How does the pattern of engagement of new teachers with the content of primary science develop over their first three years of teaching?

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I declare that this thesis is my own work.

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Abstract

This longitudinal study explores the patterns of primary teachers' engagement with science in science lessons in their first three years of teaching. There was little significant change in the patterns over time. The teachers' patterns of engagement were charted qualitatively using an Engagement Schedule developed during the main study. Case studies were used to show the participants' patterns of engagement with science over time and to report the factors that may have contributed to their patterns of engagement. Teacher types were identified for each participant; these showed that there was little change in the participants' teaching approaches over time. Another outcome of the research was the discussion of 'critical moments' in science lessons, where a small change in the teaching, could turn negative Aspects of engagement into positive ones. These 'critical moments' and the 'Engagement Schedule' are already proving to be useful tools for initial teacher education.

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Glossary of terms

Term	Definition
BA Primary Education	Three or four year undergraduate teacher training degree programme.
DES (Department for Education and Science)	Central government department that is responsible for state education. Later called the DfEE (Department for Education and Employment), now called the DfES (Department for Education and Skills).
EAL (English as an Additional Language)	Pupils for whom English is not their mother tongue
Ofsted (Office for Standards in Education)	Central government body responsible for inspecting all educational establishments, for example schools and ITE providers.
GCE 'O' Level (General Certificate in Education, Ordinary level)	Pupils take these examinations at aged 16 years. This examination was replaced by the GCSE in 1988.
GCE 'A' Level (General Certificate in Education, Advanced level)	Pupils take these examinations at aged 18 years.
GCSE (General Certificate in Secondary Education)	Pupils take these examinations at aged 16 years.
HMI (Her Majesty's Inspectors)	Responsible for inspecting educational establishments, now a part of Ofsted.
INSET (In Service Training)	Courses that serving teachers may attend.
ITE (Initial Teacher Training)	Period of university or school based teacher training.
LEA (Local Education Authority)	Local government body that is responsible for state education in that geographical area.
National Curriculum	Introduced in 1989, it is the national compulsory syllabus for pupils aged 5-16 in state education.
NQT (newly qualified teacher)	Teacher in his/her first year of teaching post qualification.
Primary PGCE (postgraduate certificate in education)	One year postgraduate teacher training programme
QCA (Qualifications and Curriculum Authority)	Government body that develops curriculum materials for schools. The QCA science scheme was introduced in 1989.
SATs (Standard Attainment Tests)	National tests in English, mathematics and science, taken by primary pupils at ages 7 and 11
SE (School Experience)	Period of time in which participants were observed.
TTA (Teacher Training Agency)	Government body that determines the ITE Curriculum for trainee teachers (since 1998)

Chapter 1 Introduction to the thesis

1.1 The thesis and I

This study grew out of my own experiences as a primary school teacher that many of my colleagues lacked the confidence to teach science, especially the physical sciences and so were often reluctant to engage with these topics. The teachers in the schools in which I taught identified their poor science subject knowledge and understanding as the key reason for their lack of confidence to teach science. Many of my colleagues, all female, did not study science beyond year 9 (aged 13-14 years), and those who did, invariably studied biology. When my fellow pupils, all girls, made choices for 'O' level GCE (ordinary level General Certificate in Education) in 1974, chemistry and physics were optional, whereas all pupils had to study biology. Although many schools offered integrated science (aspects of the three disciplines, biology, chemistry and physics), these courses were often aimed at the low ability pupil. It has only been in the past 18 years that GCSE (General Certificate in Secondary Education) science has been compulsory for all pupils aged 16 years. Thus it was not surprising that my primary colleagues had little or no science and consequently believed that their lack of science was the most important reason for their lack of confidence to teach science. I was not, however convinced that this lack of knowledge was the most important factor in determining their confidence to teach science, even though the teachers identified it to be.

My interest in teachers' confidence and engagement with science was further stimulated by my work as a science education tutor involved in primary ITE (initial teacher education), which had made me ponder on the following questions:

- Why do many trainee teachers say that they do not feel confident to teach primary science?

