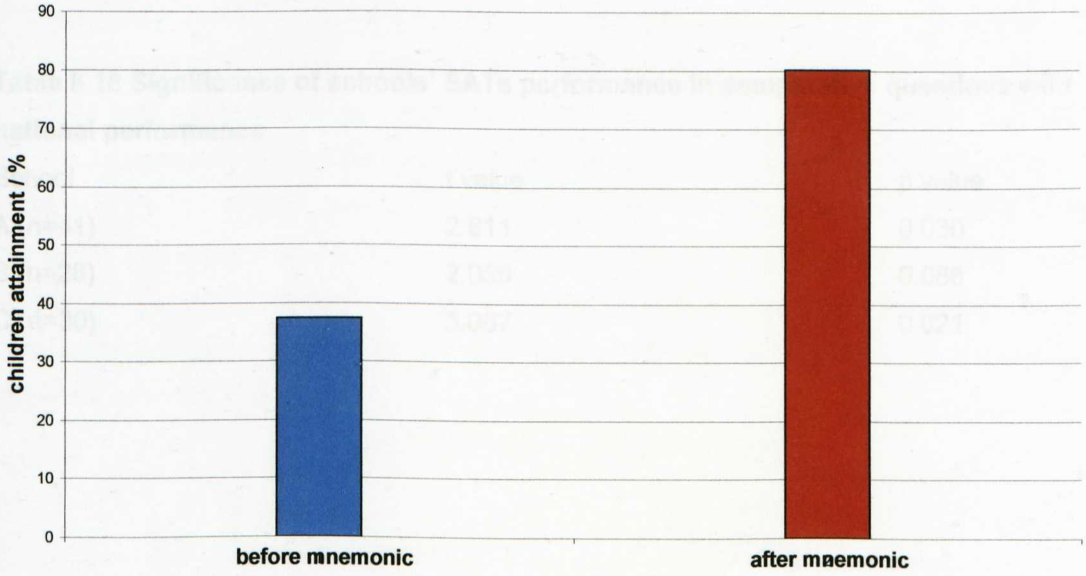

Figure 6.29 Comparison of SATs performance in comparative questions before and after mnemonic

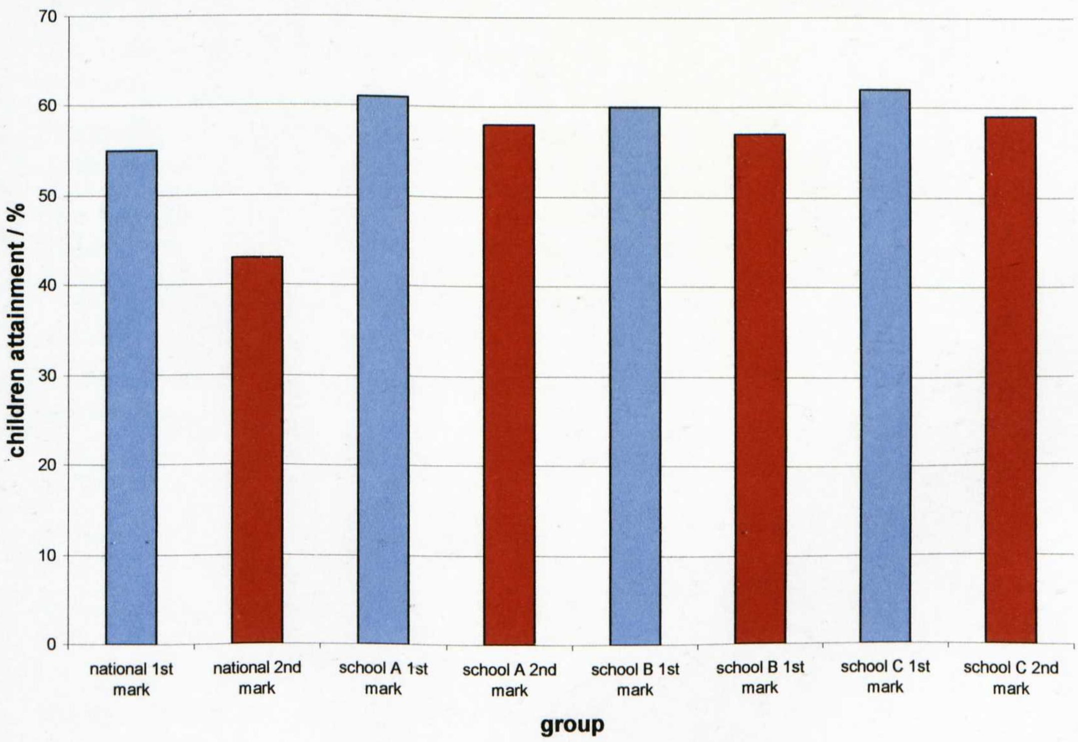

Figure 6.30 Comparison of schools' SATs performance in comparative questions with national performance

The statistical significance of these was analysed using a *t*-test comparing the national facility values to the individual schools in turn and the increase in scores for schools A and C was statistically significant and for school B was not quite statistically significant in conventional terms, but again referring to the overall CAT scores for these children, something has improved their performance.

Table 6.18 Significance of schools' SATs performance in comparative questions with national performance

School	t value	p value
A (n=41)	2.811	0.030
B (n=28)	2.056	0.085
C (n=30)	3.087	0.021

6.9 Triangulation questionnaires and interviews

6.9.1 Discussion of questionnaire

This aspect comprised two strands a) a survey of fifteen Headteachers and b) more detailed interviews of six Headteachers. Data from the survey are shown in Table 6.19 The overwhelming response to this survey was that Headteachers (n=15) valued the intervention, that staff had undergone professional development and that children had gained from the school's involvement. Looking at the survey data, the Headteachers stated that all staff involved had become much more confident in teaching science and more knowledgeable about science. They also noted that colleagues not directly involved, had gained through interaction with their colleagues. The Headteachers highlighted improvement in children's attainment in science and in improved children's attitudes to science.

Table 6.19 Survey of Headteachers

	Item	Strongly disagree	disagree	Cannot say	agree	Strongly agree
1	The intervention has been beneficial to your school			1	2	12
2	Teachers who have been directly involved with the intervention in school have reacted positively				4	11
3	Teachers who have not been directly involved with the intervention have reacted positively			1	4	8
4	The subject knowledge of teachers involved has improved			2	3	10
5	Teachers involved are more confident in teaching science as a result of the intervention				3	12
6	There have been opportunities to discuss the work of the intervention with other colleagues in school		2	1	4	8
7	There have been direct changes to whole school science as a result of the intervention		1		4	9
8	The headteacher has been directly involved with the intervention		3	3	3	6
9	The science co-ordinator has been directly involved in the intervention				2	13
10	Children in the target group have progressed as a result of the intervention				4	11
11	Assessment evidence shows that children in the target group have achieved higher levels of attainment			4	3	8
12	The attitude to science of children in the target group has improved				5	10
13	The school is implementing an evaluation of children achievement as a result of the intervention		1	3	3	8

Any other comments:

There were a few differences in responses between Headteachers of schools in the second year of the intervention and those for whom it was the first year of involvement in the intervention. Some of the Headteachers of schools in the first year noted that they had not really been involved in the project (item 8) and that they had not had opportunities to discuss the project with colleagues (item 6). Some of these Headteachers also noted that they were not yet able to identity gains in attainment (item 11) as a result of the intervention, and had not yet looked at the possibility of evaluating children's achievement as a result of involvement (item 13). These outcomes were to be expected. It had already been emphasised that the first year of involvement is one of rapid learning, and that policy changes require longer time. These data demonstrate that Headteachers of all schools in the second year of the project agreed or strongly agreed with virtually every item in the survey, and that many Headteachers from the first year cohort agreed with most items

The Headteachers reported, in their free comment section, that as a result of the intervention, alterations had been made to the topics being taught in science and to the manner in which they were taught. The Headteachers also reported that investigative science was now taught to younger children and that revision and test materials provided by the project had been incorporated into classroom practices. They were clear about the roles of their science co-ordinators, and some had already implemented ways to support the initiatives once the intervention had finished. These data demonstrated that schools in the second year of the intervention had moved towards institutionalising changes to science teaching practices. In these schools, developments in science teaching and improvements in children's learning were more obvious, ongoing and likely to continue than was the case for schools in their first year of involvement.

Six of the Headteachers were interviewed by an interviewer independent of the intervention. All these Headteachers expressed the view that the intervention had been of value to their school, especially through the professional development provided to their staff and through the reorganisation of their schemes of work. This could be deduced from the words of the responses as well as the positive way in which these were expressed in the recordings. This illustrates immediately the value of recording the responses. Also the interviewer from her notes indicated the positive nature of the responses. All these data triangulate and corroborated the evidence from other aspects, that there has been an extremely positive impact.

The questionnaire used by the interviewer is given in appendix 10.7.

6.9.2 Discussion of individual questions

The interviews of Headteachers as a means of triangulation and evaluation of the whole intervention was chosen for several reasons. The networks were selected to give all the facets of a range of schools. There was one school that was new to the intervention, one school that had mixed experiences, one special school and three other schools. The interviewees were Headteachers, therefore in a senior position in the school so used to being truthful in responses. The interviewer had also held a senior position in a school so was familiar with education and its arrangements and used to communicating at a senior leadership level. Also because the interviewer was not directly involved in the intervention, she was able to keep an independent view of the evidence. The Headteachers had all been involved in the intervention from their initial meetings, questionnaires, and their general monitoring throughout the intervention. Headteachers have an overview and might be prepared to divulge areas of dissatisfaction. There is a question with many interview studies where circumstances and personal views may affect the extent to which the interviewee freely gives, or partially withholds certain views. This criticism of the introduction of bias was highlighted by Tuckman (1972) but this did not seem to be the case here as the Headteachers were able to give positive and negative opinions about the impact of the intervention and these opinions were checked against the researcher's views of how the intervention had progressed and whether or not the research questions had been answered. The interviewer reported that the interviews had been responded to honestly and frankly. There is no numerical evidence for this assumption and this is where the interviewer has to make a value judgement about truthfulness and frankness, since this an experienced senior leader in a secondary school, she should be capable of making such judgements. The interview was seen as an informal method of gathering data, so was popular with Headteachers who perceived this as simply talking about the intervention. All the interviews were prearranged so the Headteachers had allocated the time for the interview in their schedule. A focused interview was chosen as the most appropriate type of interview for this purpose and based on the work of Merton et al (1990) the structure was based on the principles they set out and modified slightly to suit our needs. All the interviews were conversations with a structure and purpose that were controlled by the interviewer, the outline of the questions had been prepared previously. The questions were devised to test the hypotheses in the research questions and the findings through the intervention. The questions based on these hypotheses were devised prior to the interviews, yet the interviewer was open to new and unexpected responses and the interviewer was free to explore and clarify these responses.

Since the interviews were recorded as well as the interviewer making brief notes about the conversations taking place, the intonations of the responses and the tone of voice, which may have a major significance could be recorded, along with the words actually used. As Kvale (1996) considers "the subject matter not as object data, but as meaningful relations to be interpreted", or as Rubin and Rubin (1995, p 39) state "Knowledge in qualitative interviewing is situational and conditional". Hitchcock and Hughes (1995) describe two main strategies for analysing data firstly, become very familiar with data and secondly create meaning and analytical categories –in this way the meanings are grounded in the data they emerge from and reflect the data. So these recommendations of Miles and Huberman (1994) were followed. The responses were based on the subjective experiences of the Headteachers and the validity of the responses could be tested. The tapes were listened to in addition and transcribed so the responses could be coded according to the triangulation principles and answering research questions. This type of research does not have to look objectively and interviews can be free of bias and provide objectivity by the agreement among the different aspects of the analysis. Then analysing the data according to Kvale (1996), narrative structuring created the coherent stories; and meaning condensation abridged the comments expressed by the interviewee into briefer statements and categorisation for coding of the responses. Analysis of data below includes a sample of the responses as well as interpretation of these responses which was initially completed by the researcher and interviewer jointly. This interpretation of the transcribed interview by the interviewer and researcher led to evidence that could be considered as general, and was reliable and verifiable. Some responses indicate validity generally and some responses rely on interpretation.

The Headteachers spoke of their staff developing new questioning techniques for science and of pacing science lessons more effectively. They also spoke of the new enthusiasm of their staff for science and the confidence to develop a pragmatic approach to alter classroom practices through team teaching and demonstration lessons. All of this was different from a more theoretical approach to teaching science. The Headteachers had no doubts that the subject knowledge of their staff in science had increased markedly, and that teachers were now more confident in planning for and teaching science. As part of the intervention, the researcher had worked side by side with teachers in their classrooms. Headteachers identified this aspect of the project as crucial to influencing the day to day practice of teaching science, in demonstrating effective techniques for teaching science and in the longer term professional development of their staff.

An interpretation of a sample of Headteachers' responses from the interviews are given below:

Question 1

Example quotes from Headteachers are as follows:

"Oh, yes. Certainly. In many different ways ... In many different ways ... In terms of INSET, delivery, quality of teaching and learning, materials. Yes, certainly. Yes."

"Yes ... invaluable. We have got a lot out of it. the staff training has changed the way, in which they teach science drastically."

"Yes, it has. Overall, it has. As I said, we have had contrasting experiences, the first year not being as successful as the second.

This contributes particularly to the triangulation process, since it was true that the school referred to in the third response had had differing experiences in the two years. In the first year there was minimal contact due to a variety of circumstances and therefore little involvement. In the second year there had been much more involvement and the quote confirms this and as the quote demonstrates a much more rewarding experience.

Question 2

All the Headteachers cited the presence of the link person as being crucial. This provided a level of support not felt by other forms of INSET. Here advice could be tailored to the school's perceived major needs and this triangulates with the responses to the next question. Normally teachers would have to implement what they have learnt from the training in their particular circumstances. The responses show the value of a long term commitment to the school. A major aim from the intervention was to demonstrate that the principles we were advocating could have an impact in their classrooms with their children.

"The link person's input has drastically changed the way and the pace of the Science lessons go."
"... I have never had somebody, who has affected the teaching practice quite as much, supporting staff, certainly, the classes have progressed considerably".

In the latter quoted response to this question the headteacher confirms the important factor as being the link person, but the recordings also show with this and a number of other responses, that there is less awareness of what happens in classrooms. The responses of one Headteacher are generally more vague than is the case with the other Headteachers which again illustrates the point made by Kvale (1996) that the way something is said is at least as important as the words used. Here the researcher is making an interpretation of the responses. This is supported by other aspects of the school for example the drabness of the décor and the lack of enthusiasm among the staff - a general malaise.

Question 6

The responses to this question confirm one of the aims, which was to be realistic in the amount of new knowledge passed on. These, in the main, were not teachers with science degrees and there was no attempt to make them so and the knowledge given to them was centred around the key concepts for the topic. The teachers could then use these key concepts to answer the children's questions and make judgements about the correctness of the children's responses. This is because they were adults and have reached a level of maturity where they could apply the key concepts to a variety of scenarios. Their learning of science at school has produced compartmentalised knowledge and a lack of awareness of what were the important features which would allow for a wider application. This was the focus of the INSET sessions and the in-class support, to provide key concepts, yet the teachers felt that their knowledge and understanding had increased dramatically as the following responses illustrate:

"Drastically, yes. picks out the important strands. So, it sharpens their understanding."

The unanimous nature of these responses again illustrates the successes of our main aims which was to raise the level of teacher knowledge in key areas.

Question 7

An important aim was to improve the teacher's confidence about teaching science, by taking away the mystery of science, as they perceive it. This was the researcher's view of their perception of science as being something which is hard and this is confirmed by the unsolicited comment of one headteacher:

"Yes. Through the INSET and also through the commonsensical way of delivering it, really. Because Science can be quite mythical, in fact, to most people, can't it really, who do not understand it. I think the fact that ... What are we going to use and what are the variables and people are saying: "Gosh, it is that easy ... doesn't that make sense ?'"

Question 16

The responses demonstrated that the benefits would not be lost with the passage of time and the Headteachers were confident that by sharing good practice throughout the school that standards as assessed by SATs performance and the enthusiasm generated in the classroom, would not be lost. There were real benefits from the work that would be maintained in the future.

"Out of all the interventions that we've been involved in, I would say that a 'plus' about this is that it has been structured in such a way ... So that, as a self-contained unit, which can be continued it has been very, very useful"

However, there are some responses that indicate much more enthusiasm in doing science, which links to the next question about attitudes to science.

"Girls are doing better on the science. If what we think they are going to get in the end of SATS actually comes to fruition there will be a definite improvement.

"The motivation levels of the children are really high, because it is practical based. If you could actually look at their attendance on a Friday you would see how it has increased.

"Undoubtedly, simply because they told me what they'd been doing and how much they've enjoyed it, and their description of it has demonstrated that they have understood it

Question 20

"They enjoy science more." "Their attitude to Science is improved ... Without a doubt." "Yes, yes."

All the responses to item 20 indicate very strongly that attitudes to science have improved. This is indicated by the text and that all the responses are very positive, but also from the enthusiasm that the Headteachers showed in the way they answered.

Question 23

Again the unanimity and the strength of feeling in the nature of five out of six of the responses indicate that the whole experience has been very positive:

"No. No, not really, no. I mean, in conclusion I would say that there has been a big improvement in the quality of teaching and learning in Science, with more emphasis on investigational work and children taking control of that."

But then the interviewer asked specifically about whether the resources that had been produced for the schools had been received. *"Unless they've been sent and they've passed me by, which is quite possible."* The deputy headteacher had all the relevant copies of materials. This again illustrates the honesty related to the answers but the lack of awareness of this Headteacher.

The data from the questionnaires and interviews triangulate with the interpretations made in previous sections by the researcher about the impact on teachers and children and what the researcher was attempting to achieve.

6.10 Summary

The profile of the background of teachers has been found to be similar to that of the national profile (House of Commons Report 1995), but with the advent of science for all and the introduction of national curriculum science, the knowledge of science has increased. However, as the assessment of teachers has shown, this will undoubtedly include some incorrect ideas.

The surveys have shown that science is among their preferred choices of subject, but the preference is for life sciences rather than physical sciences. Also they find science enjoyable but do not feel confident. The training sessions to address these topics showed that the sessions were well received and the correct balance was achieved between subject knowledge and addressing their misunderstandings.

The assessment of teacher knowledge again has shown a deficit in teacher knowledge about physical sciences, but as the concept mapping analysis has shown the profile matches that of other science students as shown by Van Zele et al., (2004). Although the numbers were different the proportion of incorrect responses matched those of the children. Incorrect responses were given for friction, air resistance and rolling forces. Many teachers thought, as children did, that a force was still acting on a ball moving at constant speed and an upward force was still acting on a ball moving upwards, which illustrates the problem with transmissive teaching.

Teacher confidence was assessed on a 5 point scale over thirty two items covering the main areas of science knowledge and scientific investigations. In all cases confidence was seen to have increased. The score of the confidence level before the programme was always less than three and at the end of the programme was always greater than four, with the largest increase being in physical sciences and scientific investigations. The longitudinal data has shown both the more closely the researcher has worked with the teacher, and the longer the researcher worked with the teacher, the greater has been the impact. This confirms Joyce and Showers (1995) findings that continued professional development of teachers takes time, although the supportive nature in the classroom was considered, by the teachers, to be crucial.

Forces was chosen as a specific area of study because it was the most requested INSET topic and the one that teachers (and children) contextualised the most and contained the greatest number of wrong ideas. The research followed a constructivist format and it was with this topic that the idea of a 'limited framework' was formulated. The teachers and children changed their ideas and explanations if contradictory evidence was presented to them. So they were not wrong as implied by the term misconception, they were simply 'limited' in their ideas because they had not had contrary evidence presented to them. This applied to scientific thinking generally, where scientific ideas were constantly developing based on new evidence.

One way in which the teachers were supported, was in the thinking of activities the children could do, which would elicit ideas and provide evidence for correct scientific ideas. Also, in helping the science coordinators, the topics were arranged in a logical sequence and an order of difficulty. The aspects which would impact on the new strategies for teachers were also considered particularly the emphasis on a dialogic approach within a Non Threatening Learning Environment, the emphasis always being on the children using the evidence to enable them to form conclusions, rather than simply telling them the answer. How the scientific story develops from an open rather than a closed discussion has been related to the choice of activities, but the researcher was on hand with the teacher the moment that problems arose, but with a traditional workshop INSET this would not have been possible. A further way in which teachers were supported was in the application of existing good ideas for example planning boards for investigations which have been used to develop investigative practice. These provided a logical framework that the children find easy to follow, thus allowing the children to think about the variables, prediction, tabulation and display of results, rather than the setting out of the investigation. Comparisons have been made between developing teachers and how the teachers used and adopted the approaches and those of limited capability who found this more difficult.

The assessment of children has focussed upon assessing their understanding because this was considered more useful for addressing 'limited frameworks', whereas recall assessments could still allow 'limited frameworks' to persist. In an attempt to do this Science Reasoning Tasks were trialled but these proved to be unsatisfactory in assessing conceptual levels and particularly in differentiating between children. So a method of assessing children's knowledge and conceptual development was using pre and post tests containing some free response items. These showed a very significant improvement in post test results compared to pre test results. Further assessment of children's performance was by National Test items (SATs) because these results are valued by Headteachers, governors and Local Authorities and are used in the compilation of national league tables. A longitudinal comparison for nine schools showed a significant improvement in national tests results and this is mirrored in all the schools . A comparison was made between national test attainments and cognitive ability (CAT) scores for three schools and these have shown that attainment is much higher than that predicted by CAT scores. A comparison between attainment in recall questions and application questions has shown that attainment in recall questions is broadly in line with national averages as determined by Facility Values, but attainment in application questions showed that this was statistically significantly higher. A comparison of the impact of a mnemonic used was also shown to be positive.

Finally triangulation interviews and questionnaires from Headteachers were used to confirm the impact of the intervention on both children and teachers. The analysis of these questions indeed confirmed the positive impact on class discussion, teacher and children's confidence and teacher's knowledge.

7 Conclusions and Recommendations

This section will discuss the main findings from the research and how this relates to current literature. The development of children is a complex issue, it depends upon the children themselves, the teachers, the interaction between the two and the activities with which they are provided, how the children interpret this evidence and communicate their ideas to others. This is in agreement with the beliefs of Keys and Bryan (2001) who state that virtually every aspect of teaching is influenced by the complex web of attitudes and beliefs teachers hold and this determines how they will interact with the children. The result of this is that no one of these can be dealt with in isolation, nor can it have the same impact as when all of them are developed. Each aspect will contribute to the whole experience of the child. This is a little more refined than the imaginary scenario 'try everything in the hope that some things work'.

Teachers' beliefs of confidence are seen to be important in determining the efficacy of a teacher. An aim was to improve the self-efficacy beliefs and the results of the surveys demonstrate a significant improvement and this effect is greater with a closer involvement of in-class support rather than solely attendance at a workshop.

Discussions were better if the teacher developed the skills to promote an atmosphere of trust, where all the children were expected to contribute. The children were encouraged to inspect the evidence, in drawing their conclusions because this is crucial in developing scientific concepts. This makes the experience more rewarding for both teacher and child. This encourages the children to think about their science and the children can make links between the current topic and other topics within science.

Children's attainment is being influenced by success in a SATs culture prevalent in many schools. However this research analyses attainment using a constructivist approach, showing that performance in understanding is much better than when answers are simply recalled. The next sections attempt to highlight some of the main issues surrounding teacher development and children's attainment.

Although all these facets of the research are inter-related there is an attempt to structure the conclusions in terms of the original research questions. Namely:

1. How can the confidence of teachers be analysed and what evidence of increased confidence in this group of teachers can be found?
2. How can a constructivist approach be used to improve teacher effectiveness in teaching science?

3. How can methods of assessment of children's ability be used to assess 'understanding' rather than 'recall' of scientific concepts?
4. What evidence was there that children's and teachers' talk had developed as a result of the intervention?

7.1 Self-efficacy and Capability

Teaching in science is about the teaching activities involving curriculum, developing learning and assessment and a factor which will have an strong influence on this is the teacher's own beliefs about their self-efficacy. A common weakness prior to the intervention was teachers' insufficient understanding of how promoting skills of scientific enquiry contributes to conceptual development in children. Teachers tended to be more skilled at teaching knowledge and understanding of science than scientific enquiry and this is typical of many primary teachers nationally, when teaching science. Their epistemology was predominantly positivist even though some teachers declared that science in itself was not completely positivist but the bulk of their practice was more in line with positivist beliefs, they taught science as if it were a set of right answers. There was no attempt to gather any evidence to support this belief and, indeed, many of the teachers would deny a positivist approach, but informal classroom observations from the researcher and conversations with the teachers demonstrated this to be the predominant practice in many circumstances. This intervention did not focus on the 'shortcomings' or 'inadequacies' of teachers, but focussed on a different way of teaching science. This research demonstrated to the teachers involved the importance of inquiry based approaches to the development of children's concepts and their understanding of science.