- What makes one teacher more able to engage with the science content of a lesson than another?
- What factors determine teacher confidence?
- To what extent is the teacher's own science knowledge and understanding the determining factor in teacher confidence?
- How much science do trainee teachers need to know and understand in order to engage with science effectively?
- What strategies do trainee teachers employ when they do not feel confident to teach science?

These questions contain what became the two key concepts in the research, *engagement with* science and *confidence. Engagement* with science is a description of what the teacher says and does to 'draw out' the science content of the lesson and involve the pupils with the learning of science. Engagement with science is of course a necessary pre-requisite of teacher effectiveness when teaching primary science, for it would be difficult to teach science effectively without engaging with science content knowledge, understanding and skills.

Confidence is a term readily used by trainee teachers, their class teachers and the tutors who assess them, when describing the trainee teacher's ability to teach, but 'confidence' does not always have a shared meaning. Here I was interested in confidence to teach science, not confidence to teach generally.

While engagement and confidence must affect teacher effectiveness this research does not study teacher effectiveness directly, as this would involve assessing pupils' knowledge, understanding and skills, before and after teaching. This research focuses only on teachers' engagement with science with the aim of accounting for the factors that determine this engagement, including confidence.

1.2 The context of the research

This section briefly describes those aspects of the UK educational system that are salient to this research, that is the primary school system in which the participants worked the and curriculum they taught. It also describes how the participants were trained and their first year of teaching post qualification.

The primary school system and primary curriculum

Pupils start primary school in the year when they reach the age of 5 years and leave at age 11years. The National Curriculum defines what pupils in compulsory education (5-16 years of age) are taught. The National Curriculum is defined in subjects, namely, English, mathematics, science, information communications technology (ICT), history, geography, music, art, design technology (DT) and physical education (PE) for the primary years. Pupils must also be taught religious education (RE) from age 5 years, but it is not a National Curriculum subject. The National Curriculum was introduced in 1989; before this, schools determined their own curriculum. The National Curriculum is organised into two Key Stages. Key Stage One (pupils aged 5-7years) and Key Stage 2 (pupils ages 7-11 years). At the end of each Key Stage all pupils are tested using national tests, SATs (standard attainment tests). Pupils are tested in English, mathematics and science as these three subjects are the 'core' subjects. National strategies for teaching English and mathematics were introduced in 1998 and 1999 respectively. These strategies NLS (National Literacy Strategy) and NNS (National Numeracy Strategy) are not statutory, that is, schools can choose to use them if they wish.

The Qualifications and Curriculum Authority (QCA) introduced a scheme of work for science based on the National Curriculum for science in 1998. Many schools use this scheme, but it is not compulsory to do so.

Most schools in London have pupils for whom English is not their mother tongue. These pupils have EAL (English as an additional language). Most schools provide support teachers for EAL pupils.

How the participants were trained

The two main routes through which primary teachers are trained are the BA Primary Education and the Primary PGCE programmes. These training programmes are called ITE (Initial Teacher Education). The BA Primary Education is a three or four-year undergraduate programme that trains people to teach all National Curriculum subjects and RE to pupils aged 5-11years. The Primary PGCE programme is a one-year training course that trains graduates to teach all National Curriculum subjects and RE to pupils aged 7-11years.

Trainees on both programmes follow subject studies at university and undertake School Experiences in primary schools. During School Experience trainees teach all National Curriculum subjects and RE to a class. School Experience is an assessed part of ITE programmes. The trainees' performance is judged by school-based mentors, the trainees' class teachers and university based tutors. Trainees are observed at least three times a week, they receive written and oral feedback about the quality of their teaching. The university does not specify what subjects the trainee should be observed teaching, but most trainees are observed teaching all subjects at least once. Trainees on a PGCE programme undertake two School Experiences of six weeks each. These School Experiences, are in two different schools.