There are significant demands on any teacher, which is why the researcher strongly believes that these significant demands cannot be developed fully by attendance at a one off workshop. It must be truly continued professional development over the whole of their teaching career. This idea is endorsed in particular by Feiman-Nemser (2001) who has designed a programme to sustain teaching throughout a period of change.

Fishbein (1967) stated that self-efficacy is part of the teachers' belief system and van Driel, *et al.* (1998) state that these beliefs will affect the teaching practices that occur. So here the researcher was attempting to modify these beliefs; a much more demanding task than tinkering with one or two activities that teachers may or may not, adopt. Since this is much more demanding, the process is going to take much more time and the teachers have to be in a state of mind 'ready for the change' and if the teacher's paradigms conflict with the new epistemologies, they will engender negative responses, Cobern and Loving (2002) found this with pre-service teachers. Quite often, teachers will adopt a teaching style that they experienced as students (Eick and Reed, 2002). In this research, as nationally, many of the primary teachers were women and many of these have not found science to be a rewarding experience, so they have negative experiences to draw on. What is the motivation and how do you demonstrate the effectiveness of the new strategies which will change these beliefs? The researcher believes that more effective changes to epistemologies could be obtained by demonstrating effective science teaching in their own classrooms with their own children and this is supported by the response from the Headteachers in the triangulation interviews, where they quoted the link person with the school as being pivotal in developing teacher confidence. The researcher was absolutely convinced that a major contribution to the success of the intervention was this cooperation, although the only direct evidence was from the triangulation studies. Luft (2001) found that inquiry based teaching programmes could change the beliefs of pre-service teachers but only the practices of experienced teachers. This research contradicts these findings and the researcher believes this is because the effectiveness of the strategies was due to modelling these strategies with the teachers' own classes and it is this which brought about a change of epistemology. Because they experienced success, virtually all teachers modified their self-efficacy beliefs (Bandura, 1986) to a greater confidence at teaching science, but the extent of the increase was dependent on their readiness and 'capability' for change.

This research has shown that continued professional development performed in the classroom with the help of an 'expert other' was a powerful way of developing expertise, partly because the researcher had time to think about what activities were suitable. For instance if a child said something of note the researcher could reflect on this and by the following session had a further activity to try, whereas the teacher involved in day-to-day teaching did not. The data on teacher confidence (summarised by Figures 6.11 - 6.14) show a considerable increase for all the main aspects of the curriculum and especially scientific inquiry, with many teachers moving from having limited confidence to being confident to teach science effectively. The data also show by the responses to the self-efficacy belief versus involvement, (Figure 6.15), that self-efficacy increases dramatically in the second year of input. The first year is concerned with developing the skills needed and the second year in putting these ideas into practice. Real improvement in teacher confidence takes considerable resource commitment both in terms of time and therefore finance. The pathways that led from teachers assimilating ideas to a change in epistemology leading to a significant change in teacher practice was happening alongside everything else linked to the children, the teachers, the school and the surrounding community. The complexity of the research means that it is impossible to isolate the different factors from each other.

Murphy *et al.* (2007) have shown in their research that teacher confidence remains an issue and Jones and Carter (2007) state the study of teachers' beliefs is still in its infancy, it is hoped that this research has contributed to this development. Consideration was not given as to how long it takes for a teacher to change their epistemologies nor in how far had they to move in order to achieve this change. From observations of these teachers some achieved the change quite quickly if they were receptive, ordinary teachers achieved change in two years and for some, the intervention had limited effect because the teachers themselves had limited capability to change. A future direction may be to research into what constitutes a capable teacher and this would be useful for both universities and schools which are both involved in the selection of high quality teachers.

7.2 The learning environment and discussions

Many classroom discussions which were either audio or video recorded or evidenced from fieldnotes, took place and these are far too numerous to include and these could not always be recorded, it was not possible in a working environment. In all the discussions the children demonstrated the way they thought about science, their experiences and their examination of evidence. There were ground rules such as "the child is never wrong" but as with all rules there were exceptions. However "the child is never wrong" directed the teachers to think in a different way about children's ideas, a more constructivist way.

The most successful discussions took place where there was an open non-threatening learning environment and the teacher concentrated much more on eliciting children's ideas based on scientific evidence, rather than the right answer 'tell me what you think not what you think is right', 'there are no rights and wrongs'. It was vital that the teachers developed an atmosphere in their classrooms an environment where it was acceptable "to ponder out loud" in this type of environment. As commented on by Cowie (2000), the relationship between the teacher and child and the ensuing mutual trust is vital if ideas are to be elicited to inform the teacher what the child is thinking about scientific ideas and concepts. The teachers needed to think about how the children might learn and to be much more receptive to children's ideas and to accept that it is alright to admit they do not know everything about science. Also this attitude was encouraged in the children, so that they would not expect the teacher to answer their question directly, but more to hold a discussion surrounding the topic. The researcher intervened when there were opportunities to develop the child's idea. The researcher was now actively listening for the likely occasions when intervention would develop the teacher's confidence or ability to hold an open discussion. This is where in-class support had an advantage over a simple workshop. As their confidence developed, the teachers became more attuned to these opportunities which again illustrates where a constructivist approach was really invaluable, because the researcher could judge what help was needed and in which direction it was needed. The teachers were beginning to adopt the principle of "you don't know who, you don't know when, but you know someone will", again a constructivist approach supporting the teacher.

If children are going to be receptive to new ideas, these must fit in with the evidence they obtain and the new ideas must provide a 'better' explanation than their own previously held ideas. This is illustrated strongly in the topic of forces (discussed more fully in section 6.4 and detail of the activities is given in appendix 5). The chosen teaching activities and the approach were not behaviourist, but constructivist, and the outcome was a successful understanding of a notoriously difficult and contextualised topic. The new ideas must be Intelligible, plausible and fruitful (Hewson,1981; Posner *et al.,* 1982). These children are changing from the concrete stage of their conceptual development to the concrete operational so they are changing from children who can learn the names of processes and properties of materials to those who can reason out evidence and use this to make conclusions. So the phrase 'don't tell them anything' can be applied to this style of learning. The teacher's role is changing from that of 'the person who knows the answers to the person who knows the questions'. The teacher's role is now that of one who can select or adapt or devise activities from which evidence can be drawn so that children can use their ideas to give a more reasonable explanation. If the teachers provide experiences for the children which widen their 'learning framework' they will make different conclusions than those from limited evidence, then if the teacher provides the equivalent experiences that the scientists have, they will come to the same conclusions as the scientists. Thus the teacher is making a significant change in his or her role, but the researcher would argue that this is a much more satisfying role. Increasingly the teachers were able to devise examples of activities that provided an open discussion, for example the activity which used a mixture of soluble and insoluble, white and coloured powders and where the teacher just asked the children to observe and provide explanations for their observations. In this example the teacher had devised a path and had a view of the end goal he wanted to achieve. The teachers slowly developed the expertise to recognise dead ends or the openings of fruitful discussions, the researcher (and later the teachers) differentiated between questions that would develop the scientific story and those that were left till later. The researcher and teacher would find the time within the lesson researcher to explain what was good and why.

It was more challenging (having to devise activities and the order of teaching within topics) yet much more rewarding, because the teacher in a freer open discussion allowed the children much more freedom to hypothesise, thus providing the teacher with instances of surprise and reward, showing that the child is thinking and rationalising a science topic that is a 'eureka moment'.

The teachers with the support of the researcher were thinking of a sequence of lessons, which incorporated the principle of learning demand, and particular activities which provided evidence for development of the scientific story. They were adopting the sequence of idea → evidence→ previous experience→ sequence of learning but all through this sequence is the principle of a Non-Threatening Learning Environment. Learning demand is key in ordering a sequence of activities, here the researcher was able to offer support in a variety of topics and ability levels.

Because it was in their own classroom then the lesson could be tailored to suit the ability level and the experiences of the children and because the in-class support was constructivist the problem of "how will that apply to my year?" or how will that apply to a particular topic was being addressed, but always showing the teacher how the children could attain at a higher level than the teacher had thought previously.

The teacher needs to know how to manage these discussions and the discussions need to develop the principle of a non-threatening learning environment as proposed by Watts and Bentley (1987). Teachers need to alter their agenda in discussion. They need to move away from the traditional mode of questioning to elicit a closed answer to a more open dialogue as found by Collins and Stevens (1982). In order to do this teachers must change their emphasis from thinking what they think, to what the children are thinking "tell me what you think, not what you think is right". (Howe *et al.*, 2000), showed that discussion can contribute to the development of conceptual understanding in science and Mercer (1995) used the term *Exploratory Talk*, which had very similar aims to these discussions. His stated criteria were:

- all relevant information is shared;
- all members of the group are invited to contribute to the discussion;
- opinions and ideas are respected and considered;
- everyone is asked to make their reasons clear;
- challenges and alternatives are made explicit and are negotiated, and
- the group seeks to reach agreement before taking a decision or acting.

The discussions demonstrated to the teachers that if they allowed freedom and openness, some children could go far beyond the what had been planned for the majority of children in the lesson, they will have these 'eureka moments', for example in the discussion about evaporation, explaining the differences between evaporation of the salt and the water in the sea, or in the discussion about forces, or the explanation of all aspects of the flight of a paper plane, which was equivalent to the exemplar material (sky diver) for assessing children's progress and is quoted at National Curriculum level 7, (Dcsf, 2009). Teachers need to open up discussions adopting a Constructivist not a Behaviourist strategy. Many strategies developed which were rooted in giving the children time to think for example, voting, these were too numerous to mention in the workshops, but they represent the little things that make all the difference. The development of a Non-Threatening Learning Environment takes time and therefore a constructivist approach in class was beneficial and non-judgemental (to children). Teachers were now supportive of all the children, especially those who were nearly at the next stage of their development.

This research has shown that this aspect takes time and in many cases a change in culture, but if the school develops a culture of life long learning and promotes teacher-teacher interaction this is feasible.

7.3 Development of children's ideas

Researchers have used many terms for describing children's ideas namely 'misconceptions', 'alternative concepts' and 'phenomenological primitives'. The researcher feels that *'limited frameworks'* is a much better way for teachers to consider children's ideas because these ideas are based on children's experiences along with their interpretation, and these are based on limited evidence so their conceptual frameworks are limited. There are many examples from this research such as those from reversible and irreversible changes, where they have learnt examples of evaporation, condensation and dissolving in isolation and they do not see the link even though they 'learn' the water cycle and materials which are soluble and insoluble up to Key Stage 3. For both these ideas of evaporation and dissolving, it is possible to use the words evaporation and dissolving without a real understanding of what the process entail. Here they are using the words as 'verbal wrapping paper' (Prestt 1980), which goes against everything the researcher is trying to achieve.

In this research the researcher and the teacher are attempting to improve the child's ability to communicate their ideas effectively and eventually scientifically. In the example of a bulb in a circuit, their first response would be "it will work", but this was changed to "the bulb will light up", here knowledge of scientific vocabulary is being used to communicate their scientific ideas effectively and efficiently, they are saying what to look for and what will happen. In a more complex process the first stage of this was to communicate the nature of the phenomenon using their own language and their own vocabulary so that the teacher and researcher could check the children's understanding of the process. They might at this stage be using their basic interpersonal communicative language to demonstrate their understanding of the process involved. Then they have to change their BICS to CALPs and communicate their ideas using the syntax and vocabulary of science. A simple starting activity is about a bulb in a circuit. Their first response would be "it will work" but this was changed to "the bulb will light up", here knowledge of scientific vocabulary is being used to communicate their scientific ideas effectively and efficiently, we are told what to look for and what will happen. Here it is easier to say "the water has evaporated into the air", if everyone in the community of the classroom or wider scientific community has the knowledge that the word evaporation means 'the water vapour is still in the air but the particles are too small to be seen', or 'the particles are still in the solution, but again they are too small to be seen'. The appreciation of the reverse of these processes is then much easier to comprehend. This must be done with the use of an appropriate activity; the teacher cannot simply tell them the answer. When they discuss the processes in the context of an investigation such as weighing dishes of covered and uncovered water over time, the children will all eventually predict a covered dish will not lose mass and that an uncovered dish will lose mass. Then they link the ideas they have to the investigation and to the water cycle and the can explain the appearance of condensation on the cover, whereas before the activity they could not do this. Similarly for dissolving (Figure 7.1) the ideas that children had about conservation of mass on dissolving, from this research and as found by other researchers, Holding (1987), Stavy (1990), Calick *et al.* (2007).

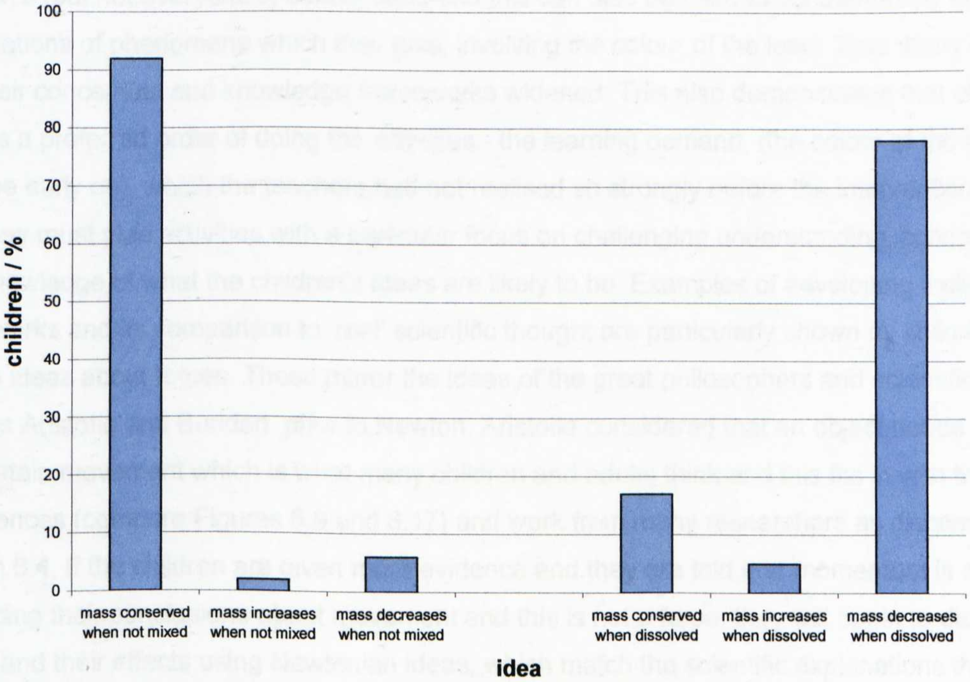

Figure 7.1 Children's ideas about conservation of mass when dissolving

The data show that most of the children (greater than 90%, n=27) believed that mass was conserved when the two containers were placed on the weighing scales, but fewer than 20% predicted that the mass would be conserved when the substance was dissolved in water. When the evidence was presented to them (of the conservation of mass) many of the children could give a correct scientific explanation of this phenomenon. When they were challenged, the children were quite happy to accept the evidence and plausible explanations for this, put forward by other children and could repeat it. Prior to the intervention the children were not challenged by seeing the evidence, the teachers had not thought that this was the key to developing the children's understanding of dissolving. The teachers had previously told the children the 'correct' answer and some of the children had accepted what the teacher said, but were still unsure of how to demonstrate this. Also when the children see the evidence they will not hold on to their original ideas as strongly. 'Misconceptions' are notoriously difficult to change (Cumming, 1998) as with teacher telling, however if the teacher shows the children evidence that their 'misconceptions' do not concur with the evidence presented, they will accept the new idea more readily.

A further simple example was from light. The children often think of 'seeing' as an active process which is understandable, but when they are presented with evidence (such as cats on a wall, see section 6.5.5.3), they talk about light entering the eye they discuss the process in a completely different way which is more akin to the scientific way of describing seeing, but nobody has told them anything. In electricity, many students even from Key Stage 4, believe that the colour of the lead will make a difference to what is happening in a circuit, however by them doing a simple activity where changing the colour of the lead does not make a difference, this will change many children's (but not everyone's) conceptions and this can also be used to contradict any later explanations of phenomena which they give, involving the colour of the lead. Thus many children had their conceptual and knowledge frameworks widened. This also demonstrates that often there is a preferred order of doing the activities - the learning demand, (the colour of the lead must be early on), which the teachers had not realised so strongly before the intervention. So now they must plan activities with a particular focus on challenging understanding, concomitant with knowledge of what the children's ideas are likely to be. Examples of developing limited frameworks and its comparison to 'real' scientific thought are particularly shown by children's (and adults) ideas about forces. These mirror the ideas of the great philosophers and scientific thinkers such as Aristotle and Buridan, prior to Newton. Aristotle considered that an object needs a force to maintain movement which is what many children and adults think and this fits in with their experiences (compare Figures 6.9 and 6.17) and work from many researchers as discussed in section 6.4. If the children are given more evidence and they are told that momentum is a way of describing their conclusions about movement and this is not a force, they will begin to discuss forces and their effects using Newtonian ideas, which match the scientific explanations that scientists hold. The children now have an expanded framework in which to describe their ideas, whereas before they only had limited evidence and were using limited evidence to reach different conclusions.

The teachers in their development of a learning culture within schools needed to promote classroom discussion, in the I - R - F format, which develops children's ideas, not counting these as wrong – but limited. This is allied to the principle of not telling them the correct science but providing evidence which then allows the children to make their own conclusions based upon the evidence. It follows that if they reach an 'incorrect' conclusion, it is because they have not been presented with the correct evidence in a way which promotes learning.

The evidence from an open activity provides the teacher with material to discuss, so the teacher is much more likely to move to the I - R - F format (Mortimer and Scott, 2003), because s/he has ideas, that the child has put forward, upon which they can question. The choice of activity has considerable influence on the type of discussion that can take place. Here the teacher can move away from I - R - E which is typified by questions such as "is the material soluble or insoluble?" to discussions about what the children observed during dissolving, for example the rate at which the powders dissolved or sank and the reasons why. The researcher found that if these ideas were proposed at the apposite moment, which is during a class activity, this had a far more significant effect on changing the teacher's practice for the future. A major thrust of the research was the development of the children to communicate their ideas effectively, but the role of the teacher was crucial in persuading the children that accurate scientific expression was a more effective and efficient way of communicating their ideas to the community.

7.4 Children's attainment

The accountability inherent in initiatives such as 'every child matters', in the UK, and 'no child left behind', in the US, carry the danger of accountability being the prize judged by learner assessment performance and league tables. This is summarised in the metaphor 'if you want to fatten a pig - do you keep feeding it, or weighing it'? Teachers have developed a familiarity with the tests and Harrison (2001) has pointed out that an increasing number of teachers are teaching their Year 6 children to the science test and that they are teaching tips, tricks and techniques to achieve higher marks. Survey inspections have found that in some schools, overemphasising preparation for the national tests in English, mathematics and science, especially in Year 6, restricts the time available for activities that can most interest and challenge children... and scientific investigation. Hence children's attainment can then become narrowly based Jurd (2000). Sturman (2003) has researched in teacher's reactions to a testing regime and found that teachers are unhappy at the way science is delivered in year 6. Some teachers start revising in September of year 6 and more than fifty per cent will be revising by January. Teachers see test preparation as a learning the facts and remembering them for the test. In Year 6 in particular, narrow teaching to the tests meant that children were becoming bored with and demotivated by science.

The research and analysis of attainment showed that these children could achieve success in their classwork, national and other tests by using constructivist strategies to develop the children's understanding. This research has found that pure revision leads to an overall increase in scores, however the researcher feels that the differential in children's attainment in the intervention was due to a differing emphasis in approach, based not on facts, but much more on understanding of the concepts and hence the application of these. The results for assessment of children's attainment are divided into:

- Examples of classwork
- Use of science reasoning tasks
- Pre and post tests
- Assessment using national test data

In the classwork activities a wealth of data were collected and overall these showed the success of the activities used. These were thought to be effective in the first usage but some were refined as the research went on. For instance in the ice pops activity the children on the first occasion said the ice on the outside had come from the freezer, subsequently a brand new sealed box of ice pops was used on each occasion. The success of the activities is shown in the filtering activities whereas almost 70% of children (n=27) thought that crystals remained in the filter paper (see figure 7.2).

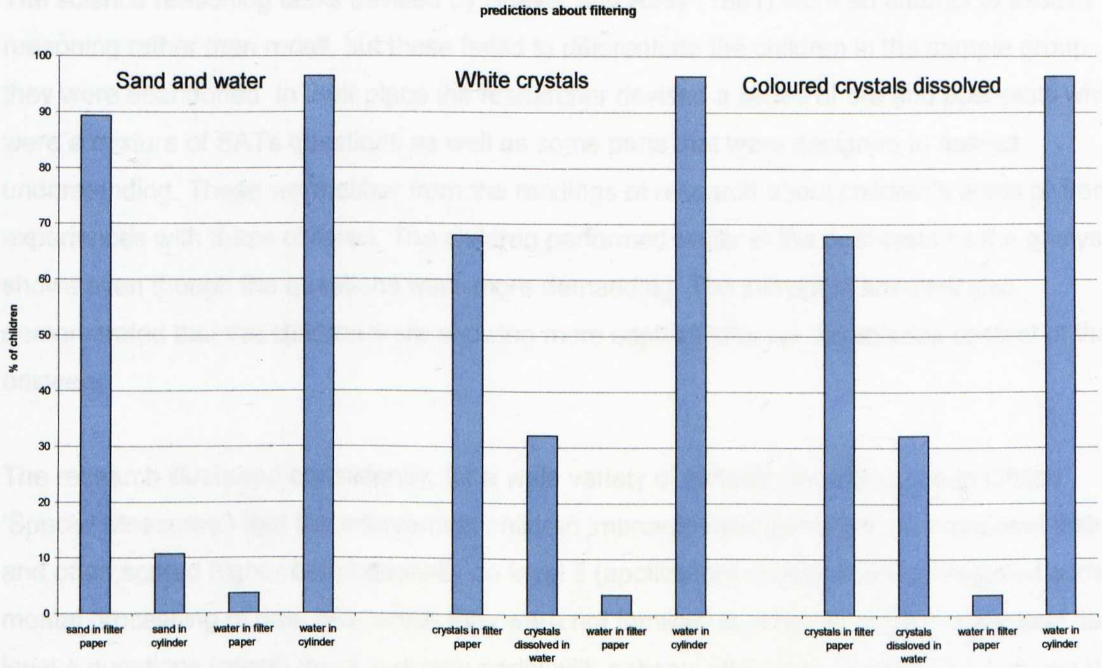

Figure 7.2 Children's ideas about dissolving before intervention

Whereas as a result of discussing their ideas and slowly going through the activities as in another group (n=24), almost 100% thought that the sand would stay in the filter paper, almost 83% thought that the white crystals would appear in the filter paper, whereas after discussing the activity with the children, only 18% thought that the coloured crystals would stay on the filter paper (figure 7.3).

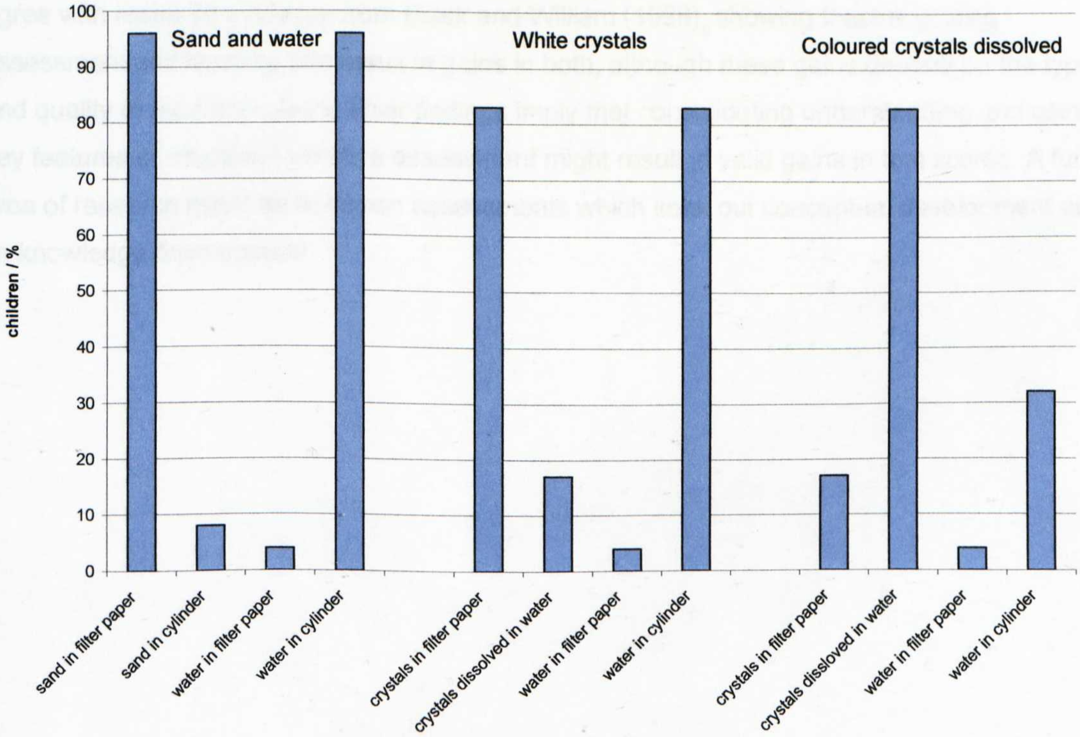

Figure 7.3 Children's ideas about dissolving after intervention

The science reasoning tasks devised by Shayer and Adey (1981) were an attempt to assess reasoning rather than recall, but these failed to differentiate the children in the sample group, so they were abandoned. In their place the researcher devised a series of pre and post-tests which were a mixture of SATs questions as well as some parts that were designed to assess understanding. These were either from the readings of research about children's ideas or from experiences with these children. The children performed better in the post-tests as the analysis shows even though the questions were more demanding. The individual answers also demonstrated that the children were showing more sophistication in the science content of their answers.

The research illustrated consistently, for a wide variety of schools (including one in Ofsted 'Special Measures') that the intervention children improved their performance in national tests and often scored higher than nationally on level 5 (application) questions which required some mental processing of data with which they were not familiar, so a higher cognitive demand, but on level 4 questions (recall) there was only parity with national standards. Section 6.8.4 shows the *ttest* analysis of performance and discusses the differences between intervention school and national performance. These data show that with considerable statistical significance the intervention children performed much better at application questions demonstrating a better understanding of concepts. It must also be remembered that the children had much lower than average CAT scores, (see Figures 6.23 - 6.24) so their attainment is that much more remarkable. These children have demonstrated that they have been able to achieve learning outcomes when effective, constructivist teaching techniques are applied in their science classrooms. These data agree with research evidence from Black and William (1998), showing that integrating assessment and learning can result in gains in both, although these gains depend on the type and quality of feedback given. Their findings imply that consolidating understanding and using key features of effective formative assessment might result in valid gains in test scores. A further area of research might be to devise assessments which seek out conceptual development as well as knowledge development.

7.5 Summary

As stated teaching is a complex activity and the teacher needs to be confident about their ability to teach science armed with sufficient knowledge about the key concepts as well as being prepared to admit they don't necessarily know the right answer. The teachers need appropriate activities to challenge and develop learning and children who will examine the strength of the evidence, the teacher needs to develop an environment where the children can communicate their ideas effectively. This research has shown that teacher efficacy can be improved by working alongside primary teachers, again adopting a constructivist approach, so they have time to assimilate and practise new strategies in their own classrooms with their own children and feel supported in developing these new skills while the appropriate support is there. Adoption of constructivist approaches has shown the teachers that some release of control over the lesson content and management, can produce a much more rewarding experience both for the teacher and the children. This development of cognitive ability in science through constructivist approaches can still improve attainment in national and local assessment. These teachers have improved their confidence, their knowledge of science and provided a much more enjoyable experience for the children.

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Appendices

Appendix 1 Key Concepts in Science

Here are some key concepts/principles that primary teachers can use to apply to searching pupil questions

Living things
Characteristics of all living things Movement Respiration Sensitivity Growth Reproduction Excretion Nutrition (MRS GREN)
Microorganisms are living so need warmth water nutrition
All living things are grouped/classified and we use keys to identify them
Living things adapt to their environment
Food chains – producer → consumer, arrows point in the direction of the food (energy) path

Animals
Vertebrates have backbones invertebrates do not. 5 vertebrate groups fish amphibians reptiles birds mammals
Bones give structure and protection, muscles help you move
Exercise needs food products and oxygen, supplied by the blood, so exercise affects breathing and heart rate

Plants
Plants need water, warmth and nutrients to grow
They need light in order to produce their own food in the leaves (to keep growing)
They get water and dissolved nutrients from the soil (usually soil, doesn't have to be) these transported round the plant
Main parts are root stem leaves flower then Stigma (female –egg) stamen (male – pollen) fertilisation is pollen joining with egg

Materials
Structure of materials affects heat transfer
Heat transfers from hotter to colder materials, measured by temperature changes
Using the word colourless, different from transparent
Sieving and filtering determined by relative sizes of holes and particles
All metals are good conductors of heat and electricity, only some metals magnetic

Changing materials
Particle arrangement in solids, liquids and gases
"Energy in" makes the particles move more rapidly, so further apart. "Energy out" reverses this
Dissolving means the crystal particles spread out, evaporating the water causes the crystal particles to join up again
Things happen faster at a higher temperature
Mass stays the same if the particles are trapped, mass decreases if particles can escape
Non reversible changes produce new materials

Sound
Sound is produced and transmitted through vibrations
Sound travels better through solids and liquids than gases due to closeness of particles
Higher pitch is produced by faster vibrations (tighter strings, shorter bars, shorter air columns)

Electricity
'Electricity' is in the all parts of the circuit and moves round the circuit through any conductor
Batteries cause the electricity to move in a particular direction, the amount of electricity flowing depends on the number and the orientation of the batteries
In a series circuit, if at least one bulb glows, electricity must be flowing through all the circuit
Electricity is not used up in the circuit-energy is released from the circuit

Light
Light comes from a source and is reflected from or passes through materials
Dark is the absence of light, blocking light causes shadows
Transparent (light through and see detail of image), translucent (light through but cant' see detail of image) opaque- no light through
We see by light reflecting from surfaces into our eyes

Forces
Understanding momentum is the key to understanding forces and motion. Moving objects have momentum and a force alters the momentum
Objects move in the direction of the force
Resultant or unbalanced forces produce a **change** in movement that is speed up/slow down.
Balanced forces therefore do not change the speed of an object - so falling parachute (not speeding up or slowing down) has balanced forces.
Momentum can be transferred when objects collide with each other
Friction and air resistance result from transferring momentum from the object to the materials (solid surface or air/water)
Upthrust in water is equal to the mass of water displaced. Bigger (more volume) objects can displace more water so can provide more upthrust. Floating objects not moving up or down so gravity and upthrust are balanced
Gravity pulls towards the centre of the earth. Gravity exists between any objects having mass the size of force is proportional to mass.
Mass is how much stuff is in the object, weight is a measure of the force between earth and object

General
Evidence is the key to understanding and reconstructing ideas
You cannot always see things so you may need other forms of evidence

Selection of Activities
Extensive use of data logging to gather evidence to promote discussion.

Electricity
A series of activities using different arrangements of batteries and bulbs and wires motors and buzzers, to decide that the best model to explain flow of electricity is the circulating current model.

Change of state
Weighing ice and water to show changes in mass, data logging heating kettle, ice pops to show that evaporation and condensation involve water particles moving through the air.

Non reversible changes
Weighing and observing before and after some changes e.g. making toast from bread, burning candles and seltzer tablets in water

Plants
Using germination sandwiches and mini greenhouses, to show the effect of different conditions on plant growth

Forces
Use of the concept of momentum with skittles, bowling and bouncing activities to show the different factors that affect movement of objects, and relating these to forces

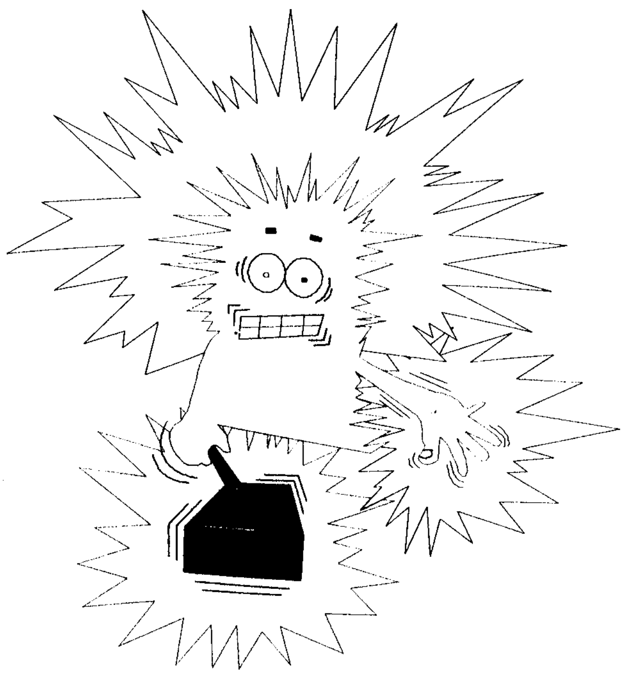
Sound
Vibrating rulers or "twangers" to investigate different sounds
Tuning forks in air, on skin, touching table, can hear through table, touching water vibrations pass through water into table

Light
Datalogging passing light through materials transparent/translucent/opaque
Shoe box to explain light entering eyes
Shadow size related to distance sundial activities real and model

Appendix 2

Science INSET Sessions

Electricity



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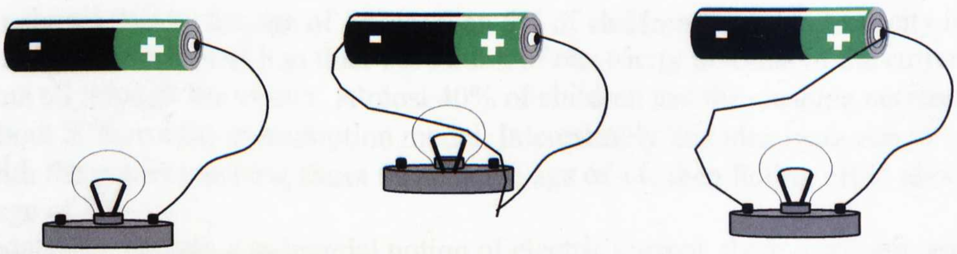
Contents

Children's ideas about electricity

Your experience will have shown you that infant children are capable of building circuits to make a bulb light up and they can look at diagrams to recognise circuits that are complete or incomplete. Children's earliest ideas about electricity show that they tend to think of electricity in terms of a source-consumer model.

The national curriculum at key stage 1 only requires children to be able to build circuits and does not demand that they have any understanding of theory of electrical circuits.

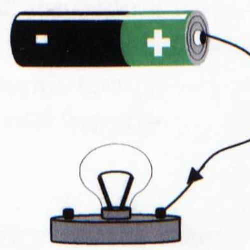
The advent of the national curriculum has increased children's knowledge of practical circuits nationally, but earlier studies have shown different ways of trying to get a bulb to light as follows. You might have seen some of these with infant children who are left to investigate for themselves.



These may well be familiar to you.

One of the issues might be when to introduce a correct understanding of what electricity is and how electrical circuits work.

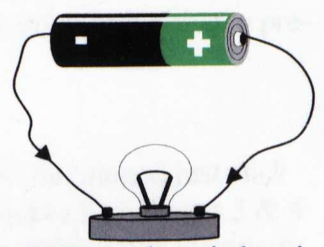
As children get older and they try to explain what is happening in the circuits that are connected correctly, four models seem to be prevalent.



This is the unipolar model.

Here the children regard only one wire as being active and even when they learn that you need the second wire to make a complete circuit, if you ask them what is the second wire is for they think it does not play an active part.

It is sometimes thought of as a safety wire

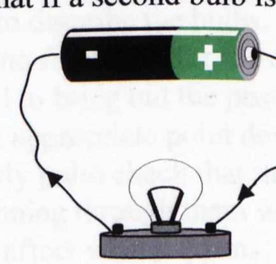


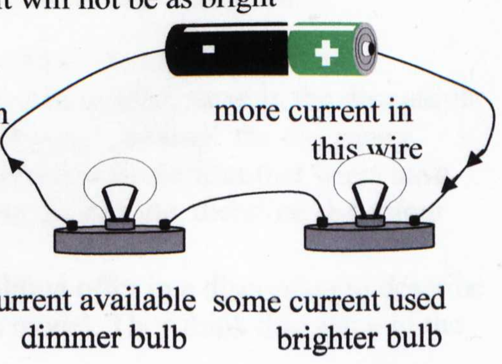
This is the clashing currents model.

The electricity is thought to flow from both terminals of the battery to the bulb. They sometimes explain the light in terms of the clash of the two currents .

The consumption model

In the third model the current is thought of as being used up by the bulb, so there is less in the wire going back to the battery than there was coming from the battery. Some children predict that if a second bulb is put into the circuit, it will not be as bright

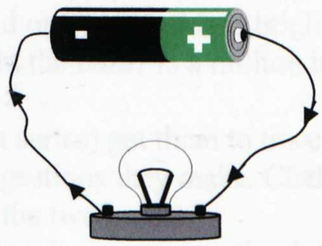




Children think that the bulbs will be equally bright, but they both use up some current - equally.

The scientific model

The fourth model shows the magnitude of the current to be the same all through the wire.



Evidence has shown that by the age of 11 less than 5% of children think of electricity in terms of the unipolar model and less than 10% think of electricity in terms of the current being the same all through the circuit. Almost 40% of children use the clashing currents model and about 50% use the consumption model. Interestingly this idea increases in popularity with the pupils reaching about 60% by the age of 14, then falling off to about 40% by the age of 17.

All these models also contain a sequential notion of electric current, there is a cause and effect. The children and many adults intuitively feel that something travels round the wire meeting and interacting with components in sequence.

Battery

At early ages children think of the battery as a 'giver' of electricity. They think of it as a store of electricity which supplies a current at a constant rate, rather than the battery maintaining a constant voltage or potential difference. This may not be surprising because they are used to the idea that a battery 'runs out'. Very few secondary pupils hold a correct concept of voltage, but it has been shown that primary children will happily accept the idea of a battery pushing the electricity around the circuit.

Current and voltage

Most children confuse these ideas, they often think that current and voltage are the same thing, or they tend to think that voltage is a property of current. This may be because current is often introduced first so it is seen as a consequence of current rather than a pre-condition for current to flow.

Developing the children's ideas

First point is to not allow the use of the word power when it is first mentioned just stick to electricity. Power has a precise meaning in science when they get to Key Stages 3 & 4 so best avoided (the reason for us is that it allows woolly thinking and permits electricity to have some 'magical' properties which don't allow explanation and never allow "it" in a science discussion, get them to name the "it"). Also get them to use brighter and dimmer to describe the bulbs.

There is no fixed way for the discussion to go, respond to the children's ideas.

You need to bring out the positive and negative symbols at some stage in the discussion and at an appropriate point develop the idea of the battery "pushing" the electricity.

At an early point check that the children are comfortable with the idea that wires have metal running through them with a plastic coating on the outside, therefore the colour does not affect what happens.

The most common 'non scientific' idea that the children offer in a discussion to describe the movement of electricity is the clashing currents model. They think that some of the

electricity goes down each wire and when it gets to the bulb it lights – some do not know why it lights "it just does!"
Why the bulb goes out if you take one wire off? A common response is "not enough electricity in one wire".
Strategies
Redo the circuit with two batteries and one bulb – this is brighter. More electricity going down both wires is this enough to light the bulb? Is a million batteries enough to light the bulb?
Connect the circuit with two bulbs (in series) get them to trace precisely where the electricity is flowing. Respond to suggestions they make. Challenge them by asking what happens in the middle wire (between the two bulbs)
Also ask the same questions of anyone who suggests a circulating current model.
If the children do not suggest challenge the circulating current theorists with "If the electricity keeps returning to the battery, why does the battery get used up?"
As more children begin to favour the circulating current model get them to predict the behaviour of an electric motor using the two ideas. "What will happen to the spin of the motor if I change the battery round?" clashing current predicts no difference circulating can predict reversing direction of spin.
Can also do short circuits two wires from the battery
Consumption model – some of the electricity is used up
Where does the electricity go? Is electricity coming out of the bulb?
Check the evidence using an ammeter at different points in the circuit, this shows that current is the same therefore electricity coming out is returned.
This is a problem because they now need to use the idea of energy. The electricity carries the energy releases it at the bulb returns to the battery and picks up more energy and so on. Batteries can be recharged i.e. the energy put back in (even non rechargeable ones can be recharged but they are not very good). Energy is not part of the KS 2 programme but there is no other way of answering this question.
Buzzers only work if you connect them the right way round in the circuit (can be fun - don't tell them response is "miss my buzzer's broken" get them to draw exactly how they have connected it. Pool ideas, may need prompting.

Electricity

Electricity is probably one of the most useful things we have available today. Every day it is used to run millions of appliances at home, in work, in service industries and in manufacturing. It is so useful because: -

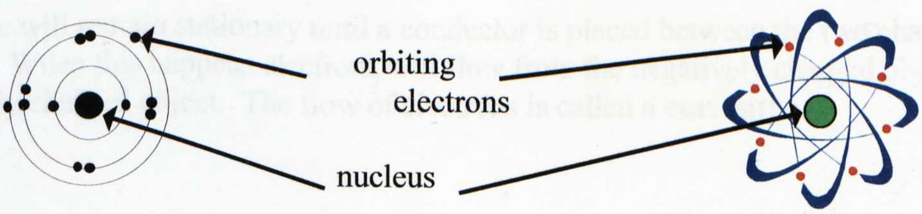
a) it is a means of transferring energy from one place to another and it can do this quickly, cleanly and over large distances.
b) the energy can easily be used by different appliances e.g. light bulbs, heaters, moving machinery.

What is Electricity?

Electricity is another of these things in science which ultimately becomes difficult to say exactly what it is, but we can talk about it adequately using fairly simple ideas. Electricity is a charge and it can be in one place i.e. static electricity or moving i.e. current electricity.

Where does the charge come from?

Everything is made up of atoms and they contain particles with electrical charge. There are two different charges **positive** and **negative**. There are several ways to represent atoms e.g.



In the centre of each atom there is a **nucleus**, this is positivley charged. Tinier particles orbit around this nucleus. These are called electrons and are negatively charged. The nucleus and **electrons** both carry an electric charge, but the charges are of opposite types.

Electrons have a negative (-) charge.

Nucleus has a positive (+) charge

We get an electrical effect produced when the electrons move from one atom to the next and as the electrons move, they carry energy which can be used to do work. Electricity is a **flow of electrons** through a material.

Conductors and Insulators

There are two types of materials – **conductors** and **insulators** and the children need to know these words. Conductors are materials that allow the electrons to flow through them easily, so conductors can carry electrical charge (and therefore energy) from one place to another. Conductors are **all** metals and carbon (used in batteries and pencil leads).

Insulators are materials that do not allow electrons to flow through them. Most non-metallic materials are insulators e.g. plastic, rubber, wood.

Insulators (not conductors) can become charged when they are rubbed. The rubbing causes electrons to be transferred from one material to another. If a material gains or loses electrons, there is no longer an exact balance between the - and + charges within it. The material in which this imbalance occurs is said to be **charged**. Charged materials are sometimes said to have "static electricity" on them. Since insulators do not allow electrons to flow then the imbalance cannot be evened out. Static electricity can build up wherever two non-conducting surfaces rub together, especially clothing in artificial fibres, balloons, cars. There is a large build up of opposite charges on the surfaces and this can be enough to produce sparks. The sparks are produced because the charge is jumping or 'arcing' across the gap. It is "**earthing**".

Charge does not build up on a metal because the charge flows easily and spreads out.

Moving Charge

A charge will remain stationary until a conductor is placed between the two charged objects. When this happens electrons will **flow** from the negatively charged object to the positively charged object. The flow of electrons is called a **current**!

Circuits

The electrons will only flow if there is somewhere for them to move to i.e. another conducting atom. If there isn't anywhere to go they stop. This is why you need a circuit. The electrons in the wires are moving about randomly but if you want an electrical current all the electrons must move in the same direction - you will need something in the circuit to make this happen. A battery (or the "mains supply"), will do this it provides a "push" for the electrons to move. It does this by setting up an **electric field** and all the electrons will move the same way when this electric field is set up.

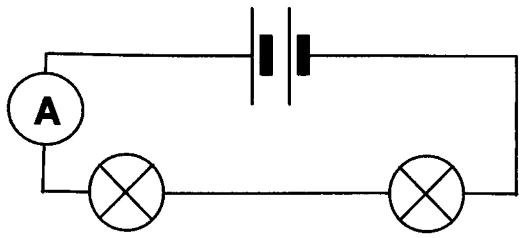
Cells and Batteries

The things we buy for a torch or a cassette are called **cells** (if we are being precise) and the ones we normally get are 1.5 volts. A **battery** is a collection of cells connected in series - a car battery <u>is</u> a battery, it has six 2 volt cells, giving 12V.

In the cell a chemical reaction occurs which makes the outer case negative (-) and the central section positive (+). When a conductor such as copper is placed between the terminals (ends) then the electrons are **pushed** out of the negative end and flow around to the positive end. This creates a flow of electrons. When the chemicals in the cell are used up no more electrons can be pushed out. The cell is "flat."

Current

The word current describes the "**flow**" of electrons around a circuit, they flow from the negative terminal to the positive, a conductor connects the positive and negative terminals and a complete circuit exists.
We can measure the flow of charge around the circuit (current) using an **ammeter**.
The ammeter being connected in line with the flow (in series). The unit for current is amp (A). A larger current flows when you move <u>more</u> electrons or move them <u>faster</u>.

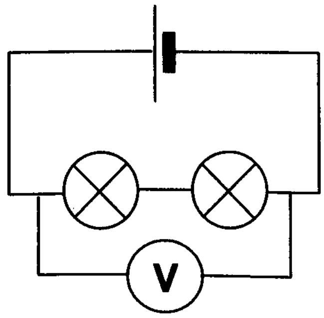


Current Problem

Due to an early lack of understanding about the movement of electrons most circuit diagrams have arrow heads going from the positive to the negative terminals. These <u>do not</u> show the flow. They just give the direction from positive (+) to negative (-) round the circuit. This is called **conventional current.**
As we know the electrons actually flow from the negative (-) to the positive (+) terminals. This is called **real current.**

Voltage

When electrons are pushed out of a cell they carry energy with them. When the electrons reach an appliance e.g. a bulb, then the energy they carry is used by the appliance to do its job. In this example the energy carried by the electrons is released by the bulb as the filament glows.
Some cells have a larger energy difference between their positive and negative terminals. As such these cells can send more electrons through the component and the electrons carry more energy and so more energy is released – the bulbs are brighter.
We describe such cells have a higher **potential difference** or **voltage.** The actual potential difference or voltage can be measured using a **voltmeter** which is connected across the battery terminals. Voltage is a measure of energy difference.

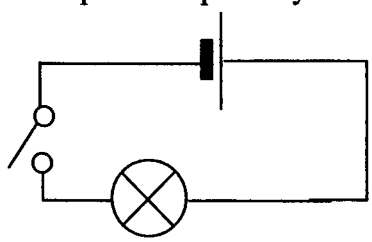


Resistance

All metals conduct electricity, but some are better than others. Copper is a very good conductor and so a current can easily flow through it, but lead is not so good. The reluctance to allow electrons to flow is called **resistance**. Some alloys are specially made to have high resistance. When the electron flow meets resistance some of the energy carried by the electrons is used and the metal may get warm or glow. So by using different wires with different resistance values we can control the electrical flow and how the energy is released.
Tungsten - this metal also has quite a high resistance, it also however has a very high melting point. When the current passes through it, the tungsten becomes so hot it gives off a brilliant white light. Having a very high melting point the tungsten can be kept white hot without melting, so it is used in light bulbs (lamps).
Also thinner wires have a higher resistance than thicker ones, the filaments in bulbs are made very thin, so they get very hot.

Simple circuit

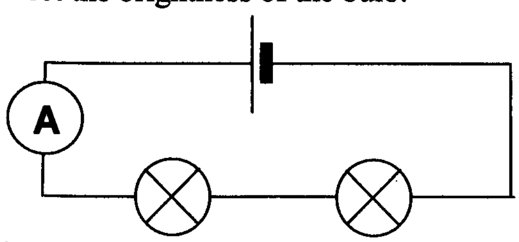
This is simply a battery, wires and a component – possibly a switch.