The first year after qualification

Trainees in their first year of teaching are called newly qualified teachers (NQTs). During this year they receive some further training and at the time of my research this occupied on average ten days spread over the year. The relevant Local Education Authority (LEA) provides this training. The LEA is a local government organisation, which provides for

schools in its area. At the time this research was conducted LEAs and schools were not obliged to provide this NQT training. This has subsequently changed, so that now all NQTs must undergo a compulsory induction year, for which LEAs must provide some training, although the individual school is responsible for most of the training. Schools may also pay for teachers to attend INSET (in-service education and training) courses, which are usually provided by LEAs.

1.3 The thesis in outline

The thesis is presented as eight chapters.

Chapter 1 is a brief introduction to the research and explains my initial interest in teachers' engagement with science and their confidence to teach science. It describes the thesis in outline, and provides an overview of the research giving signposts as to where the reader can find the main events of the research (table 1.1).

Chapter 2 describes the background to the research and the events that led to formulating the research questions. The assumption was made that personal confidence would lead to a fuller engagement with science and that an exploration of the factors that contributed to the feeling of confidence would be useful to the research. A survey of my trainee teachers showed that they identified subject knowledge and understanding as the key factor in determining their confidence to teach science. I hypothesised that as the teacher gains experience, so their level of engagement with science would increase. Thus the idea of a longitudinal study took shape. The intention was to observe a group of trainee teachers during their training year and two subsequent years post qualification, to see if their level of engagement with science increased with an increase in teaching experience.

Chapter 3 is the survey of relevant literature; it explores the role of subject knowledge and understanding in relation to teacher confidence and effectiveness. It shows that although subject knowledge is a very important factor, the picture is a complex one.

Chapter 4 reports on a pilot study of how trainee teachers engaged with science in their lessons, with the aim of developing an observation tool that could be used to measure the level of engagement with science. It was as a result of the pilot study that I decided that it was not feasible to measure level of engagement with science, and so the focus changed from a quantitative approach to a qualitative approach, where the pattern of engagement with science was described. The idea of using an *observation tool* to chart the trainees' engagement with science was also abandoned, as when it was trialled, new aspects of engagement, not in the tool, were observed. I decided that the development of what I have called an *engagement schedule* was necessary. The engagement schedule, which was not to be finalised until after the analysis of the final set of lesson observation was completed, was then used to chart the participants' engagement with science over the three years of the main study.

Chapter 5 describes the two methods used for the main study. These were the case study approach and the development of the engagement schedule, using an iterative approach. It was decided to report the findings as a set of ten case studies, as this was the best method for reporting the development of the ten participants over the three years of the main study. As the development of the engagement schedule was grounded in the observations of the participants, it had to be developed using an iterative approach.

Chapter 6 describes the development of the engagement schedule from the analysis of the first set of lesson observations to the final set, three years later. Using extracts of lesson transcripts, I show how *incidents* of engagement were identified during each set of lesson observations, how these incidents were sorted to form *aspects* of engagement and how these aspects were then sorted to form the six *categories* of engagement, which made up the engagement schedule. I also discuss an unexpected product of the research, the identification of 'critical moments' in the lessons. These critical moments in the lesson occurred when the engagement with science was negative. The negative moments are described, using extracts

from the transcripts, and suggestions are made as to how the participant could have made the incident positive.

Chapter 7 contains the case studies of the ten participants. Each case study describes the participants' feelings about teaching science and attitudes to science. The case studies describe the lessons observed and report on the factors that may have affected and /or determined engagement. Each case study includes a figure showing that participant's pattern of engagement with science over a period of up to three years. The participants' teaching styles are discussed in relation to the literature. The participants' patterns of engagement did not show any significant change over the three years of the main study.

Chapter 9 is an evaluation of the research and the methods used. By opening up the data to the scrutiny of others, I show that the data collection methods and methods of analysis and interpretation are both reliable and valid. The usefulness of the research is explained in terms of identifying ways in which primary teachers engage with science and 'critical moments' in primary science lessons. Further questions arising from the research are discussed briefly, these include, the nature of feedback given to trainee teachers by those observing them.

An overview of the research showing where the research questions are developed and answered is shown in table 1.1.

Table 1.1 An overview of the research

Activity	Date	Reference in thesis
Developing the initial research questions	April 1994	Section 2.4
The pilot study The final research questions	1994-95	Chapter 3 Section 5.1
The main study	1996-98	Chapter 6
Analysis of the findings The answers to the research questions	1998-2004	Chapters 7 Section 7.5

Chapter 2 Background to the research

2.1 Background-critical events

The critical events that provided the impetus for this research came from my experiences as a science coordinator in two north London primary schools, and as an Induction Tutor in a north London Local Education Authority (LEA), 1991 - 1993. In both roles I worked closely with newly qualified teachers (NQTs). As an Induction Tutor I supported for a group of NQTs. In my discussions with the NQTs it was apparent that many of them lacked the confidence to teach science, along with design technology and information technology. I found that this was also the case with more experienced teachers.

In 1994 I became a university tutor teaching science to BA Primary Education and Primary PGCE trainee teachers. The BA Primary Education undergraduate trainees followed a three-year programme, which trained them to teach all subjects to pupils aged 5-11years. The Primary PGCE trainees were graduates who followed a one-year, programme, which trained them to teach all subjects to pupils aged 7-11years. As a tutor, I again found that many trainees said that science was difficult to understand and difficult to teach.

Another source of my interest came from my role in observing trainee teachers teaching science, giving appropriate feedback and grading lessons on a twenty-point scale (which was an assessment scheme used by my institution). The application of this twenty point scale was often problematic, as there was little agreement between tutors and school based mentors about what constituted a grade one (excellent), ten (average) or twenty (fail). I was interested in developing more explicit criteria for judging trainee teacher performance, which could be shared with my fellow tutors, mentors and trainee teachers.

But it was two 'events' in early 1994, when I had just started to train teachers, which led me to formulate the questions in section 1.1 and to embark on this research. The first event was an observation of a PGCE trainee teaching science. The second event was the results of a questionnaire on trainee teachers' attitudes to science and to teaching science that I gave to a group of third year BA Primary Education trainee teachers (see appendix 2.1). In 1998, when the research was well underway, a third event confirmed that this research area was important. A group of class teachers and school based mentors, involved in assessing trainee teachers on school experience, observed a video of a science lesson and discussed suitable feedback to be given to the trainee. The significance of these three events is described below.

2.1.1 The first event: a science lesson without science

In the first event I observed Martha, a PGCE trainee teaching science to a year five class. The class's teacher also observed the lesson. At the end of the lesson, the class teacher and I discussed the lesson. I then met with Martha to discuss the lesson, without the class teacher being present. All the names used in this chapter and throughout the thesis are pseudonyms.

The focus of the lesson was making 'electrical quiz cards'. This involved making a card where questions are linked to answers with strips of aluminium foil covered with masking tape. A circuit is made using cells, a buzzer and wires. When the ends of the wires are placed on a question and the correct answer, the circuit is completed and the buzzer sounds. The pupils were asked to work in pairs and could choose any topic on which to base their quiz cards. The trainee showed the pupils an example of a card that she had made; she demonstrated how to use it, but did not explain how it worked.

The extract from Martha's lesson, shown in figure 2.1 is not a precise verbatim account of the lesson and post lesson discussions, but it does give an accurate impression.

Figure 2.1 Extract from Martha's lesson

Introduction (about ten minutes, all pupils on the carpet).

M "Today we are going to make one of these (holds up a quiz card), it's a quiz card. This one is about numbers. How many is this?" (*she places one wire on image of three items).*

ch "Three!"

Martha puts other wire on image with the figure three written on it, the buzzer sounds. The pupils laugh and look impressed. She repeats this using the other numbers on the card, sometimes she puts the second wire on the wrong answer and the buzzer fails to sound.

M "It only works when you connect the question to the right answer. You are all going to make your own quiz cards. You can make them about anything you like".

Martha shows examples of cards with colours and with animals and demonstrates how to make a card. She talks about using tin foil to connect the question to the answer, and sticking the foil down carefully with masking tape.

Development (about 25 minutes, pupils working in pairs).

The pupils talked enthusiastically about the topic to choose for their cards. The next 25 minutes were spent making the cards. Martha helps the pupils to cut the foil and masking tape.