Series and Parallel Circuits

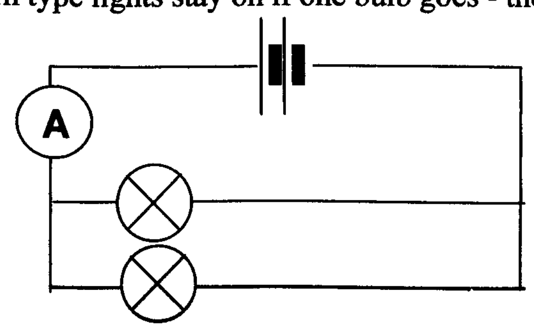
These two specific types of circuits frequently require explanation.
A simple circuit contains one appliance then there are two ways by which we can add further appliances and this will affect the brightness of the bulb.

a) In series



These bulbs are connected in series i.e. one after each other. In this formation appliances have to share the battery voltage(energy), half to bulb each in this case, so each one glows dimly. If one bulb is removed the circuit is broken. The other bulb goes out. The best working example of this for the children is older type Christmas tree lights one bulb goes they all go out. More modern type lights stay on if one bulb goes - they are connected differently as below.

b) In Parallel



These bulbs are connected in parallel i.e. each bulb is on its own branch. In this formation each appliance has a direct connection to the battery so each gets the full battery voltage, so each glows brightly (the same as one cell, one bulb). But together, the bulbs take twice as much current as a single bulb. Energy is taken from the battery at a faster rate, so the battery goes "flat" more quickly. If one bulb is removed there is still an unbroken circuit through the other bulb. So the remaining bulb continues to glow brightly. The best working examples of this circuit being car headlights and household lights i.e. if one goes the other remains on.

Tips

Use all the bulbs the same so that you can compare brightness properly
Bulbs can be connected any way round, but buzzers and motors need to be connected the correct way positive and negative.
Power – children often use this word loosely for electricity. It means something quite precise especially in electricity, it means the rate at which you use electrical energy and is measured in Watts(W) or kilowatts (kW). Try to get the children to talk about "flow of electricity" not "the power goes round".

National Curriculum Electricity

Pupils should be taught:

About everyday appliances that use electricity;

About simple circuits involving batteries, wires, bulbs, buzzers and motors;

How a switch can be used to break a circuit.

To construct circuits, incorporating a battery or power supply and a range of switches, to make electrical devices work;

How changing the number or type of components in a series circuit can make bulbs brighter or dimmer;

How to represent a series circuits by drawings and conventional symbols, and how to construct series circuits on the basis of drawings and diagrams using conventional symbols.

National Curriculum level	1. Pupil expectation
Level 1 (observe)	recognise electrical appliances, recall how to make a complete circuit, observe and record/describe the effect of changes in a circuit
Level 2 (compare)	observe and compare the way components e.g. bulbs, work in different circuits,
level 3 (link)	can link cause and effect e.g. breaks in a circuit, using a switch
level 4 (explain)	use their knowledge to explain why a circuit needs to be complete, and to explain different observations about circuits
level 5 (apply)	explain how current moves round a circuit, be able to represent a circuit using a circuit diagram, able to predict how to make bulbs brighter or dimmer and can explain why using scientific vocabulary
level 6 (use models)	use an abstract idea such as flow of charge/energy to explain electrical effects.

NOTE in the original booklet there was then a series of resources that the teacher could use in classrooms.

For example

Teaching plan

Grouping electrical/non-electrical conductor/insulator mains/battery plus pairs game cards

Flash cards for electricity words

A4 size pictures of components

A4 size circuits that would/would not light

Table of common circuit symbols and pictures

Cut out and stick pictures

Cut out and stick symbols

Simple circuits related to questions that might arise from discussion for example direction of flow, 2 bulbs, 3bulbs +-+-+- , +--+-+, blown bulbs and live bulbs

Electricity analogies

Questions for teachers in given scenarios

Measuring voltage and current activity (for teachers)

Appendix 3

QCA Scheme of Work (amended) Key Learning Outcomes

Year 1	***Unit*** 1A ***Title*** Ourselves
KeyLearningOutcome1	Name the main parts of body and the senses
Assessment1	Label a diagram, or deconstruct a body into named boxes
All1	Arm, leg, head (1)
Most1	Above plus knee, ear, nose eye and tongue(1)
Some1	Other parts(1)
KeyLearningOutcome2	Know that many other living things are animals
Assessment2	Can group animals
All2	Humans are in the group animals (1)
Most2	Animals include insects and common invertebrates (1)
Some2	Can correctly identify as animals examples they have not met before and can justify their choice (2)
KeyLearningOutcome3	Know the stages of growth
Assessment3	Identify the stages of growth
All3	Can name baby, child, adult for humans, can identify differences between all three (1)
Most3	Can sequence growth stages for a selection of common animals (minimum 3) (2)
Some3	Can sequence growth stages for a selection of common animals (minimum 3) and justify choice(2)
KeyLearningOutcome4	Make measurements and observations on themselves
Assessment4	Group animals together, make linear measurements of their bodies
All4	Can correctly measure body height to nearest 10 cm e.g. with simple block measure (1)
Most4	Can correctly measure length to nearest cm and tally groups e.g. hair/eye colour (2)
Some4	Can measure length in standard units and recognise patterns in measurements found (2)
KeyLearningOutcome5	Identify living animals
Assessment5	Can correctly assign characteristics of living animals.
All5	Can recall in any appropriate way that humans move, feed and use senses (1)
Most5	Can recall in any appropriate way that animals move, feed and use senses and living things need water. Match foods to common animals (2)
Some5	Can correctly predict food/methods of movement using observations on less common animals (3)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 1	***Unit*** 1B ***Title*** Growing plants
KeyLearningOutcome1	Name parts of plant
Assessment1	Can name parts of plant
All1	Can match labels of root, stem, leaf and flower (1)
Most1	Can draw recognisable features of each part (2)
Some1	Can describe purpose of roots (1)
KeyLearningOutcome2	Observe/compare different plants
Assessment2	Observe and compare growing plants
All2	Can group plants according to similarities/differences (2)
Most2	Can explain reasons for their choice of grouping (2)
Some2	Can recognise different leaf or root shapes (2)
KeyLearningOutcome3	Record growing plants
Assessment3	Observe and record growing plants
All3	Can grow plants (know they need some water) (1)
Most3	Can make comparisons of growth (1)
Some3	Can measure/record growth in an appropriate way (2)
KeyLearningOutcome4	Plants need light to grow
Assessment4	Grow plants in light and dark conditions
All4	Can identify plants grown in light and dark conditions (2)
Most4	Can observe and record differences between plants grown in the dark and light (2)
Some4	Describe how evidence shows that plants need light to grow well (3)
KeyLearningOutcome5	Plants provide food
Assessment5	Research and/or group pictures or drawings of plants
All5	Group and/or name plants we eat/don't eat (2)
Most5	Group and/or name plants we eat/animals eat/aren't eaten (normally) (2)
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 1	***Unit*** 1C ***Title*** Sorting and Using Materials
KeyLearningOutcome1	Know materials have many properties
Assessment1	Write descriptions round a picture or example of an object e.g. spoon
All1	Can use words, hard, soft, shiny, dull (1)
Most1	Above plus rough and smooth and bendy. (1)
Some1	See through, waterproof, transparent, flexible. (2)
KeyLearningOutcome2	Name several common materials.
Assessment2	Sort collection of objects into groups (2) and label.
All2	Name wood, metal, plastic, glass (1)
Most2	Name above plus sand, rubber, stone. (1)
Some2	Clay, cotton, wool. (1)
KeyLearningOutcome3	Properties determine choice of material.
Assessment3	Can give a reason for choice of material for specific purpose.
All3	Link wood, metal, plastic to hard, shiny, soft (2)
Most3	Link sand, rubber, stone to rough, smooth, bendy (2)
Some3	Link plastic, glass to transparent, waterproof, flexible (2)
KeyLearningOutcome4	Know some materials are magnetic
Assessment4	Test materials and sort into magnetic, non magnetic.
All4	Identify magnetic/non-magnetic objects (1)
Most4	Predict which objects are magnetic(metal)/non-magnetic(not metal) (2)
Some4	Recognise not all metals are attracted. (2)
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 1	***Unit*** 1D ***Title*** Light and Dark
KeyLearningOutcome1	Identify a number of light sources
Assessment1	Name or draw luminous and non luminous sources
All1	Name/draw 5 luminous and 5 non luminous sources (include sun) (1)
Most1	Compare brightness of different sources (2)
Some1	
KeyLearningOutcome2	That sources of light show up best at night.
Assessment2	Name conditions where lights show up best
All2	Give examples of lights showing up in night and day (1)
Most2	Can rank places/conditions where lights will show up better/worse (2)
Some2	Can give a reason why lights do not show up in bright areas e.g. a torch shining on a brighter light (3)
KeyLearningOutcome3	Objects cannot be seen in the dark.
Assessment3	"Black box" experiment (QCA) or dark cupboard
All3	Recognise that light source (e.g. torch) is necessary to see an object. (3)
Most3	Relate brightness of source to how well they can see (3)
Some3	Give a simple explanation of how they can see objects (relate source, object, seeing) (4)
KeyLearningOutcome4	Shiny objects are not a light source but need a light to be shiny
Assessment4	Shining torches on reflective materials and in the "Black box" experiment (QCA) or dark cupboard
All4	Group objects into shiny and dull (2)
Most4	Describe/state that shiny objects need a light source in order to shine and cannot be seen in the dark (3)
Some4	Give a reason why shiny objects reflect light better than dull objects (3)
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 1	***Unit*** 1E ***Title*** Pushes and Pulls
KeyLearningOutcome1	Some objects move and some don't
Assessment1	Select from a range of pictures things that move.
All1	Name examples of objects that move/can be moved/don't move (1)
Most1	Talk about objects using vocabulary including "swing" "turn" "go round" etc. describing movement (1)
Some1	Use terms such as go faster, go slower. (2)
KeyLearningOutcome2	Our bodies can move in different ways
Assessment2	Through response to different instructions/directions.
All2	Move in response to one direction at a time - e.g. move forwards. (1)
Most2	Link together two different movements - go forwards and turn round. (2)
Some2	Link together a sequence of movements to include different directions and speeds. (2)
KeyLearningOutcome3	To know the difference between a push and a pull
Assessment3	Be able to sort a variety of objects into those that can be pushed and those that can be pulled by trying them out.
All3	Know they can make an object move by pushing and pulling it along. (2)
Most3	Predict which movement will be required for different objects (2)
Some3	State which shapes and sizes move most easily. (2)
KeyLearningOutcome4	Moving objects can be stopped.
Assessment4	Select from variety of pictures which objects they would be able to stop themselves.
All4	Know that they can safely stop small objects/toys but other heavy objects are dangerous to try and stop. (1)
Most4	Describe different ways of stopping toys/objects. (1)
Some4	Describe some factors involved in slowing down and stopping e.g. speed, direction, floor covering. (1)
KeyLearningOutcome5	Wind and water move objects
Assessment5	Identify two things wind/water moves and two they don't.
All5	Name something moved by wind and something by flowing water. (1)
Most5	Devise simple test to see if wind is blowing. (2)
Some5	Relate the movement of a windmill and watermill turning to pushes (3)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 1	***Unit*** 1F ***Title*** Sound and Hearing
KeyLearningOutcome1	There are lots of different sounds. We hear sounds with our ears.
Assessment1	Make sounds and listen to them
All1	Identify sources of sound. List different sounds. (1)
Most1	Can group similar sounds or sources of sounds. (2)
Some1	Can describe the sequence of how sound is made and how we hear it (3)
KeyLearningOutcome2	We can make sounds in different ways. Sound is made when something vibrates.
Assessment2	Make sounds in different ways
All2	Can make different sounds with musical instruments e.g. hit, shake and pluck. (1)
Most2	Can recognise and describe that making sounds produces movement (3)
Some2	Can describe how sounds are made using the word vibration. (3)
KeyLearningOutcome3	Sounds get quieter the further away they go.
Assessment3	Listen to sounds at different distances
All3	Identify a sound is louder when it is near and quieter when far away (2)
Most3	Can relate loudness of sound to different distances (3)
Some3	
KeyLearningOutcome4	Sound travels in all directions.
Assessment4	Locate a sound source in a listening game
All4	Can locate a source/direction of sound in a listening game (2)
Most4	Describe how we can channel sounds e.g. cones, tubes, funnels (3)
Some4	
KeyLearningOutcome5	Sound can travel through some materials better than others
Assessment5	Investigate muffling sounds using different materials
All5	Can name the best material for muffling sound (1)
Most5	Can put different materials in order of muffling (2)
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 2	***Unit*** 2A ***Title*** Health and Growth
KeyLearningOutcome1	Humans need food to stay alive
Assessment1	Group foods and non foods
All1	Can group foods we eat (2)
Most1	
Some1	
KeyLearningOutcome2	We eat different types and amounts of food
Assessment2	Can record amounts/types of food eaten
All2	Can keep a record of foods eaten (1)
Most2	Can compare amounts of food eaten (3 categories: large, smaller, tiny) (2)
Some2	Can give a reason for the different amounts of foods we eat (3)
KeyLearningOutcome3	We need exercise
Assessment3	Record observations before and after exercise
All3	Can notice a change - temperature, sweating, heart rate, breathing (1)
Most3	Can notice 3 significant changes (1)
Some3	Can give consequences of exercise /lack of exercise (3)
KeyLearningOutcome4	Animals produce young, they grow and need care
Assessment4	Can identify stages of growth of animals
All4	Can group main stages e.g. baby / child /parent (1)
Most4	Can identify growth and movement differences for the main growth stages for familiar animals (2)
Some4	Can give examples and reasons, how and why young need care (3)
KeyLearningOutcome5	Medicines can be beneficial and harmful
Assessment5	Know what a medicine does
All5	Know that medicines are not sweets and may be harmful (1)
Most5	Can name 2 types of medicines and what they are for (1)
Some5	Give an effect of a medicine e.g. remove pain /inflammation (2)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 2 ***Unit*** 2B ***Title*** Animals & Plants in the local Environment.

KeyLearningOutcome1	Plants and animals live in different habitats
Assessment1	Recognise different habitats for animals and plants
All1	Identify 4 animals and 4 plants from different habitats (1)
Most1	Match 4 animals and 4 plants to their habitat. (2)
Some1	
KeyLearningOutcome2	Identify differences between 2 habitats and the living things found there.
Assessment2	Observe and record features of 2 different habitats
All2	Can state a feature which links a plant/animal with a habitat (2)
Most2	Identify characteristic features that match animals/plants to habitats (2)
Some2	Can give reasons for an animal's choice of habitat (3)
KeyLearningOutcome3	Seeds come from flowering plants.
Assessment3	Identify seeds from a range of fruits and flowers.
All3	Identify some common seeds/fruits. (1)
Most3	Identify some less common/obvious seeds/fruits. (2)
Some3	
KeyLearningOutcome4	Seeds produce new plants.
Assessment4	Investigate growing plants from seed
All4	Observe & record changes in features of plants grown from seed (1)
Most4	Make comparisons/identify patterns in growth (2)
Some4	Recall that seeds need some things (e.g. warmth, water) to start to grow, but not necessarily other things (e.g. soil) (3)
KeyLearningOutcome5	Animals and plants reproduce
Assessment5	Identify some from eggs/babies/seeds grow into new plants/animals
All5	Match some common plants/animals to seeds/eggs/babies (2)
Most5	Can describe the changes which occur from reproduction to maturity for one plant/animal (2)
Some5	Identify all of the above. (2)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 2	***Unit*** 2C ***Title*** Variation
KeyLearningOutcome1	Decide whether a living thing is an animal or plant.
Assessment1	Group a selection of living things into animal or plant
All1	Group common animals and plants (2)
Most1	Classify with explanation - eyes, leaf etc. (2)
Some1	Classify less familiar animals and plants and justify. (2)
KeyLearningOutcome2	Humans have similar characteristics but also ways in which they are different.
Assessment2	Using photographs and themselves to identify similarities and differences.
All2	Identify similarities/differences - e.g. legs, eyes, height, eyes colour (2)
Most2	Identify that some characteristics change as people get older. (2)
Some2	Identify some characteristics that will not change as people get older (2)
KeyLearningOutcome3	Some differences between themselves can be measured.
Assessment3	Measure a characteristic in standard units
All3	Measure the characteristic in broad standard units of measure (2)
Most3	Measure the characteristic with appropriate accuracy (2)
Some3	Identify appropriate patterns in the characteristic (2)
KeyLearningOutcome4	Group living things according to observable features.
Assessment4	Make groups from a variety of pictures of living things.
All4	Create a group with similar feature - e.g. wings (2)
Most4	Create a number of groups and explain their choices (2)
Some4	
KeyLearningOutcome5	Plants are similar in some ways but different in others.
Assessment5	Identify similarities and differences using photographs, pictures, video's etc. (2)
All5	Identify parts common to plants e.g. stem, leaf, etc. (1)
Most5	Identify differences - shape of leaves, thickness of stem. (2)
Some5	Identify that the appearance of a plant changes with time. (2)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 2	***Unit*** 2D ***Title*** Grouping / Changing Materials
KeyLearningOutcome1	Materials can be grouped according to properties
Assessment1	Grouping materials
All1	Put materials into groups according to their own criteria (2)
Most1	Put materials into groups of metal, wood, plastic, leather etc (2)
Some1	Group materials as natural or manufactured (2)
KeyLearningOutcome2	Materials can be altered for uses
Assessment2	Alter materials
All2	Can make different shapes by squashing, cutting, bending etc (1)
Most2	Describe how they have done this (1)
Some2	Describe how commercial materials have been changed (2)
KeyLearningOutcome3	Heating can change materials
Assessment3	Can change a material by heating
All3	Identify 2 differences (1)
Most3	Observe and record main differences in properties (1)
Some3	Can describe what happens to other things when heated e.g. food, clay (2)
KeyLearningOutcome4	Melting and freezing
Assessment4	Melt ice and observe changes
All4	Observe and record difference between ice/water (1)
Most4	Match changes to heating and cooling (in a freezer) (2)
Some4	Can give other examples of melting/freezing (freezing not always cold) (2)
KeyLearningOutcome5	Boiling and condensing
Assessment5	Observe changes in boiling water
All5	Observe and record differences between water and steam (1)
Most5	Match changes to heating and cooling (steam to water again) (2)
Some5	Can identify that the condensed water comes from steam (2)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 2 ***Unit*** 2E ***Title*** Forces and Movements

KeyLearningOutcome1	Describing how objects change their shape.
Assessment1	Changing shape of objects e.g. plasticine/elastic band.
All1	Write down key words that is push, pull, how plasticine and elastic band changed shape. (1)
Most1	To write/draw/label using correct vocabulary. (1)
Some1	
KeyLearningOutcome2	That pushes and pulls can make things speed up/slow down/change direction.
Assessment2	Moving an object on a slope.
All2	Record how to stop the moving object/make it change direction. (2)
Most2	Describe the changes in speed and direction of moving objects (2)
Some2	
KeyLearningOutcome3	That speed is affected by surface, force of push and angle of slope.
Assessment3	Investigation using a ramp and different surfaces
All3	Carry out simple test with a slope changing surface/angle/push. (2)
Most3	Predict the effect of the change (3)
Some3	Explain the effect in terms of amount of force (3)
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 2 ***Unit*** 2F ***Title*** Using Electricity.

KeyLearningOutcome1	Everyday appliances use electricity.
Assessment1	Can group electrical and non-electrical appliances.
All1	Identify electrical appliances. (1)
Most1	Can group into categories e.g. sound, light, heat/battery, mains. (2)
Some1	
KeyLearningOutcome2	Main electricity must be used safely.
Assessment2	Identify hazardous situations from a poster/picture.
All2	Know that mains electricity is dangerous and can kill (1)
Most2	Can identify dangerous situations/actions (1)
Some2	
KeyLearningOutcome3	Batteries supply safe electricity.
Assessment3	Correctly insert a battery into an appliance.
All3	Use devices with batteries and state that batteries are safe. (1)
Most3	Draw and label devices with batteries. (2)
Some3	
KeyLearningOutcome4	Make a simple circuit.
Assessment4	Construct a simple circuit
All4	Make a simple circuit to light a bulb(lamp) (1)
Most4	Draw/compose pictures of the simple circuits they make. (2)
Some4	Can construct circuits from drawings. (3)
KeyLearningOutcome5	An electrical device needs mains/battery and a complete circuit in order to work.
Assessment5	Identification and correction of incomplete circuits.
All5	Identify why a simple circuit doesn't work. (3)
Most5	Can correct the fault in a simple circuit (3)
Some5	Can make correct predictions and explanations for faulty/non faulty circuits. (3)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 3	***Unit*** 3A ***Title*** Teeth and eating.
KeyLearningOutcome1	Describe a varied and balanced diet suggesting foods needed for growth and some that enable us to be active.
Assessment1	Sort food (pictures) in a variety of ways.
All1	Can describe food and sort according to given criteria. (2)
Most1	Sort food pictures into healthy/unhealthy giving reasons. (2)
Some1	Can sort foods in a variety of ways and justify choice (2)
KeyLearningOutcome2	Know how to look after teeth and why it is important
Assessment2	Poster - How to look after teeth.
All2	States why teeth need to be taken care of and can identify some foods as particularly damaging (2)
Most2	States the difference between adult and milk teeth and how they should look after teeth e.g. brushing/diet. (2)
Some2	Able to name different teeth and give functions. (2)
KeyLearningOutcome3	
Assessment3	
All3	
Most3	
Some3	
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 3	***Unit*** 3B ***Title*** Helping plants grow well
KeyLearningOutcome1	Water is transported through plants
Assessment1	Can describe / draw coloured water transported through plants
All1	Can draw movement of water through plant (1)
Most1	Describe that water comes from soil to roots to stem to leaves (1)
Some1	Can describe the effect of underwatering (3)
KeyLearningOutcome2	Investigate growing plants
Assessment2	Can grow, observe and record, plants in different conditions (light, temperature and water)
All2	Observe and record growing plants in different conditions (1)
Most2	Can compare a feature of growth for different plants (2)
Some2	Can relate growth factor to condition (3)
KeyLearningOutcome3	Recognise healthy / unhealthy plants
Assessment3	Compare pictures/examples of healthy/unhealthy plants
All3	Can group plants as healthy / unhealthy (2)
Most3	Can match amount of light, water to condition of plant (2)
Some3	Can give reasons for effect on conditions of plant (3)
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 3	***Unit*** 3C ***Title*** Characteristics of Materials.
KeyLearningOutcome1	To identify the properties of various common materials (using appropriate terms)
Assessment1	Sorting activity - pictures and/or objects.
All1	Sort into hard, soft, smooth, rough. (2)
Most1	As above plus transparent/opaque/translucent. (2)
Some1	As above plus flexible/strong and any other groupings from children's own ideas. (2)
KeyLearningOutcome2	To know that materials can be used for a range of purposes.
Assessment2	Match pictures/words of use to appropriate material.
All2	Identify uses for glass, wood, paper. (2)
Most2	As above plus metal, plastic. (2)
Some2	Can match variation in material to use e.g. glass for windows can be clear/frosted/tinted. (2)
KeyLearningOutcome3	To know that some materials are more suitable for certain jobs/purposes than others.
Assessment3	Choose appropriate materials for purpose.
All3	Simple criteria/choices to be made. (2)
Most3	More complex/multi choice options that is wood for door, glass for window with reasons (2)
Some3	Can give advantages/disadvantages of alternative materials for a given use e.g. glass/plastic for bottles (2)
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 3 ***Unit*** 3D ***Title*** Rocks and Soils.

KeyLearningOutcome1	Observe and describe characteristics of rocks.
Assessment1	Record observations about rocks
All1	Describe characteristics of rocks & group according to observable features. (1)
Most1	Name different types of rock. (1)
Some1	Relate characteristics to uses of rocks. (2)
KeyLearningOutcome2	Rocks occur naturally.
Assessment2	Oral/written/drawn explanation.
All2	States that rock is under the soil (1)
Most2	Recall that all soils come from rock. (1)
Some2	Can relate that different rocks produce different types of soil. (2)
KeyLearningOutcome3	Rocks wear away and this affects their uses.
Assessment3	Demonstrate that rocks can be worn away and at different rates
All3	States that rocks wear away at different rates. (2)
Most3	Can put rocks and order in degrees of hardness. (2)
Some3	Relate degrees of hardness with uses of rock. (2)
KeyLearningOutcome4	Rocks can be permeable and this affects their uses.
Assessment4	Researches or investigates permeability of rocks
All4	States that some rocks are permeable and some are not (2)
Most4	Can put rocks and order in degrees of permeability. (2)
Some4	Relate findings/results to uses of various rocks (2)
KeyLearningOutcome5	Compare different types of soil
Assessment5	Observe and record features of different soils
All5	Can classify soils in terms of colour and particle size (2)
Most5	Can predict the effect of sieving on various (dry) soils (2)
Some5	Can explain how sieving separates the soil particles (3)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 3	***Unit*** 3E ***Title*** Magnets and Springs.
KeyLearningOutcome1	That there are forces between magnets and they can attract.
Assessment1	Investigate magnets
All1	Describe situations where magnets can attract other magnets. (1)
Most1	Describe situations where magnets attract and repel. (2)
Some1	Describe the behaviour of magnets in terms of forces (3)
KeyLearningOutcome2	That magnets attract some metals and not others.
Assessment2	Investigate magnetic and non magnetic materials
All2	Recall that if a material is not a metal it will not be magnetic (2)
Most2	Recall that not all metals are magnetic. (2)
Some2	Can categorise materials according to: not metallic/magnetic metal/non magnetic metal (2)
KeyLearningOutcome3	When a spring is stretched it exerts an opposing force.
Assessment3	Investigate stretching and compressing springs
All3	Predict which way a spring will go if you stretch/compress it and let go. (2)
Most3	Predict what will happen when you put various weights on a spring. (2)
Some3	Identify which way the forces are acting. (3)
KeyLearningOutcome4	That springs are used in a variety of ways.
Assessment4	Written/drawn/collage of uses of springs
All4	Name some uses. (2)
Most4	
Some4	
KeyLearningOutcome5	Know that gravity is a force
Assessment5	Describe how gravity acts upon an object
All5	Gravity pulls an object
Most5	Gravity pulls an object towards the centre of the earth
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 3	***Unit*** 3F	***Title*** Light and Shadows.

KeyLearningOutcome1	Shape of a shadow is like the shape of object
Assessment1	Puppet shadow theatre.
All1	Draw a shadow the same shape as the object. (2)
Most1	Recognise that changing the position of an object/light source changes the size of shadow. (2)
Some1	State that a shadow is caused by the object blocking the light (3)
KeyLearningOutcome2	Describe what happens to the shadow of a stick during the day and predict what the shadow will be like at intermediate times.
Assessment2	Investigate a sundial e.g. rounders post on the playground
All2	Record the shape and position of the shadow during the day (1)
Most2	Relate the length and position of the shadow to the position of the sun in the sky (3)
Some2	Make predictions with reasons to identify how the shadow changesduring day (model on paper). (3)
KeyLearningOutcome3	Apparent movement of sun is due to the movement of the earth.
Assessment3	Object (e.g.1cm high) on globe and rotate, using torch/lamp/OHP to represent the sun
All3	State that the sun doesn't move, earth rotates/spins and this changes the shadow (2)
Most3	Describe how the shadow of the pencil changes as the earth rotates. (2)
Some3	Relate the behaviour of the model to the behaviour of the sundial (3)
KeyLearningOutcome4	Opaque materials form dark shadows (do not let light through) and transparent materials make faint shadows (block some light).
Assessment4	Investigate shining a light through different materials
All4	Know and can group objects as transparent, translucent and opaque. (2)
Most4	Know that transparent objects make faint shadows. (2)
Some4	Explain why you get different shadows from translucent, transparent and opaque materials. (3)
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 4	***Unit*** 4A ***Title*** Moving and growing.
KeyLearningOutcome1	Describe the life cycle of plants and humans
Assessment1	Draw/label the life cycle of a plant and a human
All1	Can correctly sequence the life cycles of plants and humans (1)
Most1	To make and record observations about bones and skeletons. (1)
Some1	
KeyLearningOutcome2	Locate and name main bones.
Assessment2	To recognize and name main bones in the human skeleton.
All2	Describe and name main bones in the skeleton. (1)
Most2	Relate sizes of bones to growth and differences in people (2)
Some2	
KeyLearningOutcome3	Not all animals have an internal skeleton.
Assessment3	Observe some invertebrates.
All3	To compare bodies of invertebrates with the human body. (2)
Most3	To use secondary sources to find out how bodies are supported. (2)
Some3	To explain how different bodies are supported. (3)
KeyLearningOutcome4	Movement is a result of muscles contracting and relaxing.
Assessment4	Demonstrate/explain how muscles work.
All4	State that animals with skeletons have muscles attached. (1)
Most4	Recall that a muscle has to contract to make a bone move. (3)
Some4	Can explain how muscles act in pairs to produce movement. (4)
KeyLearningOutcome5	Exercising makes your muscles work harder
Assessment5	Makes measurements related to exercise and movement
All5	Can observe and record changes resulting from exercise e.g. breathing/heart/tired/temperature (2)
Most5	Can make comparisons of own or groups observations (2)
Some5	Can relate observed changes to air/lungs/blood circulation (3)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 4	***Unit*** 4B ***Title*** Habitats
KeyLearningOutcome1	Match habitats with organisms
Assessment1	Identify different habitats and organisms that live there
All1	Can describe a habitat and match to an organism (3)
Most1	Can give a reason for their choice (3)
Some1	Can quantify different conditions or numbers of organisms and represent graphically (3)
KeyLearningOutcome2	Identify organisms using keys
Assessment2	Identify organisms (plant or animal) using a key
All2	Use a simple key (4 alternatives/ significant differences e.g. legs (2)
Most2	Use a key to identify organisms with differences in number/type/pattern of characteristic (2)
Some2	Use a key to identify different types(species) of some organisms (2)
KeyLearningOutcome3	Be able to construct a food chain
Assessment3	Can draw a food chain
All3	Can correctly order a food chain for 3 organisms (2)
Most3	Identify producer, predator, prey in food chain (2)
Some3	Create their own food chain (2)
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 4	***Unit*** 4C ***Title*** Keeping warm
KeyLearningOutcome1	Measuring temperature using thermometers and touch
Assessment1	Record a range of temperatures
All1	Identify by touch and measure a range of temperatures hot/warm/cold (2)
Most1	Can relate observations to a scientific reason (3)
Some1	Can explain the significance of room temperature to things cooling/warming (4)
KeyLearningOutcome2	Describe how to use thermal insulation to maintain constant temperatures
Assessment2	Investigate how to keep things hot or cold
All2	Group materials as good/poor thermal insulators and relate the terms insulator and conductor as opposites (2)
Most2	Can put materials in order of their insulating properties and relate thermal conduction with electrical conduction (2)
Some2	Can relate thickness/layers of materials to thermal insulation (3)
KeyLearningOutcome3	
Assessment3	
All3	
Most3	
Some3	
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 4	***Unit*** 4D/5C ***Title*** Solids, liquids, gas and separation.
KeyLearningOutcome1	Know the differences and general properties of solids, liquids and gases
Assessment1	Can correctly group solids, liquids and gases
All1	Can correctly group and name solids, liquids and gases and can justify their choice (2)
Most1	Describe how to reverse named solid, liquid, gas (2)
Some1	State that some materials e.g. metal have to be heated to a very high temperature before they melt. (3)
KeyLearningOutcome2	That melting and freezing are changes that can be reversed and are the reverse of each other.
Assessment2	Complete diagram by adding melting/freezing arrows and names of materials.
All2	Give ice melting water and back to ice as an example. (3)
Most2	State for other everyday materials. (3)
Some2	Give examples requiring extreme temperatures e.g. lava, metals. (3)
KeyLearningOutcome3	That solids can be mixed and it is often possible to get the original materials back.
Assessment3	Separate solid mixture by sieving.
All3	Use a sieve to separate e.g. sand/dried peas. (1)
Most3	Choose correct grades of sieve to separate solids of varying sized particles e.g. flour, salt, lentils. (2)
Some3	Relate size of hole to size of particle as the important factor in sieving (3)
KeyLearningOutcome4	Solids which do not dissolve or react with the water can be separated by filtering.
Assessment4	Use filtering to separate solid from water.
All4	Choose filtering to remove sand from water. (3)
Most4	Choose filtering to remove soil from muddy water. (3)
Some4	Explain filtering in terms of very small holes acting as sieve. (4)
KeyLearningOutcome5	Changes occur when some solids are added to water
Assessment5	Identify soluble and insoluble materials
All5	Group and name 4 soluble and 4 insoluble solids (2)
Most5	Can describe what happens during dissolving (2)
Some5	Can explain evaporation to recover crystals and filtering to recover insoluble materials (4)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 4	***Unit*** 4E ***Title*** Friction
KeyLearningOutcome1	Use a forcemeter to measure force
Assessment1	Any investigation using a forcemeter
All1	Can obtain a reading (number) for a pulling force using a forcemeter(3)
Most1	Can make a careful measurement and quote the units as newtons(3)
Some1	Can estimate or give fractions of units, will repeat readings to check(4)
KeyLearningOutcome2	The force between moving surfaces is friction
Assessment2	Any friction investigation
All2	Group surfaces related to friction slowing down movement(3)
Most2	Represent directions of forces and state friction acts in the opposite direction to movement(3)
Some2	Can explain scientifically how friction occurs(4)
KeyLearningOutcome3	Air resistance slows down movement through air
Assessment3	Any helicopter/parachute/paper plane investigation
All3	Recognise shapes with high air resistance(2)
Most3	Can identify the factors which alter air resistance and state/draw directions of forces(3)
Some3	Can explain scientifically how air resistance opposes movement(4)
KeyLearningOutcome4	Water resistance slows movement through water
Assessment4	Boats investigation
All4	Recognise shapes with high water resistance(2)
Most4	Can identify the factors which alter water resistance and state/draw direction of forces(3)
Some4	Can explain scientifically how water resistance opposes movement(4)
KeyLearningOutcome5	Identify weight as a force.
Assessment5	Describe the effects of forces on objects.
All5	Identify weight as a force(3)
Most5	Identify the pull of gravity on an object(3)
Some5	Identify that an object may have more than one force acting upon it(4)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 4	***Unit*** 4F ***Title*** Circuits and conductors
KeyLearningOutcome1	That a complete circuit is needed for a device (include switches) to work and explain why certain circuits do not
Assessment1	From a diagram - identify which circuit will work and state why others will not
All1	Construct a simple circuit from a simple drawing (3)
Most1	Construct a circuit with increased number and arrangements of components (3)
Some1	
KeyLearningOutcome2	Some materials are conductors and some insulators
Assessment2	Group materials into conductors or insulators
All2	Can use a circuit to test conductors and insulators (3)
Most2	Predict the effect on the circuit by nature of the material (3)
Some2	Can relate materials used in components to electrical properties e.g. plastic plug, copper wire (3)
KeyLearningOutcome3	Know the effects of additional components in a circuit
Assessment3	Altering the number of batteries/bulbs in a circuit
All3	Observe and record the effects of changing a circuit (1)
Most3	Predict the effect of altering the number/type of components (3)
Some3	Explain the effect of changing the components (4)
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 5	***Unit*** 5A/6B ***Title*** Keeping healthy/micro-organisms
KeyLearningOutcome1	Know the effect of/need for exercise
Assessment1	Do exercise and measure breathing/pulse rate
All1	Can measure and record breathing rate - before and after exercise (2)
Most1	Relate effects of exercise to circulation increase (3)
Some1	Explain breathing rate/pulse rate relates to muscle activity and good health (4)
KeyLearningOutcome2	Know the main features of the circulation system
Assessment2	Describe/label/draw/arrange heart, veins, arteries, protective bones
All2	Label heart, veins, arteries, ribs (1)
Most2	Describe the heart as a pump , arteries carry blood away from the heart, veins to the heart (3)
Some2	Link the circulation system to supply of oxygen/food for exercise (3)
KeyLearningOutcome3	Harmful substances
Assessment3	Poster/poem/picture/drama on smoking or drinking or drugs
All3	Know the harm of smoking, drugs, drinking (1)
Most3	Make a presentation on useful drugs and harmful substances (2)
Some3	Describe some side effects of beneficial drugs/overdose effects (2)
KeyLearningOutcome4	Recognise that micro- organisms can be both harmful and useful
Assessment4	Produce a piece of research (CD ROM etc)
All4	Know that micro-organisms are very small living things (1)
Most4	Describe 2 ways by which micro-organisms spread infections and 2 ways in which micro-organisms help to produce food (1)
Some4	Research a discovery/cure of a disease and relate to a particular micro-organism (3)
KeyLearningOutcome5	Micro-organisms grow and feed on material, causing decay and food poisoning
Assessment5	Leave soft fruit/cheese/bread in a sealed container.
All5	Recall that food will decay, mould will grow and food is inedible (1)
Most5	State the most beneficial conditions for growth of micro-organisms and are familiar with the term food poisoning (2)
Some5	Can relate conditions to support the idea of mould as a living thing (feed, grow, reproduce) (3)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 5	***Unit*** 5D ***Title*** Changing State and dissolving
KeyLearningOutcome1	Evaporation is when a liquid turns to gas, condensation is the reverse
Assessment1	Explain processes of evaporation and condensation
All1	Recall that water evaporates from warm surfaces and condensation takes place on cold surfaces (3)
Most1	Know that many liquids evaporate and this can happen at different speeds (3)
Some1	Explain some factors which affect the rate of evaporation (4)
KeyLearningOutcome2	Know the water cycle
Assessment2	Draw a labelled diagram of the water cycle
All2	Label most parts with correct terminology (3)
Most2	Draw and label own diagrams (3)
Some2	Explain the sequence of events and processes with correct scientific terminology (4)
KeyLearningOutcome3	Evaporation, not filtration, separates dissolved solids from liquids
Assessment3	Describe what happens if solutions evaporate
All3	Can identify the solids remaining as the one dissolved (3)
Most3	Can explain why solids remain after evaporation (4)
Some3	Can explain using forces of attraction between particles, why liquids do/solids do not evaporate (5)
KeyLearningOutcome4	Know how to change the rate of dissolving
Assessment4	Dissolve solids under different conditions e.g. temperature
All4	Can produce meaningful results to fit prediction (3)
Most4	Can relate different conditions to rate of dissolving (3)
Some4	Use energy input and movement of particles to explain the change in rate of dissolving (5)
KeyLearningOutcome5	The amount of solid that can dissolve in water is limited and depends upon the type of solid
Assessment5	Dissolving solid in water
All5	Can observe and record amounts that dissolve (2)
Most5	Can give a sensible explanation of limit of solubility (4)
Some5	Can identify that some solids are more soluble than others (4)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 5	***Unit*** 5E/6F ***Title*** Earth Sun and Moon, shadows and how we see
KeyLearningOutcome1	To recognise difference between shadows and reflections
Assessment1	Investigation or written work on shadows and reflections
All1	State a shadow forms when light is blocked(opaque material) and reflection changes the direction of light (3)
Most1	Uses a ruler to draw diagrams to show shadow formation and angle of mirror and the 2 rays of light (3)
Some1	Explain the differences between shadow and reflection in terms of path of light (4)
KeyLearningOutcome2	We see because light enters our eyes
Assessment2	Labelled diagrams/written work
All2	State we see light sources and objects because light from them enters our eyes (2)
Most2	Correct drawings of arrow (ray of light) from source to eye and source to object to eye(4)
Some2	
KeyLearningOutcome3	Shiny surfaces reflect better than dull ones
Assessment3	Arrange surfaces in order of reflectiveness
All3	Can produce a justifiable order for reflectiveness (2)
Most3	Can relate change in appearance to order of reflectiveness (3)
Some3	Explain why shiny surfaces are good reflectors and dull surfaces scatter light (4)
KeyLearningOutcome4	Knows why shadows move as sun appears to move
Assessment4	Carry out a shadow investigation
All4	Describe how shadows change in length and position (N,S,E,W) as sun appears to move in the sky (3)
Most4	Can relate the changing shadow pattern to the spin of the earth. (3)
Some4	Explains the changing shadow pattern in terms of the rotation/spin of the earth. (4)
KeyLearningOutcome5	Know the relative size, positions and movements of the sun, the earth and the moon
Assessment5	Using models or pictures (of own choice) to illustrate
All5	Chooses spheres/circles to demonstrate sun, earth, moon (1)
Most5	Model/diagram shows orbits, rotations and timescale day/month/year (3)
Some5	Uses models/diagrams to explain the repeating cycles of year/seasons/month/day (4)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 5	***Unit*** 5F ***Title*** Changing sounds
KeyLearningOutcome1	Vibrations pass through materials
Assessment1	Describe activities and occasions where sound passes through material
All1	Give examples of sounds passing through solids, liquids and gases (2)
Most1	Can describe how the sound passes through solids, liquids and gases using vibrations (4)
Some1	Can explain why solids transmit sounds better than liquids, liquids better than gases and why no sound passes through a vacuum (4)
KeyLearningOutcome2	Know that pitch can be higher/lower and is changed by length, thickness, tightness of material
Assessment2	Investigate changing sounds
All2	Can distinguish and correctly use high/low for sounds of different pitch (3)
Most2	Match high/low pitch to length, thickness, tension. (3)
Some2	Explain change in pitch in terms of speed and length of vibration (4)
KeyLearningOutcome3	Changing pitch in air
Assessment3	Investigate changing pitch with air columns/instruments
All3	Can distinguish and correctly use high/low pitch (3)
Most3	Match high/low pitch to length of air column (3)
Some3	Can explain change in pitch in terms of length of vibration of air column (4)
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 6	***Unit*** 6A/5B ***Title*** Interdependence and Adaptation
KeyLearningOutcome1	Know that nutrients help plants grow well
Assessment1	Label simple diagrams of plants showing transfer of nutrients through the roots
All1	Recall that plants get nutrients from the soil (1)
Most1	Recall that fertilisers are added to soils to provide nutrients for plants (2)
Some1	Explain how the roots are adapted to anchor the plant and take up water and nutrients (4)
KeyLearningOutcome2	Interdependence and suitability.
Assessment2	Label a diagram/flow chart showing links between living things
All2	List some animals that need each other and give reasons (3)
Most2	Use adaptations to match unfamiliar plants and animals with appropriate environment (3)
Some2	Explain how adaptations help animals and plants live in a certain environment (4)
KeyLearningOutcome3	Describe the conditions for germination of plants
Assessment3	Grow plants from seed
All3	Identify conditions for seed to germinate (2)
Most3	Explain the need for conditions (4)
Some3	Identify how the conditions relate to living things (4)
KeyLearningOutcome4	Know the different methods of seed dispersal
Assessment4	Matching types of seed dispersal
All4	Be able to recognise different types of seed dispersal (2)
Most4	Match dispersal type to structure of seed (3)
Some4	Explain why seed dispersal is beneficial (4)
KeyLearningOutcome5	Describe the process of pollination
Assessment5	Create a pollination poster
All5	Draw/label parts of a flower petal, stamen, stigma (sepals, ovary) (3)
Most5	Group plants as wind or insect pollinated (3)
Some5	Can predict and justify unknown plants as wind/insect pollinated (3)

QCA Scheme of Work (amended) Key Learning Outcomes

Year 6	***Unit*** 6D ***Title*** Irreversible changes
KeyLearningOutcome1	Recognise irreversible changes
Assessment1	Describe a selection of irreversible changes
All1	Can observe and record changes and identify as irreversible (3)
Most1	Can give an explanation of irreversibility in terms of 'new substances formed' (3)
Some1	Make predictions for new situations and give reasons. (3)
KeyLearningOutcome2	Know examples of burning
Assessment2	Describe what happens in burning
All2	Recognise burning as an irreversible change (2)
Most2	Can explain why burning is an irreversible change (new substances) (3)
Some2	Can relate burning to using up oxygen to give new substances (4)
KeyLearningOutcome3	
Assessment3	
All3	
Most3	
Some3	
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 6	***Unit*** 6E ***Title*** Balanced and unbalanced forces
KeyLearningOutcome1	Identify weight as a force
Assessment1	Describe the effects of forces upon objects
All1	Identify weight as a force (3)
Most1	Identify the pull of gravity upon an object (3)
Some1	Identify that an object can have more than one force acting upon it (3)
KeyLearningOutcome2	Describe the effects of balanced/unbalanced forces
Assessment2	Describe the movement of objects in terms of the forces acting upon them
All2	Give examples of objects starting to move because forces are acting on them (3)
Most2	Give examples where unbalanced forces change the movement of an object and balanced forces do not (3)
Some2	Explain how balanced/unbalanced forces affect the movement of an object (4)
KeyLearningOutcome3	To describe how an object behaves in water
Assessment3	Describe and explain what happens to a range of objects in water
All3	State that water provides an upward force (upthrust) (3)
Most3	State that an object floats due to balance between gravity and upthrust (3)
Some3	
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

QCA Scheme of Work (amended) Key Learning Outcomes

Year 6	***Unit*** 6G ***Title*** Changing Circuits
KeyLearningOutcome1	To be able to use symbols to represent circuits.
Assessment1	Draw circuit diagram correctly using appropriate symbols
All1	Can identify symbols used in circuits (4)
Most1	Correctly draw simple circuit diagrams (4)
Some1	Draw more complex circuit diagrams (4)
KeyLearningOutcome2	To be able to build a circuit using a diagram (diagram interpretation)
Assessment2	Build appropriate circuit correctly.
All2	Can relate a simple circuit diagram to a drawing of a circuit (4)
Most2	Construct circuit from diagram using conventional symbols (4)
Some2	Interpret and build more complex circuits from circuit diagrams (5)
KeyLearningOutcome3	To know the 'flow' within a circuit can be changed e.g. brightness of bulb, speed of motor
Assessment3	Set up circuit to investigate changing flow
All3	Can change the brightness of bulb/speed of motor by using more/fewer components (3)
Most3	Can change the brightness of a bulb/speed of motor by altering the arrangement of components (3)
Some3	Can explain the observations in terms of flow of electricity (4)
KeyLearningOutcome4	
Assessment4	
All4	
Most4	
Some4	
KeyLearningOutcome5	
Assessment5	
All5	
Most5	
Some5	

Appendix 4

QUESTIONNAIRE 1 - PARTICULATE THEORY

Which statements are true? Put a tick 4or a cross x or ? (if you don't know)

1 Solids:
   a) diffuse with other solids;
   b) are often strong;
   c) change their volume according to their container;
   d) do not change shape unless acted on by outside influences;
   e) can only be hard or malleable.

2. Gases:
   a) change their volume to fill their container;
   b) can be compressed;
   c) do not change shape unless acted on by outside influences;
   d) do not diffuse;
   e) are weak.

3. Particles of solids:
   a) are closely packed together;
   b) move easily around each other;
   c) do not have any space between them;
   d) are held together by strong forces;
   e) transfer energy by the process of convection.

4. Particles of liquids:
   a) always have the same amount of energy;
   b) vibrate about a fixed point;
   c) move around each other;
   d) are held by strong forces;
   e) transfer energy when high energy particles rise together.

5. Particles of gases:
   a) are largely unaffected by attractive forces;
   b) avoid colliding with each other;
   c) collide with the walls of their container to exert a pressure;
   d) have more space between them than the particles of liquids;
   e) transfer energy by the process of conduction.

QUESTIONNAIRE 1 - ANSWERS

1. Solids:
a) do not diffuse with other solids;
b) are often strong, although they can be weak like cotton wool;
c) do not change their volume to fit their container;
d) do not change shape unaided;
e) can also be non space filling or easily melted

a) 8 b) 4 c) 8 d) 4 e) 8

2. Gases:
a) spread out to fill their container;
b) can be compressed
c) change shape readily;
d) diffuse easily;
e) are weak.

a) 4 b) 4 c) x d) x e) 4

3. Particles of solids:
a) are closely packed together;
b) cannot move around each other, they vibrate about a fixed point;
c) have very small spaces between them;
d) are held together by strong forces;
e) transfer energy by conduction not convection.

a) 4 b) x c) x d) 4 e) x

4. Particles of liquids:
a) have different amounts of energy, as do the particles of solids and gases;
b)/c) move around each other;
d) particles of solids are held by strong forces, in liquids the forces of attraction between the particles are weaker
e) transfer energy by convection, that is when high energy particles rise together.

a) x b) x c) 4 d) x e) 4

5. Particles of gases:
a) are unaffected by forces, except during collisions;
b) frequently collide with each other;
c) frequently collide with the walls of their container to exert a pressure
d) have much more space between them than the particles of liquids
e) transfer energy by convection not conduction.

a) 4 b) x c) 4 d) 4 e) x

QUESTIONNAIRE 2 - CHANGE OF STATE

Which statements are true?

Which statements are true? Put a tick 4or a cross x or ? (if you don't know)

1. During change of state
a) The effect of the attractive forces between particles is always weaker.
b) The volume of the substance always change
c) The temperature of the substance goes up during melting and boiling and down during solidifying and condensing.
d) The distance between particles remains the same.
e) The number of particles involved remains the same.

2. About melting
a) Melting is when a solid gains energy and changes to a liquid
b) During melting, the volume of the solid decreases.
c) During melting, the energy is being used to rearrange the particles of the solid.
d) During melting, the temperature of the solid rises.
e) All solids melt.