Plenary (about 10 minutes, pupils on carpet)

M "Henry what is your card about?"
H "Flags"
M "That's interesting, are you interested in flags?"
H "Yes"
M "Hold up your card, can everyone see? What is the flag of Denmark?"

Several pupils guess, Henry places the wire onto the correct answer. The buzzer sounds.

M "Very good"

Martha and John demonstrated the rest of the answers; another child is invited to demonstrate her card, as John had done.

At no time during the lesson did Martha talk about the 'science' aspects of the lesson, that

1. electricity needs a circuit to flow,
2. some materials (in this case aluminium foil) conduct electricity,
3. some materials (in this case masking tape) do not conduct electricity.

As the pupils were in year five, I expected Martha to use the terms 'conductor' and 'insulator', but she did not.

In my discussion with the class teacher it was clear that she was very impressed by Martha's lesson. Her comments were that the "lesson was well organised, paced and resourced, the activity engaged pupils' interest". The pupils worked very well together in pairs. The product (quiz cards) was differentiated by outcome and could be used to form an effective interactive display. The class teacher also said that Martha had "introduced and explained the task clearly" and that she was "obviously very confident".

Whilst I agreed with many of these comments, I was concerned that the class teacher said nothing about Martha's ability to teach science. All of the class teacher's comments were about generic teaching skills. I was also unsure about what she meant by 'confident', but did not pursue this with her.

When I met with Martha to discuss her lesson, I started by asking her how she thought the lesson went. Martha felt that the pupils enjoyed the lesson, most had completed the task correctly and that they had behaved well. I asked what the learning outcomes were for the lesson, that is what science did she intend the pupils to learn as a result of this lesson. Martha talked about electricity needing a circuit to flow. Martha was able to explain the role of the masking tape as an insulator, preventing the electricity flowing in all directions. When asked if she thought that the pupils knew this, Martha said that she was unsure. I emphasised

the importance of identifying the 'science' within the lesson and making it clear to the pupils.

As a tutor, I felt that my role was to give trainees feedback that would help them to become better teachers of the subject that I observed them teaching, be it science, mathematics or history and not simply how to be a better teacher. I was concerned that although Martha had many good teaching skills, she had not taught a good *science* lesson. Some of the pupils in her class may have understood the science aspect of the lesson, but Martha had not said anything explicitly to develop this. In the discussion after the lesson, it was clear that Martha understood the science involved in the lesson, but she had not enabled the pupils to engage with the science. I thought that with some relatively minor adjustments, this lesson could have been greatly improved. Martha was already a very competent teacher; she now needed some guidance, in order to become a competent teacher of science.

A teacher must possess certain generic teaching skills such as, management of pupil behaviour, organisation of resources, pacing a lesson, before they could teach any subject, but every subject requires its own subject specific teaching skills.

2.1.2 Trainee teachers' perceptions of factors which affect confidence to teach science

The second event that highlighted the importance of this research was the result of two questionnaires that were given to different cohorts of BA Primary Education trainee teachers. The first questionnaire was to find out what factors contributed to a lack of confidence to teach science. The second questionnaire was to find out if there was a link between trainee teachers' pre course science qualifications and their confidence to teach science.

My earlier observation of NQTs and experienced teachers was that they often reported that they did not feel confident to teach science. The aim of the first questionnaire, A (Appendix 2.1) was to find out what the source of this lack of confidence might be. The questionnaire was given to 73 third year BA Primary Education trainees to elicit their ideas and feelings

about science and teaching primary science. Although this questionnaire was a 'kite flying' exercise, it did yield some interesting results. I asked trainees what science topics they felt most confident to teach, (results in table 2.1), and why, (results in table 2.2). They were also asked which topics that they did not feel confident to teach, (results in table 2.3) and why, (results in table 2.4). The questionnaire allowed the trainees to give a free response. The results of this questionnaire echoed the findings of Smith and Peacock (1992); my trainees were most confident to teach Human Biology, Plants, Sound, Senses and Colour. They were least confident to teach Energy, Forces, Electricity, Magnetism and, Air and Flight.