3. About evaporation
a) Evaporation only takes place at the surface of the liquid.
b) The hotter the weather, the faster evaporation takes place.
c) During evaporation low energy particles escape from the liquid.
d) During evaporation the average energy of the particles of liquid which remain fails, causing the temperature of the remaining liquid to drop.
e) Some liquids evaporate more easily than others.

4. About boiling
a) Boiling occurs both at the surface of, and throughout, the liquid.
b) The boiling point is lower if the atmospheric pressure is lower.
c) Liquids boil at 100^0C, which is called the boiling point of liquids.
d) The bubbles in boiling water are air.
e) Water always boils at the same temperature.

QUESTIONNAIRE 2 - ANSWERS

1. During change of state

a) The effect of the attractive forces between the particles does change, but the effect of the forces is only weaker when a solid melts and a liquid evaporates or boils because particles move further, apart during melting, evaporating and boiling. When a liquid solidifies and a gas condenses the effect of the forces between the particles is stronger because the particles are moving closer together.

b/d) During melting (not ice), evaporating and boiling, the distance between the particles increases, therefore the .volume increases. During solidifying and condensing the distance between particles decreases, therefore the volume decreases, so both the distance between particles and the volume always change.

c) The temperature remains the same while change of state is occurring.

e) The number of particles does remain the same.

a) x b) 4 c) x d) x e) 4

2. About melting

a) This statement is true.

b) When ice melts, the volume decreases but this is an exception. Normally when solids melt there is an increase in volume.

c/d) The energy is being used to lessen the effect of the attractive forces between the particles, so that the particles can move further apart, or be rearranged, during melting. This is why the temperature stops rising.

e) Some solids, particularly biological materials, do not melt but change in a different way. A few solids sublime, that is they change directly to a gas.

a) 4 b) x c) 4 d) x e) x

3. About evaporation

a) This is a true statement.

b) On a hot, humid day, evaporation can be slower than on a cooler and breezy day with little water vapour in the air.

c) High energy particles escape during evaporation.

d) Because high energy particles escape, this does cause the average energy of the remaining particles to fall, lowering the temperature of the remaining liquid.

e) This is true. For example, nail varnish remover evaporates faster than water.

a) 4 b) x c) x d) 4 e) 4

4. About boiling

a) This is a true statement.

b) This is also true.

c) Pure water at standard pressure only boils at 100^0C. Other liquids have different boiling points.

d) The bubbles in boiling water are water vapour bubbles.

e) Atmospheric pressure or the presence of impurities can alter the boiling point of water.

a) 4 b) 4 c) x d) x e) x

QUESTIONNAIRE 3 - CHEMICAL CHANGE

Which statements are true? Put a tick 4or a cross x or ? (if you don't know)

1. a) An atom is made up of protons, neutrons and electrons.
   b) Protons orbit the nucleus of an atom.
   c) A molecule is made up of three atoms.
   d) Elements are different from each other because their atoms have different numbers of protons.
   e) The forces holding the atoms together in a molecule are weaker than the forces holding together the molecules of a solid.

2. a) A burning candle is an example of change of state.
   b) When a candle burns, energy is transferred to the surroundings.
   c) When a candle burns, hydrogen and oxygen gases are released.
   d) When a candle burns, a chemical change called combustion takes place.
   e) As long as there is wax left, a candle will continue to burn.

3. a) Chemical change takes place when the constituents of the molecules are changed during a reaction.
   b) Boiling is a kind of chemical change.
   c) Chemical change is when solids change into gases.
   d) New materials are produced during chemical change.
   e) Materials must always be heated before a chemical change takes place.

4. a) Oxidation is a chemical reaction in which oxygen gas is released.
   b) Iron needs only water to rust.
   c) Combustion takes place when a fuel combines with oxygen to form carbon dioxide and water and energy is transferred to the surroundings.
   d) Oxidation takes place when oxygen combines with another substance to form a new material.
   e) An endothermic reaction is one in which energy is transferred to the surroundings.

QUESTIONNAIRE 3 - ANSWERS

1 a) This statement is true.
b) Electrons, not protons, orbit the nucleus.
c) Molecules can have any number of atoms. A water molecule has three atoms.
d) This statement is true.
e) The forces holding the atoms together in a molecule are much stronger than the forces holding the molecules themselves together.

a) 4 b) x c) x d) 4 e) x

2 a) Although solid wax does melt and run down the side, this is not the complete picture. Burning is a kind of chemical change.
b) This statement is true.
c) Carbon dioxide and water vapour are the gases released.
d) This statement is true.
e) If a candle is to continue burning, oxygen, a wick and energy from the flame are all needed as well as the fuel, wax.

a) x b) 4 c) x d) 4 e) x

3 a) This statement is true.
b/c) In boiling, a change of state from liquid to gas takes place but the molecules themselves remain the same. In chemical change, there may be a change from liquid to gas or from a solid to a gas as in the Alka-Seltzer activity, but what is important is that the actual constituents of the molecules change.
d) This statement is true.
e) Many chemical changes do require heating to both initiate the reaction and to keep the reaction going, but some will take place without heating, as in rusting and the activities using Plaster of Paris and Alka-Seltzer.

a) 4 b) x c) x d) 4 e) x

4 a/d) A process where oxygen combines with another material to form a new substance is called oxidation. Oxidation does not involve release of oxygen gas.
b) Iron needs both water and oxygen to rust.
c) This statement is true.
e) In an endothermic reaction energy is transferred from, not to, the surroundings.

a) x b) x c) 4 d) 4 e) x

QUESTIONNAIRE 4 - MIXTURES

Which statements are true? Put a tick 4or a cross x or ? (if you don't know)

1. a) Dissolving is a kind of chemical change.
   b) All solids dissolve in water.
   c) Oxygen dissolves in water.
   d) If citric acid is dissolved in water, the citric acid and water can be separated by filtration.
   e) Miscible liquids can be separated by distillation.

2. a) A solution is a mixture of two or more substances.
   b) A solution can only be the result of a solid dissolving in a liquid.
   c) A solution is formed when the molecules of one substance mix with the molecules of another substance, the molecules being held together by attractive forces.
   d) A solution results when sugar dissolves in water.
   e) Dissolving does not involve gases.

3. a) Solutions are clear, colourless liquids.
   b) A saturated solution is a solution in which no more solid will dissolve at that temperature.
   c) A concentrated sugar solution contains less sugar than a dilute sugar solution.
   d) The solubility of a solid in a liquid is how much solid will dissolve in 100 g of the liquid at a given temperature.
   e) In a sugar solution, the sugar is called the solvent and the water is called the solute.

4. a) The main difference between solutions and colloids is that the molecules in solutions mix together. In colloids groups of molecules of the minor constituent are held up in the major constituent.
   b) Colloids cannot be separated by filtration.
   c) Like solutions, suspensions do not settle out.
   d) Colloids must consist of a liquid held in another liquid, like milk.
   e) The main difference between colloids and suspensions is that suspensions have smaller groups of molecules suspended in the major constituent than colloids.

QUESTIONNAIRE 4 - ANSWERS

1 a) Dissolving is considered by scientists to be a physical not chemical change.
b) Although all solids dissolve to some extent some hardly dissolve at all and scientists generally say that some solids, such as sand, are insoluble in water.
c) Oxygen does dissolve in water, otherwise fish would die.
d) A solution of citric acid in water cannot be separated by filtration. The water has to be evaporated, leaving the citric acid behind.
e) Miscible liquids can be separated by distillation

a) x b) x c) 4 d) x e) 4

2 a) A solution is a mixture of two or more substances - although it is not the only example, colloids, suspensions and sand and water type mixtures also fit this description.
b) Solutions are not restricted to solids in liquids.
c) A solution is formed when the molecules of one substance mix with the molecules of another substance, the molecules being held together by attractive forces.
d) A solution does result when sugar is dissolves in water.
e) Gases can dissolve in liquids, forming solutions.

a) 4 b) x c) 4d) 4 e) x

3 a) Solutions are clear but can be coloured or colourless.
b) When no more solid will dissolve, the solution is said to be saturated.
c) A concentrated solution has more sugar than a dilute one.
d) This is the correct definition of solubility.
e) Sugar is the solute and water the solvent.

a) x b) 4 c) x d) 4 e) x

4 a) The statement correctly shows the main difference between solutions and colloids.
b) The groups of molecules in colloids are too small to be separated by filtration.
c) Suspensions do settle out.
d) Colloids are not restricted to liquid/liquid mixes.
e) Colloids have smaller groups of molecules than suspensions.

a) 4 b) 4 c) x d) x e) x

Appendix 5

Forces Strategies used

There follows a sequence of activities used to develop an understanding of forces. These were used over a sequence of sessions, developing the concepts at an appropriate pace.

The concept was introduced with skittles and a ball. This is non-gender orientated and familiar to all the children. It was introduced as an isolated topic and a combination of weight (because they are more comfortable with and use the term weight rather than mass – although this will need modifying at a later stage), speed and direction. The word momentum is not introduced until they have made a wide range of observations related to the mass/weight of the ball, the speed of the ball and the direction the ball is moving. When they are comfortable with these features they can be combined in the term momentum.

The children needed to be encouraged to observe carefully what happened to the skittles and the ball before and after impact. In the various case studies the children had varying levels of powers of observation, they often had simplistic views on the movement e.g. the ball hit the skittles and knocked them over, but did not initially recognise the change of speed or direction, or explain in these terms and they tended to concentrate on the movement of the skittles rather than the ball. The children need to have their observations developed, very few children would volunteer observations related to the ball initially, but many could, when encouraged, focus on the ball only.

The following illustrates how the arguments were developed. The teacher did not know initially how the argument was going to develop. This was done intentionally, so the concept of momentum was not allowed to be in conflict with any of their existing ideas. This applied equally to the children. The activities usually started with observe and describe what happened when the ball (of about tennis ball size) was bowled at some skittles. The teaching scenario involved letting the children observe and predict. They could choose which ball to use against the skittles, and heavy/light, hard/soft balls of approximately the same size were all available. They often thought the hardness of the ball was significant in the effect produced. This was dispelled by using two balls of the same material, and therefore of the same hardness, but of different weights and asking the children about the relative effects. They could choose the speed to achieve a desired effect. It also demonstrated to the children and the teacher that they knew intuitively much of what is necessary to explain the effect of forces. There was a lot of repetition of the key words: mass/weight, speed and direction and momentum and some written work as a writing frame for the children to consolidate what they had seen, before taking them on a little further. This was not only to consolidate the concepts but also the language they needed to use in order to communicate their ideas effectively. The researcher had to encourage the children to overcome

their simplistic ideas and develop considerably their level of observational detail, for example the ball moved or the skittles fell over to the direction and speed of the ball and the movement of the skittles and the ball after a collision.
The children should be able to predict the direction of movement from the direction of the force applied and more significantly, the corollary of being able to predict the direction of the force from the observed movement. This was the key to further understanding. They must be convinced and be comfortable with, the principle that the direction of movement allows you to predict the direction of the (resultant) force. This was done by rolling the ball in different directions and them observing the direction of the force, then with their eyes closed and only opening after the ball's release, observing the direction of the ball thereby deducing the direction of the force. This relates direction of movement to the direction of force.

Another useful activity was to use roller blading as a means of using this principle of direction of movement being an indicator of direction of force. This can be done as a practical exercise, but it had also been video recorded to enable discussion to take place in the classroom. This was the first example of where the children were challenged to explain phenomena that they had not previously thought about. The video consisted of several short sequences which started from what they could predict or explain easily to those which presented challenge and a development of their frameworks. These were:

- a roller blader being pushed from behind;
- two roller bladders pushing each other;
- a roller blader pushing against a wall, and
- a roller blader rolling down a slope.

At each stage of a new challenge the ideas to take the group forward had to be those of the children (not the teacher).

One child was being pushed from behind, why does he/she move forward that is the direction of the push? – by this stage all the children were able to give a reason correctly. Two children are opposite and pushing each other. They move away from each other. Explain why. "because they push each other". At this stage it was important to fragment this and explain the two movements individually. They then need to extend this to being able to explain that child A moves backwards because he/she is being pushed by child B in that direction and similar circumstances apply for child B being pushed by child A. It is important to separate each movement and its applied force.

One child pushes against a wall and moves backwards and the class are asked to explain the movement being away from the wall. The initial most frequent response is because he/she pushed against the wall, not realising at this stage that the push is forward and the movement is backwards. By a series of discussions and recapping about direction of movement being an indicator of direction of force, some members of the group will eventually realise that the push, if the movement is away from the wall, cannot be the child's –he/she is pushing towards the wall, the push has to be from the wall on to the child. Although the number of children who actually put forward this idea is quite small there are a significant number that can see that it is an idea with merit, (intelligible, plausible and fruitful) because it does indeed fit in with their previous discussions that had taken place. Having the majority of children ready to accept ideas from the group about reasonable and logical explanations was worth investigating. There was a need to confirm these by giving them other examples where it is possible to provide evidence for the ideas proposed: for example, a trampoline, or a bouncing ball. Asking the children to describe what happens when they bounce on a trampoline and then explain their observations, demonstrates that the ideas they need to explain new phenomena are often present in the children and the changing skill of the teacher is in knowing how to elicit these ideas, rather than simply knowing the answers. The transfer of this idea of increasing stiffness of a surface culminating in a very stiff wall with varying degrees of ease and these had to be dealt with sympathetically and at a pace with which they could cope. There was again, a need at this stage to give the children the opportunity to express their ideas individually, so the teacher could give further support where needed. Once the idea of transfer of momentum and direction of force and resulting change in movement was grasped these ideas could be used to explain the various other phenomena that are relevant to an understanding of forces generally and specifically with respect to the National Curriculum. There are lots of play situations which can be used to give a context for the learning. These ideas were particularly rich when explaining new phenomena such as friction and air resistance. Friction was explained to them using the concept of momentum using a piece of long pile carpet and they could relate the transfer of momentum from a moving ball (or toy car) to the fibres on the carpet. They were then in a position to correctly predict between a long pile carpet, or a short pile carpet which will provide the greater friction. Air resistance and drag could be explained equally in terms of transfer of momentum and by this stage the more able children can do this without any prompting. Educators have always recognised the need to start where the child is and Ausubel emphasises this in his distinction of rote and meaningful learning, but as Driver *et al.,* (1985) point out, this applies not only to the level of the higher ability children in Year 4 but also more widely to children in the Year 6 group.

Acceleration and deceleration were explored using a bowling ball. This has a large enough momentum that when rolled, on a smooth, level surface this would have negligible effect on the motion of the ball. The children were able to judge that when a force was constantly applied in the same direction as movement, the ball travelled faster and faster: acceleration is proportional to force applied. If the force was in the opposite direction to the movement the ball would slow down, but when the ball was released and no (forward or reverse) force was acting, the ball travelled at a constant speed. These ideas were then developed in discussion using examples such as, what would happen if you threw a ball in space.

The next section to be dealt with was floating and sinking and this again was related to previous work, for example, roller blading to demonstrate the effect of one force compared to the effect of greater forces and opposing forces. This was to emphasise to the children the coherence of the ideas. Many children when questioned as to why something is floating will say "because it has air in it" and make no reference to any forces operating. This is not surprising considering the level of their conceptual development. As with many abstract ideas the children cannot visualise a model, so they needed to experience the push back by the water when something is immersed , for example, a balloon and that when more of the object is immersed the greater the push back is experienced until the balloon is completely immersed. Having experienced upthrust, for example, with a balloon in a tank of water, they will see that it is real and it does make sense. At the same time they need to notice that the water level is rising significantly and that the two are linked. A second extension of this activity is to use glass beads added to a floating container - as more beads are added the container gets lower and the water level rises. The children are comfortable with the explanation of this in terms of gravity and upthrust producing balanced forces. This is particularly important when dealing with objects that sink in water and apparently weigh less. Many children can accept that if two equal forces oppose each other an object will not move, but the children who can explain why a brick in water "feels lighter" are few and far between. This can be achieved quite successfully using an ordinary house brick that weighs 20N and produces an upthrust of 10N and a thermalite brick the same size which weighs just less than 10N. These convenient numbers allow the children to see why some objects, especially heavy ones like ships, float. Also it allows them to use readings on a forcemeter to predict whether an object will float or sink.

Appendix 6

Our Planning Board

We will change

We will measure

Our question is: how does ………… affect ………………..

We will keep these things the same

Our Table

What we will change	What we will measure

Our Table

What we will change	What we will measure			
	1st go	2nd go	3rd go	average

Our graph

What we will measure

A graph to show:

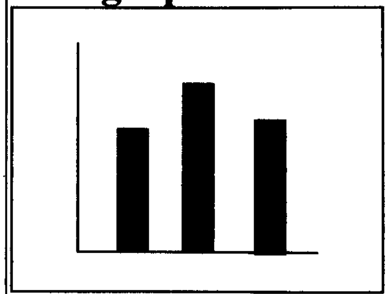
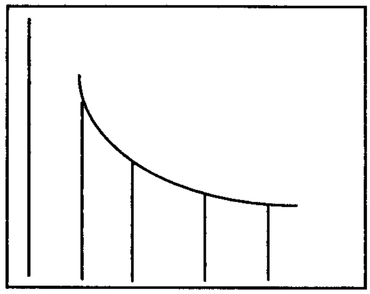
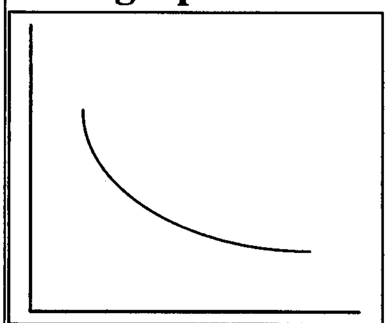
how ....

affects ....

I will draw a .... graph

What we will change

Deciding which graph to use

What I change	What I measure	Type of graph
words	words	No graph
numbers	words	No graph
words	numbers	Bar graph 
numbers	numbers	Stick graph  Line graph 

Appendix 7

Liverpool John Moores University
School of Education and Community Studies

ZENECA SCIENCE TEACHING TRUST

PRE-TEST FORCES

Pupil name

....

School name

....

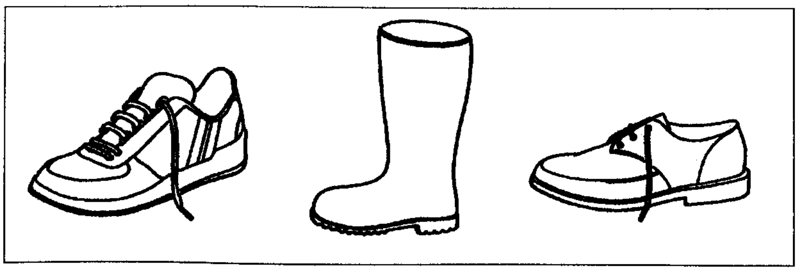
Year group

....

Date of test

....

GRIPPY FOOTWEAR



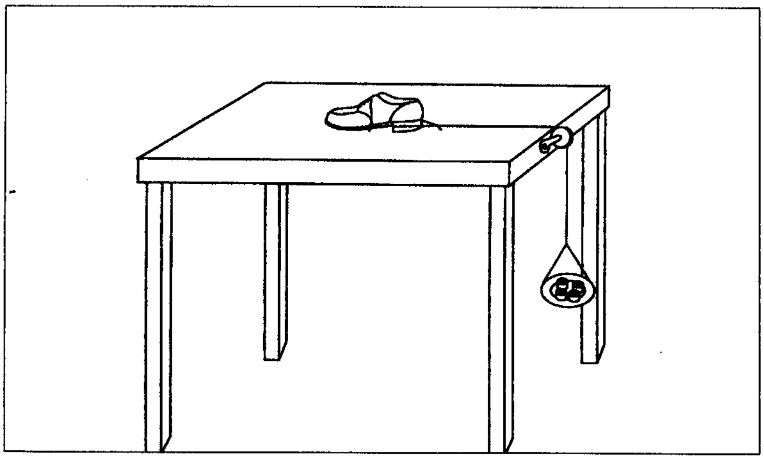
trainer rubber boot shoe

Some children did an experiment to find out which footwear had the best grip.

They tied a string to a shoe.

They put weights (masses) in the pan until the shoe just started to move.

1 (a) Draw an arrow on the diagram to show the direction in which the shoe will move



1 (b) Name the force which is pulling downwards on the pan and the weights.

....

1 (c) Name the force stopping the shoe sliding across the table

....

The children recorded their results in a table.

Footwear	**Weight in pan**
Trainer	310g
Rubber boot	720g
Shoe	440g

1 (d) Which footwear had the best grip?

....

1 (e) How did you use the results to decide which footwear had the best grip?

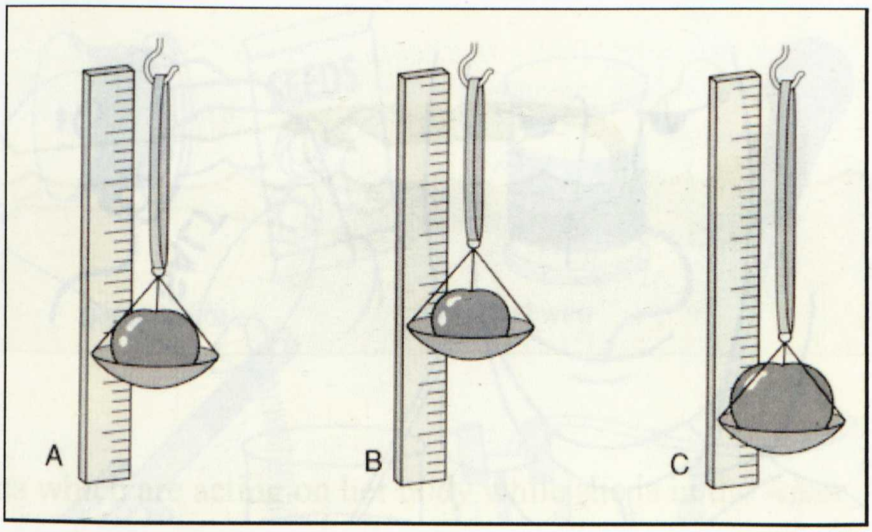
....

....

....

TOMATOES

Some children were comparing the weight of tomatoes they had grown.



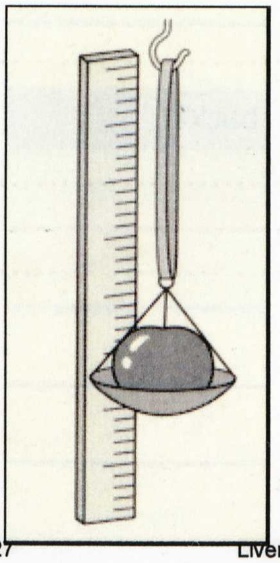
2 (a) Name the force that gives the tomatoes their weight.

....

2 (b) Why is C the heaviest

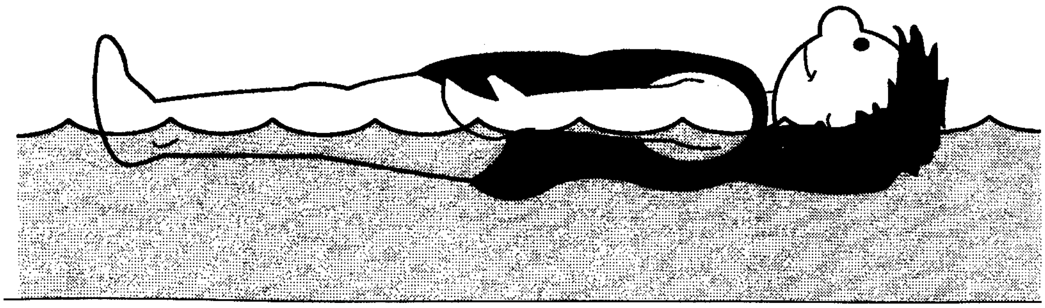
....

2 (c) Draw two arrows to show two forces acting on this tomato.



IN THE POOL

Maddy is floating in the water.



3 (a)Name two forces which are acting on her body while she is in the water

(i)

....

(ii)

....