Table 2.1 Science topics which trainee teachers felt confident to teach (trainee teachers could choose more than one subject)

Science Topic	Number of Trainee teachers confident to teach it N=73
Human Biology	26
Plants	20
Sound	19
Senses	16
Colour	11
Animals	10
Magnetism	8
Electricity	7
Earth and Space	7
Seeds	7
Light	7
Floating & Sinking	6
Minibeasts (small invertebrates)	6
Pondlife	5
Forces	4
Materials	4
Air and Flight	1
Growth	1
Energy	1
Weather	1
No topic	1

Table 2.2 The reasons why trainee teachers felt confident to teach particular science topics

Reason for confidence	Percentage of trainees N=73
Taught topic on previous School Experience	33
Personal/family interest	25
Previous qualification	23
Researched topic for assignment	9
Enjoyed University session	5
Understand concepts fully	4
Attended INSET session at placement school	1

Table 2.3 Science topics which trainee teachers did not feel confident to teach (trainee teachers could choose more than one topic)

Science Topic	Number of trainee Teachers who did not feel confident to teach it N= 73
Energy	37
Forces	31
Electricity	13
Earth and Space	9
Magnetism	7
Air and Flight	6
Human Body	4
Colour	2
Seeds	1
Pondlife	1
Minibeasts	1
Sound	1
Light	1
Plants	1
Animals	1

Table 2.4 The reasons why trainee teachers did not feel confident to teach particular science topics

Reasons for lack of confidence	Percentage of trainees N=73
Difficult concepts to grasp / not enough knowledge	65
Difficult concepts to teach	19
Missed the course session	6
No previous qualification	4
Dislike / hatred of the topic	4
No interest in the topic	1

It is interesting and perhaps puzzling that while the trainees identified their lack of knowledge as the top factor for not feeling confident, they did not identify their knowledge as the top reason for feeling confident. I believe that the trainees' experience of teaching a topic on School Experience probably meant that they felt confident in their science knowledge, even if they did not express it in these terms. Thus it was clear from tables 2.2 and 2.4 above, that the trainee teachers identified their own knowledge and understanding of science to be the key determining factor in their confidence to teach primary science. The DES (Department for Education and Science) supported this view saying in 1978 that;

> The most severe obstacle to the improvement of science in the primary school is that many existing teachers lack a working knowledge of the elementary science appropriate to pupils of this age
>
> (DES, para 100, p 25)

The results of the first questionnaire showed that the trainees' own subject knowledge and understanding was a key factor in their level of confidence to teach primary science.
In order to find out whether the level of pre course science qualifications had any bearing on

the trainees' confidence to teach science, a second questionnaire B (Appendix 2.2) was given to 89 third year BA Primary Education trainees. The results of this questionnaire are summarised in table 2.5.

Table 2.5 The relationship between pre course science qualifications and the trainee teachers' confidence to teach primary science

Pre course science qualification	Percentage of trainee teachers who felt confident to teach primary science (N= 88)
None	13
GCSE	26
'A' level	50

These results showed that the more highly qualified the trainee was in science, the more confident they felt to teach primary science. I was not convinced, however, that the trainees' own subject knowledge and understanding was as important as they thought it was. Firstly, the questionnaires did not define confidence, and so I did not know how individual trainees had interpreted it. Some may have interpreted it as 'competence' others as 'enjoy'. Secondly, I was also aware that it is possible for a teacher to teach 'confidently' with insufficient or incorrect knowledge and understanding of the subject matter, as illustrated by the following two vignettes, the 'Cartesian Diver' and 'Blood Groups' from my own experiences as a teacher.

Teaching science with confidence but not competence

I was teaching science to a group of third year BA Primary Education trainees. One of the activities involved a 'Cartesian Diver'. Although I had learned how the diver worked such that I could recite an explanation, I did not have a coherent understanding of how it worked. I was aware that during the lesson, I would have to explain it. I was also aware that I would

not be able to answer questions posed by the trainees. I prepared an OHT (overhead projector transparency) with a written explanation and diagrams. When explaining how the diver worked, I adopted a 'world weary' tone, and sped through the explanation implying that the trainees all knew how the diver worked and so I was simply affirming their understanding. I did not invite the trainees to ask questions and none did.

In 1986, as a biology teacher in a secondary school, I taught the blood donor group system to a group of GCSE pupils. I mistakenly said that it was the donor's antibodies that attack the recipient's antigens, when of course the reverse is true. Using this misinformation, the explanation of the system that I gave was coherent but incorrect. My error did not come to light, until the pupils did an 'end of unit' test. The results revealed that all but three pupils (not the most able), answered the questions incorrectly.

In the case of the Cartesian Diver, I was not confident with the subject matter, but was a confident teacher and knew my trainees. I was confident to employ a strategy to cover up my lack of knowledge and understanding. Some of the trainees may have understood the written explanation, but I had not explicitly engaged with the 'science' of the explanation of how the diver worked. In the case of the Blood Groups, I was confident in my ability to teach and in my own subject knowledge and understanding, although my confidence with the subject matter was misplaced. My teaching was effective, in that most of the pupils understood the principles taught and were able to apply what they had learned in the test situation. Once, I had discovered my error, I was able to rectify it, by re-teaching the topic. I was confident in my relationship with the pupils and in my role as a teacher to admit my error.

As these vignettes show, it is possible for teachers to *teach* confidently when they lack sufficient science knowledge for the lesson that they are teaching. In the case of the Cartesian Diver, the engagement with science was minimal as the teacher simply delivered

an explanation. In the case of the Blood Groups, there was more engagement, but unfortunately the science was incorrect.

2.1.3 Teachers generic feedback on a science lesson

The third event involved the use of a video of a trainee teacher teaching science, used for moderating purposes. The video was shown to a group of forty class teachers and school based mentors who attended a training session for staff involved in assessing PGCE trainees on school experience. All of the participants had had experience of assessing trainee teachers on School Experience. The first ten minutes of the video was shown. In it Leo (the trainee teacher) introduced the topic 'electricity' and set the class the task of trying to make a light bulb light up, using one bulb, one cell and one wire. Some of the pupils struggled with the task and Leo assisted them. The class teachers and mentors were asked to discuss what feedback they would give to Leo at the end of the lesson. The purpose of the feedback was to help Leo to improve. I did not specify what the nature of the feedback should be. I noted all of the comments made, as each pair reported back to the whole group. Comments were made about Leo's voice, the management of the pupils, the organisation of the room and so on. The seventeenth pair of teachers was the first pair to comment on the science teaching aspects of the lesson. Subsequent comments then focussed on the science teaching. As with Martha's class teacher, the class teachers and mentors had focussed on Leo's generic teaching skills, there were very few comments on his subject specific knowledge and the related teaching skills.

Reflection on Martha's lesson and the results of the two questionnaires led me to formulate the research questions listed in section 1.1. The third event, the video, confirmed the importance of the research questions, once the research was underway.

2.2 Background - thinking about teacher confidence

Teacher confidence is a term that is widely used by tutors and mentors, but one that does not necessarily have a shared meaning. The problem of defining confidence was apparent in the events that were the impetus for this research (see section 2.1). In this section I will explore what confidence means and identify what factors may affect it. An exploration of how confidence relates to the teaching of science is necessary before embarking on any more systematic research. A search for literature on the meanings of confidence yielded little.

The dictionary offers the following definitions of confidence and confident;

> confidence - firm trust belief; faith; trust in secrecy; self-assurance, self - belief; assuredness, esp.in the outcome of something;
>
> confident - trusting firmly; having full belief; (esp. self-) assured, bold.
> (Chambers, 1991,p 215)

From this definition, *confidence to teach* is characterised by a perceived certainty in the successful outcome of one's teaching, and / or the certainty or belief that one can manage any unexpected occurrence. Trainee teachers who are confident in their own *science* subject knowledge and understanding, may feel that the outcome of their teaching will be successful and that they would be able to manage any unexpected occurrence for example a pupil asking a *difficult* question. Table 2.4 shows that the two main reasons why the trainee teachers did not feel confident to teach particular science topics were first, that the concepts were "difficult for the trainee teacher to grasp/ the trainee teacher did not have sufficient knowledge" and second, that the concepts were "difficult to teach". This led to the first two areas of confidence to note.