3 (b) Use what you know about forces to explain why she can lie there

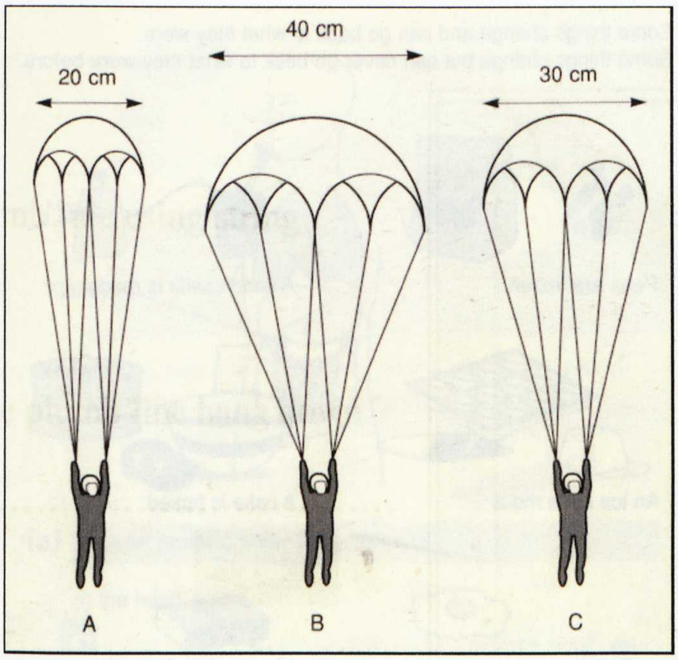
....

....

....

....

......



PARACHUTES

These parachutes were dropped from the same height at the same time.

4 (a) Which parachute will be the last to land

....

Choose the correct answer to finish this sentence.

4 (b) The parachute will be the last to land because:

(i) it is the heaviest

(ii) it is the biggest and the air has more effect on it

(ii) it is the lightest

4 (c) Why were the parachutes dropped from the same height

....

....

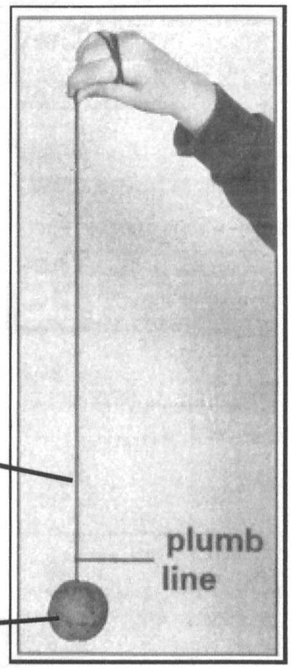
PLUMB LINE

Some children make a plumb line using string

and modelling clay

5 (a) What force makes the plumb line hang down

....



Imagine that three children are holding plumb lines at three different points on the Earth.

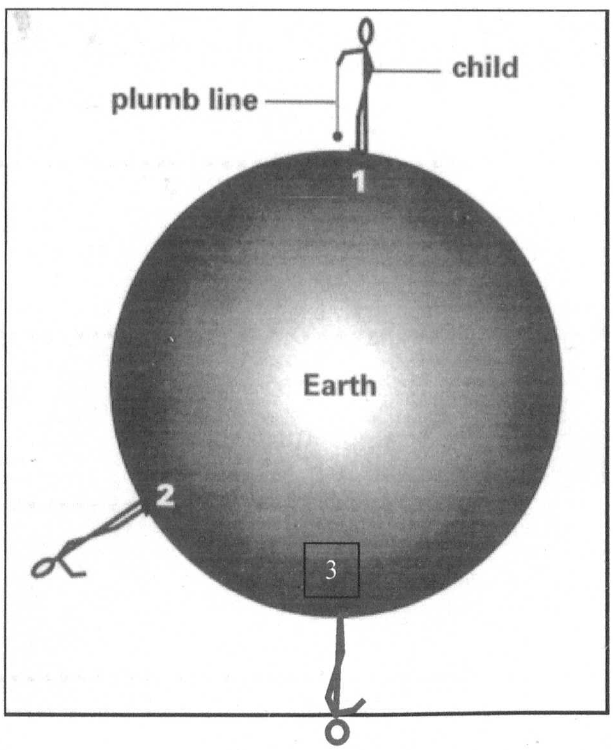
The plumb line for the child at point 1 has been drawn for you

How would the plumb line for the child at point 2 hang ?

5 (b) Draw the plumb line on the diagram

How would the plumb line for the child at point 3 hang ?

5 (c) Draw the plumb line on the diagram



Appendix 8

Liverpool John Moores University
School of Education and Community Studies

ZENECA SCIENCE TEACHING TRUST

END TEST FORCES

Pupil name

....

School name

....

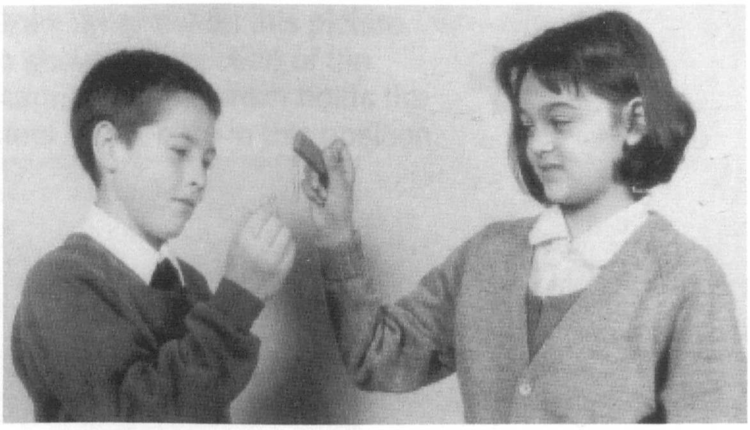
Year group

....

Date of test

....

Magnets



Children tested the strength of three magnets by finding out how many steel paper clips each magnet held.

They recorded their results.

magnet	number of paper clips held
horseshoe	3
bar	8
round	5

Look at the results in the table.

1a) Which is the strongest magnet?

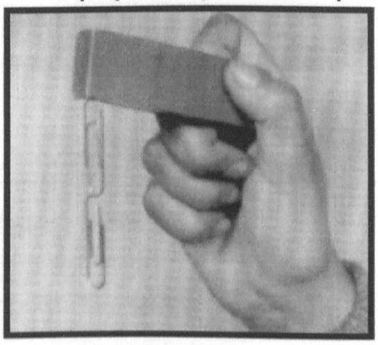
____

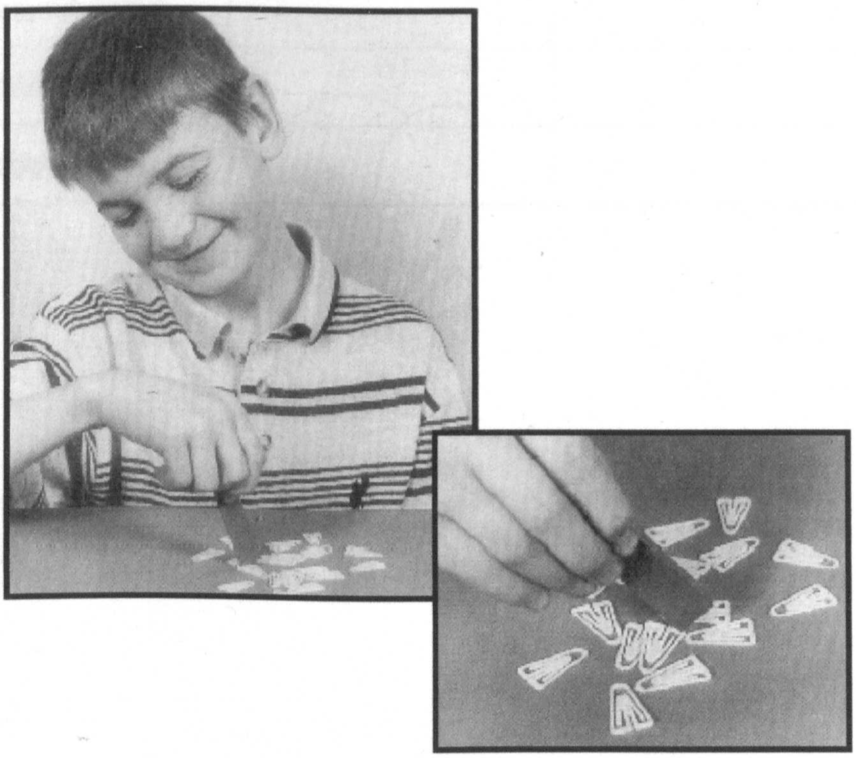
1b) Explain how you decided which is the strongest magnet.

____

(c)

Draw an arrow on this picture to show the direction of the magnetic force which holds the steel paper clips in this position.





1d) Explain why a magnet will not attract plastic paper clips.

1e) Complete the table below to show which objects are attracted by a magnet. Put a tick in the correct box for each object.

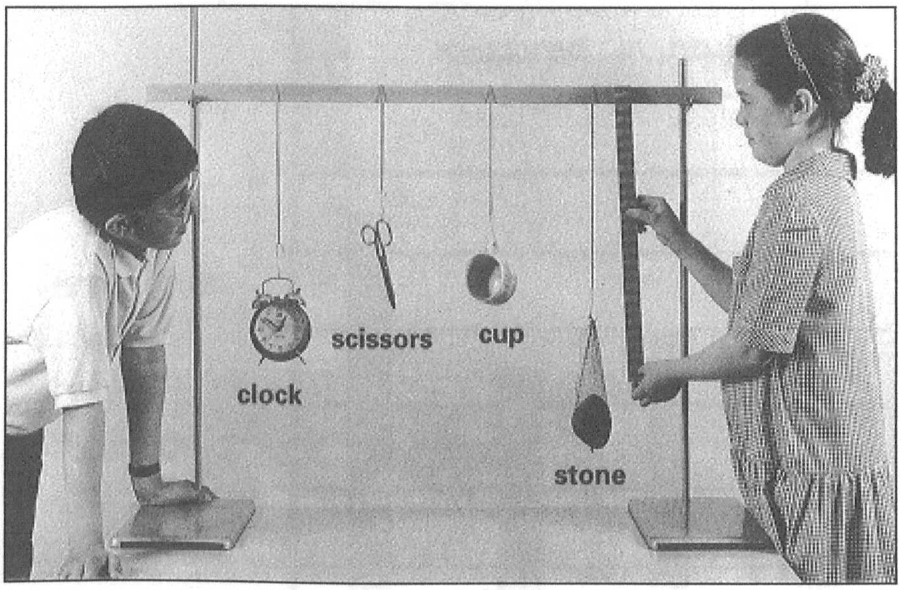
The first one has been done for you.

	is attracted	is not attracted
wooden pencil		✓
steel safety pin		
plastic bead		
cardboard box		
copper wire		

2 marks

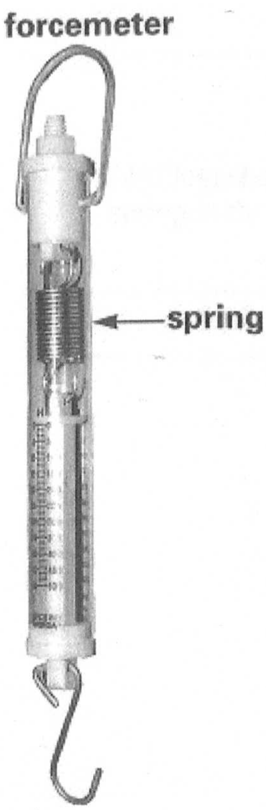
Forcemeter

Ellen and Michael investigated how four different objects stretched four identical elastic bands.



2a) Look at the picture. Which object was the heaviest?

2b) Explain why you chose that object.



They used a forcemeter to measure the weight of the objects in newtons.

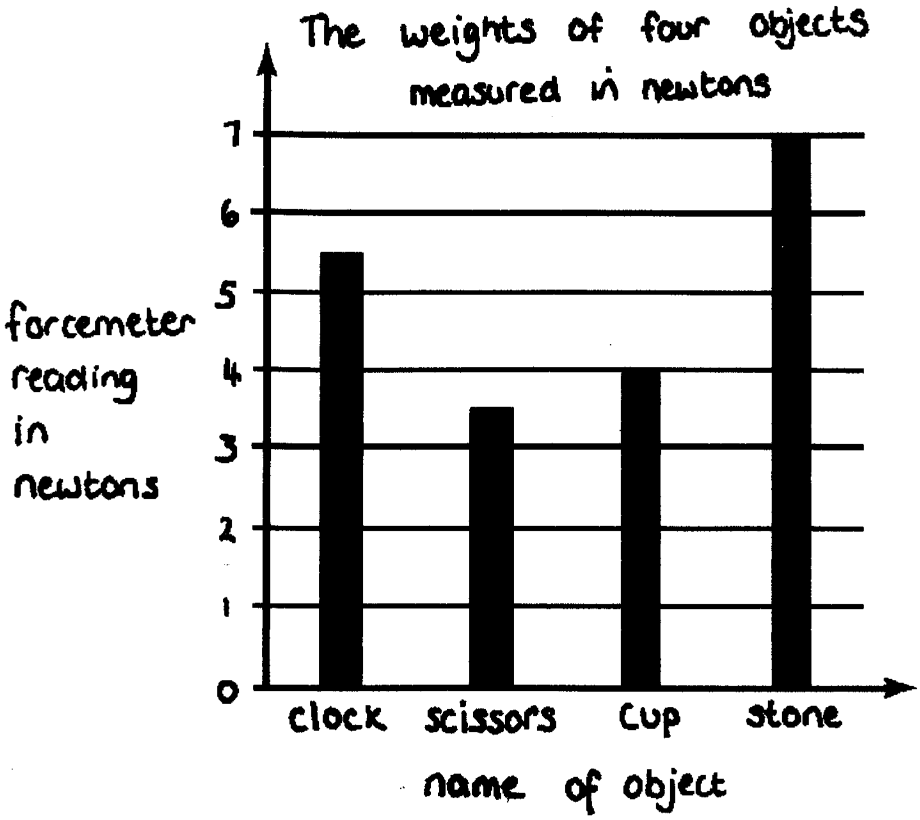
2c) Why does a forcemeter contain a spring?

Tick **ONE** box

Because the spring is:

Shiny	☐	metal	☐
Stretchy	☐	strong	☐

The children recorded their results.



2d) What was the reading on the forcemeter when **the cup** was hung from it?

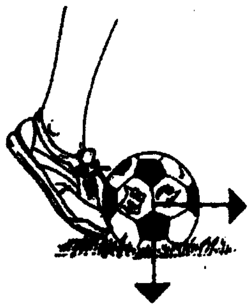
____

2e) Describe how the size of the force affects the length of the spring in the forcemeter.

____

____

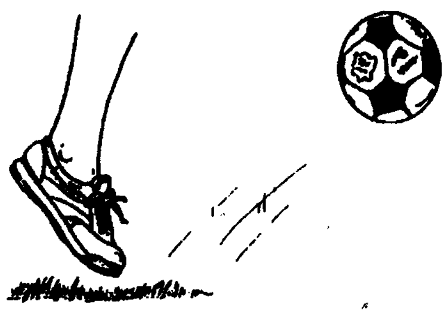
Football



A girl is kicking the football. The arrows show the direction of two forces on the ball.

The football is moving to the right through the air.

3a) Draw **two** arrows on the picture below to show **two** forces acting on the ball



3b) Name the forces you have drawn.

____

____

The football is not moving on the ground.

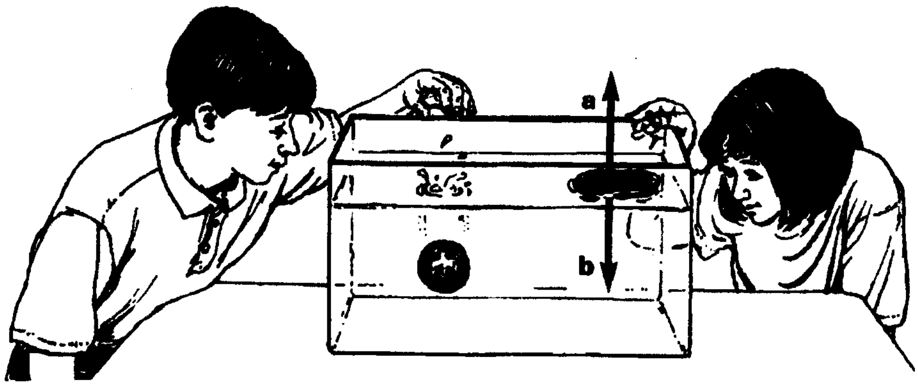
Draw **two** arrows to show **two** forces acting on the ball

Floating and Sinking

The children made shapes with modelling clay.

The solid ball sank.

The boat floated.



Look at the picture.

4a) Write the names of the **TWO** forces **a** and **b** acting on the boat.

Force **a**

____

Force **b**

____

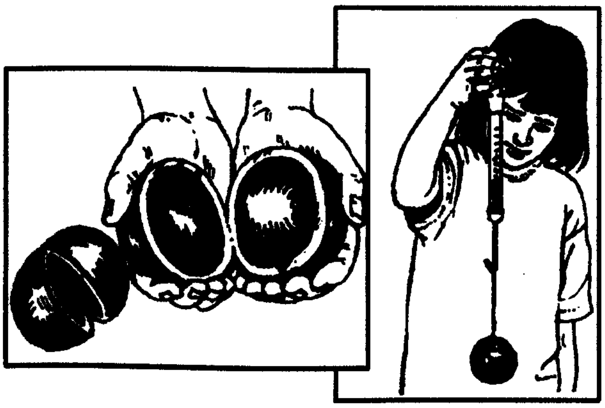
4b) The ball and the boat each have a mass of 200g.

Explain how the forces **a** and **b** make the boat float.

____

____

(c) Stacey made four hollow balls of modelling clay, each of 200 g.
She hung the balls from a forcemeter, first in the air, then in water.



size of hollow ball	forcemeter readings in air (newtons)	forcemeter readings in water (newtons)
small	2	1.5
medium	2	1.0
large	2	0.8
very large	2	0.0

4c) why did Stacey make all the balls 200g?

4d) What pattern do you notice between the size of the hollow balls and the forcemeter readings in water?

4e) Explain why the forcemeter readings are lower in **water** than in **air.**

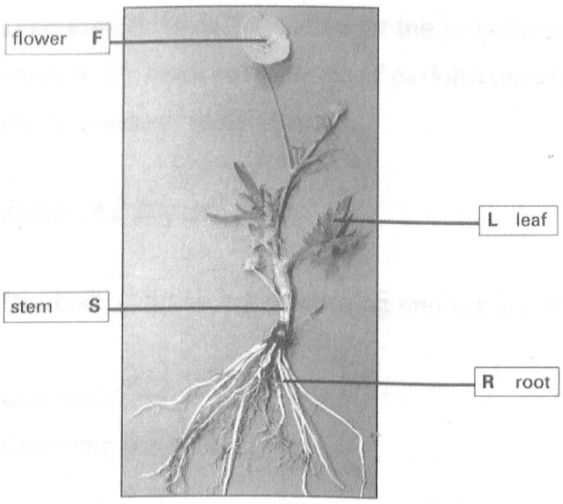
Appendix 9

Discussion of individual national test items

The following section discusses the analysis of certain items selected from the national test used in table 19. The format of presentation will be to state the test items which are given the same reference as in table 19 and then the context the children were presented with. Then each part of the question under discussion, as it appeared on the paper, the facility values and the school performance for each item. Finally the category of each type of question for example, recall or application and the discussion of relative performances for the item.

Item A1ai

Context: children are presented with a photograph which shows a plant labelled flower, leaf, stem, root.



Question:

Where in the plant do the following two things happen? Write a letter for the correct part of the plant in the box.

(i) Part of the plant where water and nutrients are absorbed from the soil

Category: Recall question:

		Performance	
Item	Facility value	School A	School B
A1ai	92	75	83

Discussion: The scores for the schools are below the facility values which illustrates the random nature in performance of recall items and further illustrates that these children were not high performing due to scoring highly on lower rated questions.

Item A1aii

Question:

(ii) Part of the plant where the seeds will grow

Category: Recall question:

Performance

Item	Facility value	School A	School B
A1aii	74	86	70

Discussion: Here the scores for the schools are both above and below the facility values, but the schools are reversed in terms of performance level which again illustrates the random nature in performance of recall items.

Item A2 bi, bii, biii

Context: children are discussing and testing different materials

Question:

Complete the table.

Materials	Properties			
	magnetic	transparent	conducts electricity	waterproof
steel nail	yes	no	yes	yes
newspaper	....	....	....	....
wax candle	....	....	....	....
copper pipe	....	....	....	....

Category: Recall question:

Performance

Item	Facility value	School A	School B
A2bi	85	86	90
A2bii	60	36	65
A2biii	65	32	50

Discussion: A sample of all the individual responses showed the errors were made randomly, but generally the average performance was below that nationally.

Item A3bi, bii c, d

Context: photograph shows some children hitting a kettle drum.

Question:

(b) Nuala uses the drum-stick to hit the skin of the drum in different ways.

Describe how the loudness of the sound is affected by the force of the stick hitting the drum.

Category: Application question:

Performance

Item	Facility value	School A	School B
A3bi	57	89	83
A3bii	40	64	68

Discussion:

(b) This type of question, where the children have to summarise data or make a generalisation, occur at various stages in the papers and indicate a level 5 response. A general fault is that children either quote results that are given in the question, or only make a statement for one scenario. This is a question type we have specially targeted to develop their ability to express their knowledge in the required format. An indication of this is that children who do not make a generalisation only gain one mark as is shown here, but it may be complicated by the children not realising that they have to make a comparative statement. The children were supported by using a mnemonic scaffold. This is discussed in more detail in section 6.8.4.6. The data show that both school A and school B have scored higher than national marks.

Question:

(c) The children turn the screws on the side of the drum to make the skin less tight.
What effect does this have on the pitch of the sound the drum makes when Nuala hits it?

Category: Application question:

Performance

Item	Facility value	School A	School B
A3c	39	86	70

Discussion:

(c) Questions like this are phrased as 'reverse items' so that the children have to use the science to work out the answer and the guessed response of the pitch goes higher is wrong. Both sets of children were given lots of opportunities to look at the effects of changing sounds and always to make a trend statement so they are used to interrogating the data and then giving a response. Again the children have scored higher than national marks, demonstrating that they can apply the information in different contexts. This is an indication of their understanding as opposed to simple recall.

Question:

(d) The children in the class listen to the sound the drum makes.
What does the sound travel through to get from the drum to their ears?

Category: recall question

Performance

Item	Facility value	School A	School B
A3d	60	89	63

Discussion:

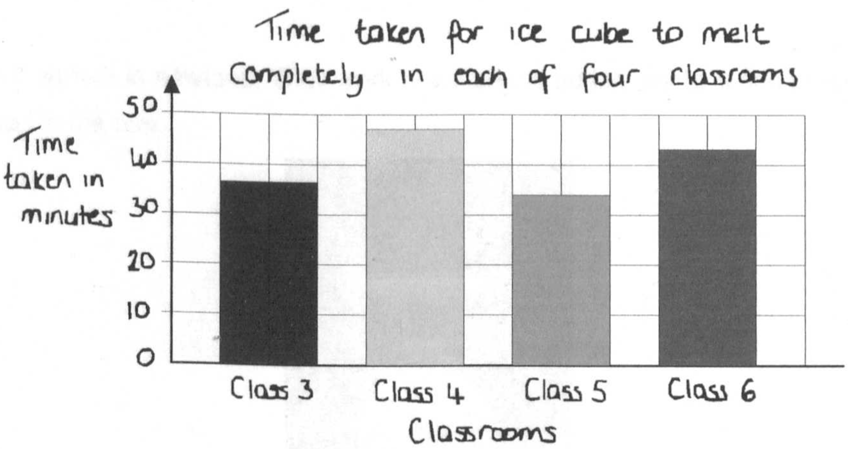
(d) As part of the teaching the children had experiences of sound travelling through different media and this was extended into the scientific model of solids liquids and gases using the particle idea. The use of simple models is not strictly speaking part of the Key Stage 2 programme of study, but was found on many occasions to be useful and helped their linking of scientific ideas to the evidence they obtained.

Item A4bi, bii

Context: using melting ice cubes to investigate which room is the warmest. A bar chart of the melting times for each room is given

Patrick used ice cubes to find the warmest classroom in school.

He put one ice cube on each of four plates and put each plate in a different classroom. He measured the time it took for each ice cube to melt completely.



Question:

(b) Describe how the temperature of a room affects the time taken for an ice cube to melt.

Category:: Interpreting and applying question:

Performance

Item	Facility value	School A	School B
A4bi	64	64	63
A4bii	44	61	58

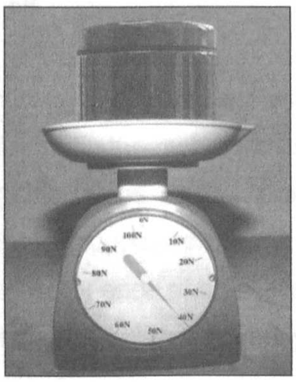
Discussion: Here the question demands interpreting trends and giving comparative statements, but the requirement of the question is stated more overtly. The children have to be able to interpret two sets of data and then make a comparative statement. One mark here is given for any indication that they have noticed one trend, and the second for a complete comparative statement. The two sets of marks are closer to each other (64,61 and 63,58) than the facility value marks are (64,44), which is an indication that they are making better comparative statements than in the national sample. In the national sample the difference between 1 mark gained and 2 marks gained was 20% for school A it was 3% and for school B was 5%. The children know they have to look for and link two sets of data and make the statement in a particular way. It does not give them rote learning of a question, because they have to identify the science concept and the trend and link the two. The mnemonic provides a framework in which to express their knowledge and understanding clearly.

Item 7a, c, d

Context: working with kitchen scales.

Question:

These scales measure in newtons. They work because the spring inside is compressed when an object is placed in the pan.



(a) The newton is the unit used to measure ....

Category: recall question

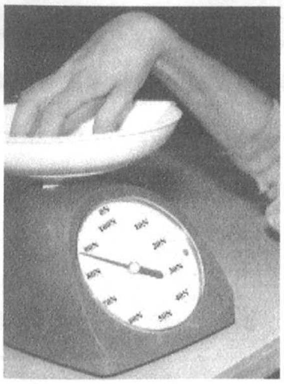
Performance

Item	Facility value	School A	School B
A7a	61	79	38

Discussion: The children have to know that a newton is the unit of force and the marks indicate the randomness again of recall questions.

Question:

(c) Jason pushes down on the scales. The pan pushes up on his hand.



What is causing the pan to push up on his hand?

Category: recall question:

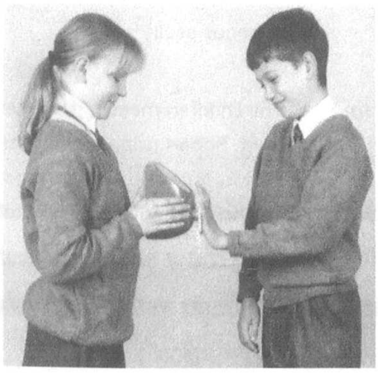
Performance

Item	Facility value	School A	School B
A7c	58	18	58

Discussion: The children have to know how weighing scales work, which may or may not have been within their experiences. The teacher in the higher performing class had actually shown them the spring on some school weighing scales, so their practical experiences might have resulted in this better performance. This is supposition on the researcher's part in this instance, but there were many occasions where experience of an activity has led to increased assimilation of the concepts. They are still in the concrete phase of conceptual development so they still need practical and evidential experiences.

Question:

(d) The teacher asked the children to turn the scales sideways and adjust the scales to zero. Jason pushes on the top of the scales and Kerry pushes on the base.



They hold the scales still. Jason's push measures 80N. What is the size of Kerry's push?

Category: Application question:

Performance

Item	Facility value	School A	School B
A7d	36	61	75

Discussion: The method of teaching forces was the same in both schools, which led to a better understanding of forces and it was not so contextually biased. We would expect children to be able to apply their knowledge to a new range of situations, as was the case in this part of the question. By using a context which was familiar to them we demonstrated that when one pupil pushes with a particular force there would always be an equal and opposite force. This method of investigating science has resulted in higher scores than national for both school A and school B.

Item B2a,b c, d

Context: photographs of children investigating ice lollies

Question:

(a) Helen and Amy put an ice lolly in a dry glass jar. After 105 minutes they saw that the ice lolly had turned to liquid. What is the name of the process when a solid turns into a liquid?

Category: recall:

Performance

Item	Facility value	School A	School B
B2a	66	71	58

Discussion: This again illustrates the random distribution of marks. There is also an issue of the children not understanding the meaning of the word *process*. If the question had asked what has happened to the ice lolly, the marks might have been much higher.

Question:

(b) They saw drops of liquid forming on the outside of the jar. What is the name of this liquid? Tick ONE box. ice lolly steam water juice mist

Category: application

Performance

Item	Facility value	School A	School B
B2b	44	61	70

Discussion: this activity had been done with ice pops, because this is one of the things that children nationally often do by rote and not by understanding as evidenced by less than half the national sample gave the correct answer, however these children scored 21% and 30% higher.

Question:

(c) What is the name of the process which causes this liquid to form on the outside of the jar?

Category: recall:

Performance

Item	Facility value	School A	School B
B2c	63	75	60

Discussion: This is similar to question (a) and the same comments may apply as evidenced by the fact that the marks gained for part (c) are very similar for facility value, school A and school B to the marks they gained for part (a)

Performance

Item	Facility value	School A	School B
B2a	66	71	58
B2c	63	75	60

Question:

(d) Where did the liquid on the outside of the jar come from?

Category: application:

Performance

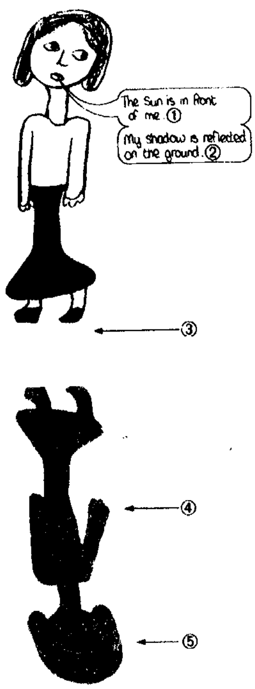
Item	Facility value	School A	School B
A2d	31	61	40

Discussion: Again, because the children had explored these ideas in a context that was familiar to them, they were more secure in their knowledge and could apply it to a range of different contexts, hence their scores were considerably higher.

Item B3b, c

Context: children were given a drawing (done by a child) of a girl with her shadow. The drawing contained some mistakes.

Question:
Maria drew a picture of herself and her shadow. She then found out more about shadows and realised she had made five mistakes. She put a number next to each mistake on her picture.



Question:
(b) Mistake number 2 was to write that the shadow is reflected. Explain how a shadow is formed.

Category: Recall question:

Performance

Item	Facility value	School A	School B
B3b	64	93	80

Discussion: one of the focuses of the project was to get the children to use the correct scientific language with the appropriate vocabulary. A common error for children is to describe a shadow as a reflection, because they do not realise that science has its own specific language and it is important to use the correct term. The difference between a *reflection* where light bounces from a surface and a *shadow* where light is blocked was emphasised, again resulting in a much better performance when compared to national scores.

Question:

(c) Describe what she should have drawn at 3, 4 and 5.

Category:: recall question

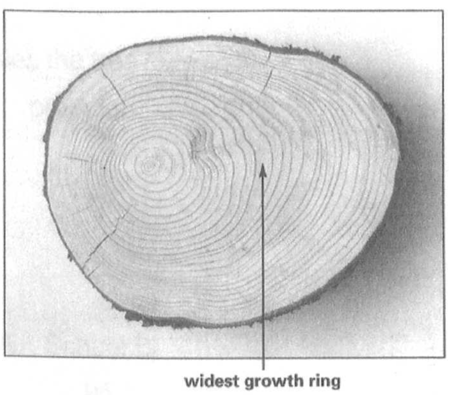
Performance

Item	Facility value	School A	School B
B3ci	63	36	68
B3cii	66	50	63
B3ciii	55	32	68

Discussion: We approached this in school B, very much from an experiential point of view and we had carried out this particular activity, because it highlights all the ideas that children typically have about shadows. These children had an advantage both from understanding and experience. This activity was a product of the constructivist approach, getting them to give their views and then looking at the evidence and then explaining the evidence. Hence they are much more secure in their knowledge and the item was recalled better. Because of the nature of the project and the teacher's input into the choice of topics selected, this activity was not done in school A. The relative performance illustrates this.

Item B4b, c, d

Context: photograph shows the growth rings on a tree, and they have to state function of roots.



Question:

(b) The roots take in moisture and nutrients. Describe ONE other thing that the roots do for the tree.

Category: recall question

Performance

Item	Facility value	School A	School B
B4b	54	54	55

Discussion: this is probably remembered by the children who can just pick up information. This is the least well remembered fact about the function of a root. It will not have been emphasised particularly in the work we did, but will have been in the revision programme.

Question:

(c) The moisture and nutrients reach the leaves. Explain what leaves do to help trees grow well.

Category: recall question

Performance

Item	Facility value	School A	School B
B4c	60	68	75

Discussion: The function of the leaf to make food was emphasised in the teaching because this is something which has been highlighted as an area of weakness in children's knowledge about plants.

Question:

(d) Which of these describes the tree?

Tick ONE box. consumer predator prey producer

Category: recall

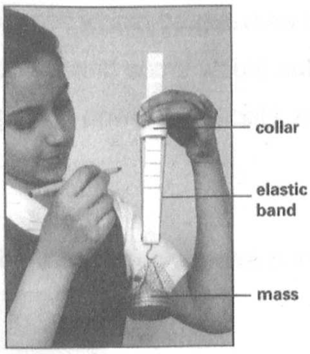
Performance

Item	Facility value	School A	School B
B4d	78	89	95

Discussion: The components of a food chain and in particular the importance of the direction of the arrows in a food chain again were emphasised in the teaching because they are things that have been highlighted as areas of weakness in children's knowledge about food chains. So in this item the children exhibited a higher level of knowledge about components in a food chain than is shown nationally.

Item B6b, c, d

Context: photograph shows Saida using a home made forcemeter



Question:

(b) Saida then made her own forcemeter using elastic bands. She used different sized masses to make the scale. What happens to the elastic bands when Saida hangs objects on her forcemeter?

Category: recall question

Performance

Item	Facility value	School A	School B
B6b	78	89	55

Discussion: as with the scales question, those children who had explored these ideas of what is happening with weights on a balance, performed better so the group who had done this activity performed better then the national group and the other school. Also there may have been some misinterpretation of the question at school B. on more detailed examination of the responses for school B, a further 16% said the elastic would expand (wrong) rather than stretch (right), several children said the elastic would come off (10%) (plus 2 children inconsistently marked).

Question:

(c) What is it that causes the force of gravity on the objects that Saida is weighing?

Category: recall question

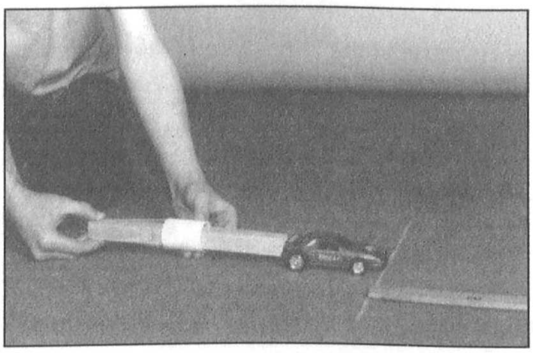
Performance

Item	Facility value	School A	School B
B6c	22	54	20

Discussion: there was generally a low performance on this item, possibly because the children did not understand what the question was asking. The answer to the question is the earth, but I suspect that many children were confused as to what they had to write in this question (in addition to those who did not know). The researcher would expect the response scores for this item to be variable since many responses would be guesses in terms of the words to write and some would hit the correct scoring points and some would not. If the children are asked, as in another test, the name of the force pulling down, the facility value score was 95%.

Question:

(d) The forcemeter measures the size of pushes and pulls.



Saida used her forcemeter to start a car moving. Here is her table of results.

Distance moved by the car using different sized starting forces

Starting force in N	1	2	3	4	5
Distance moved in cm	18	52	140	235	316

Describe how the size of the starting force affects the distance moved by the car.

Category: application question

Performance

Item	Facility value	School A	School B
B6di	46	61	48
B6dii	39	61	48

Discussion:: this is another question where the children had to identify the trend in the data, then summarise in a meaningful sentence. The facility values show a decrease in the number of marks for B6dii compared to B6di indicating they have made incomplete statements, but both schools have identical scores for B6di and B6dii indicating those children who could identify the trend, could also make a meaningful statement.

Item B7a, c

Context: children were watching a video of blackbirds and their young and are making a diary.

Question:

(a) Tick THREE things all animals do. Sing grow feed fly lay eggs reproduce

Category: Recall question

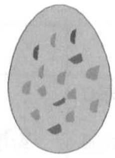
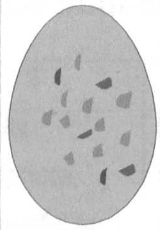
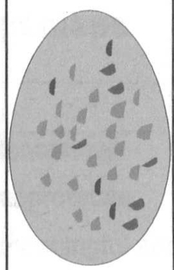
Performance

Item	Facility value	School A	School B
7ai	94	100	90
7aii	93	93	93
7aiii	94	96	93

Discussion: The high performance for all three groups, illustrates the comfort teachers and children feel with topics in the Life Processes and Living Things strand of the national curriculum. This is discussed with respect to teacher confidence in section 6.3.2.

Question:

(c) The children found some information about birds' eggs. Describe the pattern between the size of these eggs and the time taken to hatch.

Bird	**robin**	**blackbird**	**crow**	**raven**
Egg				
Size of egg	20 × 16mm	29 × 21mm	43 × 30mm	50 × 33mm
Time taken to hatch	13 days	14 days	19 days	20 days

Category: Application question

Performance

Item	Facility value	School A	School B
B7ci	55	54	60
B7cii	50	50	60

Discussion: these are successive questions (items 6d and 7c) testing the same skill and although both schools have performed comparably to the facility values the relative performance of the two schools is reversed. The researcher has no reasoning for this other than children vary in how they respond to different scenarios and have different personal and classroom experiences. This illustrates that the teacher must endeavour to find out what the children's experiences are so that the experiences can be extended. Possibly this is an example of a 'limited framework' being expanded by the teacher.

Appendix 10 Research Instruments

Appendix 10.1 The rubric for scoring the concept maps

	4	3	2	1	0
propositions	Complete, meaningful and valid	Mostly meaningful and valid	partially appropriate, meaningful and valid	tentatively appropriate, meaningful and valid	Missing or not meaningful
hierarchy	Super ordinate & subordinate concepts are valid	Super ordinate & subordinate concepts mostly valid	Some validity in concepts	Minimal validity in concepts	Hierarchy is missing or invalid.
Branches	Completely appropriate meaningful and valid	Mostly appropriate meaningful and valid	Some appropriateness and validity	Minimal appropriateness and validity	Missing, inappropriate or invalid
Examples	Complete set for the concept, valid, illustrative and significant.	Incomplete set for the concept but mostly valid, illustrative and significant.	Incomplete set for the concept but some are valid and illustrative.	Incomplete set for the concept, minimal validity, only illustrative.	Missing, or invalid
	8	**6**	**4**	**2**	**0**
Cross links	completely valid and non-trivial. Strong evidence of higher level thinking	Mostly valid and non-trivial. Some evidence of higher level thinking	Some validity but also triviality. Some evidence of higher level thinking	Predominantly invalid or trivial. Little evidence of higher level thinking	Missing or invalid. No evidence of higher level thinking

Appendix 10.2 Teacher audit

Put a ring round each one apart from q 6, and q 7 which you rank

question

1 groups	class	abilty groups	Grouping in tables		none	
2 qualifications	<14 14-16	16-19	whole degree	part degree PGCE	post degree	
3 inset	20 day	10 evening	5 evening	1 day	1/2 day	
4 scheme	very close	usually	half	sometimes	rarely	
5 reason	sch policy	teacher choice	variety	support	assessment	cost
6 science preference (rank)	english	maths	science	technology		
	geography	history	music	PE	art	
7 topic Preference (rank)	life process	human	plants	environment	classifying materials	
	change materials		Separate materials			
	electricity	forces	light/sound		earth etc	
8 teacher feelings	confident	ok	insecure	enjoyable	challenging	
	interesting	different organisation				

Appendix 10.3 Science Training Session Evaluation

Topic ....

1. What did you think of the length of the sessions?

Too short	Just right	Too long

2. How did you find the "input" session?

Timing

Too short	Just right	Too long

Language

Too basic	Appropriate	Too wordy

Stimulation

Boring		Stimulating

3. Was the content at a suitable level for your teaching requirements?

Too low	Appropriate	Too high

4. How did you find the "hands on" session?

Timing

Too short	Just right	Too long

Stimulating

Stimulating		Boring

Help your understanding

None	Little	A lot

5. How did you find the supporting literature?

Language

Too basic	Appropriate	Too wordy

Information

Too little	Appropriate	Too much

Help your understanding

None	Little	A lot

6. How did the session overall help your understanding of the content covered?

None	Little	A lot

7. Have you used any (or intend to) of the content covered in the session in your teaching.

None	Few	Many

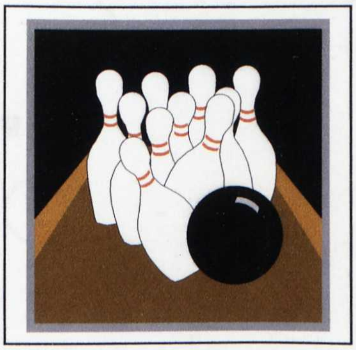
8. Overall how effective was the session in meeting your needs?

Not effective	Partly effective	Very effective

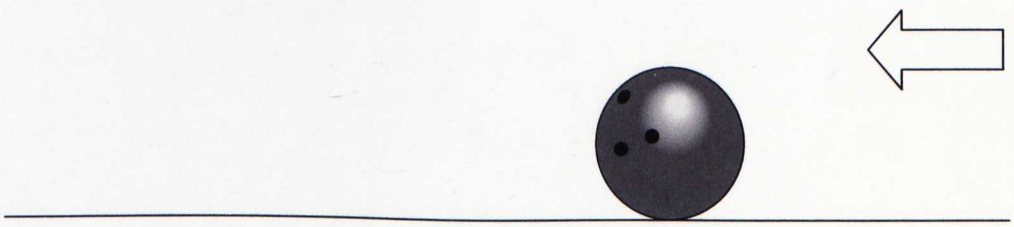
9. What were you most happy about the session?

10. What would you like to see in future sessions?

Appendix 10.4 Rolling Bowling Ball Exercise



Imagine the bowling ball is moving towards the 10 pins in the direction of the arrow.

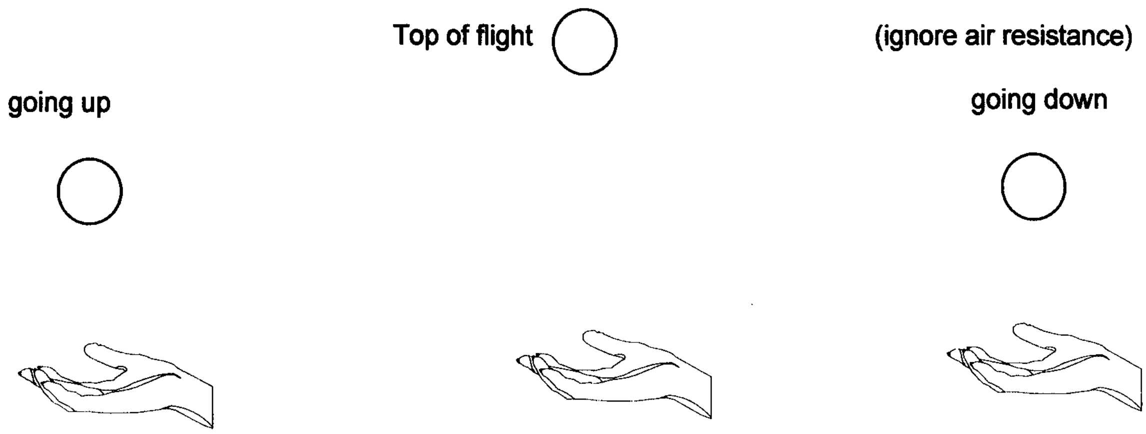


Draw on the diagram any forces that are acting. Use an arrow to show which way they go.

Use the box underneath to write out what you know about these forces.

Appendix 10.5

Buridan Balls Exercise



Appendix 10.6 Teacher confidence survey

5 Confident in the subject and can answer colleagues' questions.

4 Confident in the subject and can answer most children's questions. Can think of curriculum ideas.

3 Reasonably secure in the subject and can deal with simple children's questions. Prepared to look for ideas.

2 Fairly secure but need help in certain areas of the curriculum.

1 Lack confidence and need help to improve science knowledge in this area.

Teacher survey School .... Teacher's initials ....

A. I was involved in the project in phase 1.	agree	disagree
B. I was not involved in phase 1, but my school was.	agree	disagree
C. I am involved in the project in phase 2.	agree	disagree
D. I am not involved in the project in phase 2, but my school is.	agree	disagree

Please circle one of 1, 2, 3, 4 or 5 to indicate your feelings about each of the topics listed in the survey. Their meanings are:

1.Lack confidence and need help to improve science knowledge in this area;
2 Fairly secure but need help in certain areas of the curriculum;
3 Reasonably secure in the subject and can deal with simple children's questions. Prepared to look for ideas;
4 Confident in the subject and can answer most children's questions. Can think of curriculum ideas.
5 Confident in the subject and can answer colleague's questions.

The items in bold refer to topics in Key Stage 3

Detailed questions

Life processes and living things

1 reproduction in plants (germination, pollination, **fertilisation**, naming reproductive parts of flowers)	1 2 3 4 5
2 human life processes (circulation, **digestive** and **reproductive** systems)	1 2 3 4 5
3 **photosynthesis**	1 2 3 4 5
4 use of keys	1 2 3 4 5
5 food chains and webs, **biomass**	1 2 3 4 5
6 micro-organisms, decay processes	1 2 3 4 5

Materials and their properties

7 classifying materials (conductivity, magnetic, strength, metal, non-metal)	1 2 3 4 5
8 classifying as solids, liquids, gases	1 2 3 4 5
9 change as permanent (**chemical, role of oxygen in burning, respiration**)	1 2 3 4 5
10 change as reversible (**physical** change of state, water cycle)	1 2 3 4 5
11 **particle theory to explain change**	1 2 3 4 5
12 separating mixtures (evaporating, **crystallisation**)	1 2 3 4 5

Physical processes

13 interpreting simple circuit diagrams 14 ways of varying current on a circuit	1 2 3 4 5
15 **explaining current, voltage and resistance, parallel circuits**	1 2 3 4 5
16 gravity (explaining weight and weightlessness)	1 2 3 4 5
17 friction, including in air and water	1 2 3 4 5
1 8 balanced and unbalanced forces (floating, flying, stretching, compressing)	1 2 3 4 5
19 **density**	1 2 3 4 5
20 reflection and **refraction, images, mirages, spectrum**	1 2 3 4 5
21 how we see objects, shadows	1 2 3 4 5
22 sound and vibrations, loudness and pitch, **waves, echoes**	1 2 3 4 5
23 movement of sun, earth, moon, **solar system, eclipses**	1 2 3 4 5

Experimental and investigative science

24 closed, open and productive questions	1 2 3 4 5
25 relating science to everyday life	1 2 3 4 5
26 planning an investigation	1 2 3 4 5
27 recognising factors to change or not change	1 2 3 4 5
28 accuracy of measurements	1 2 3 4 5
29 using tables and graphs	1 2 3 4 5
30 evaluating results or data	1 2 3 4 5
31 use of information technologies to store, interpret and present data	1 2 3 4 5
32 safety issues, risk assessment	1 2 3 4 5

Appendix 10.7 Questions for Triangulation Interviews.

Coding: P if relevant to children, T if relevant to teachers and V if the questions could be used for validation.

Question:	Code
1. In your opinion, as headteacher, do you think the intervention has been of value to your school?	P T V
2. If you think this is beneficial to the school, which aspects of the intervention do you consider have made a difference?	P T V
3. What do you think has been the most important benefit overall to your school?	P T V
The following questions relate to any potential differences which may have occurred as a result of the intervention:	
4. What has been the response of the teachers directly involved with LJMU staff?	T
5. What has been the response of the teachers who have not been directly involved?	T
6. Do you think the subject knowledge of the teachers involved has improved?	T
7. Do you think that the teachers involved are more confident in teaching science?	T
8. Has there been any opportunity for teachers to discuss the work covered in the intervention?	T
9. Have there been any direct changes as a result of the intervention for example schemes of work altered; targets for science changed; INSET planned?	T
10. Have you made use of the revision or pre and end test materials?	T
11. In what ways have senior management been involved with the intervention?	T V
12. What has the science coordinator's role been in the intervention?	T
13. What were the priorities when using Zeneca funding for resources?	T
14. Has there been any evaluation of the intervention in school?	T V
15. Is any aspect of the development of science education included in the School Development Plan?	T V
16. Do you have ideas about the lasting effects of any benefits gained?	P T V
17. In what ways do think the intervention may be improved at present?	V
18. Have you any suggestions as to any future aspects of science education which the team could develop?	V
19. Do you have any evidence of attainment or progress for children in the target group?	P
20. Do you think that there is any difference in the attitude to science of children who have been involved?	P
21. If attitudes have improved, do you think such improvement may transfer to other subjects?	P
22. Have children reacted positively to any particular aspect of the science work?	P
23. Have children reacted negatively to any particular aspects of the science work?	P