1. Confidence in their own subject knowledge and understanding
2. Confidence to teach science

The second area is strongly related to the first. The teaching of science requires the teacher to know "how science differs from other disciplines that is what makes it science" (Harlen, Holroyd and Byrne 1995). If teachers understand this, they can build "bridges between their own understanding of the subject matter and the understanding that grows and is constructed in the minds of trainees" (Shulman 1991). Teachers need to feel confident that they not only understand the science themselves, but that they understand it in ways which can be successfully translated for their pupils. The trainee teachers identified this by saying, "concepts were difficult to teach".

I was also aware that a major concern for my trainee teachers is the management of pupil behaviour. If trainee teachers cannot manage pupil behaviour, they have little chance of teaching them. That mentors focus on giving trainee teachers generic feedback, including the management of pupil behaviour (see section 2.1) shows that this area of confidence is of importance. It is the third area of confidence to note.

3. Confidence to manage pupil behaviour

When interviewing the participants about the factors that affect their confidence, it was important to ask the participants about these three areas.

There are factors other than the three, listed above, that affect teacher confidence. White (1986) not only identifies confidence, but also considers factors that might affect it. White says that a teacher's confidence (self-esteem) comes if the institution (school) makes them feel valued. To enjoy self - esteem is to feel secure that one's conception of the good life is worth carrying out and to be confident in one's abilities to do so. For the teacher this means that he values his role as a teacher and feels that he is able to carry out the role successfully. A good opinion of one's self and of one's abilities may rest on all kinds of different bases.

For teachers this could be their own subject knowledge and understanding, their status within the school or the affection and respect in which the pupils hold them.

In identifying the factors that determine teacher confidence, it was important that the participants were given the opportunity to identify other areas of confidence, other than the three listed above.

2.3 Background-combining confidence and engagement

I was interested to find out if there was any link between teachers' confidence and their level of engagement with science. If I was to do this, I needed to describe engagement and confidence at different levels, and quantify them if possible. I thought that by using an observation tool comprising a list of possible engagements, I would be able to score lessons, numerically, for levels of engagement with science. To gain a 'measure' for confidence the teachers could be asked to rate their confidence to teach science. By plotting the level of engagement against confidence, I could search for a correlation, to see if an increase in confidence lead to an increase in the teacher's engagement with science. The level of engagement could also be plotted against time (teaching experience). This would show if an increase in teaching experience leads to an increase in level of engagement with science. This approach was used in the pilot study but was later abandoned and a significantly different alternative approach developed for the main study.

2.4 Initial research question and research aims

My interest in finding out how engagement was changing over a period of time as more teaching experience was gained, led to the following research questions

1. How does the level of engagement with the content of primary science vary with the level of teacher confidence and how does this change over time?
2. What factors contribute to the level of engagement with science?
3. What factors contribute to teachers' level of confidence?

The research questions therefore led to the following aims:

1. to explore, describe and define 'level of engagement with science and the factors which contribute to it;
2. to explore the concept of teacher confidence and the factors which contribute to it;
3. to quantify level of engagement and confidence and examine to what extent the level of engagement is determined by teacher confidence;
4. to see if and how the level of engagement with science in primary science lessons varied over time;
5. to examine the role of teachers' science subject knowledge in determining their confidence to teach science.

The fifth aim is part of the first aim. However, as the trainee teachers, the DES and Shulman all identify subject knowledge and understanding as the most significant factor in determining teacher confidence and /or effectiveness, I included it as a separate aim.

During their teacher-training year, trainee teachers' main concerns (worries) revolve around managing pupil behaviour, classroom organisation, maintaining their teaching file and being assessed. As trainees gain more teaching experience, that is, post qualification, so trainees gain more confidence in these areas and hence they cease to be of such concern.
These research aims led to the following hypothesis;

As teachers gain teaching experience, they gain competence in the generic aspects of teaching, so their level of engagement with science should increase.

2.5 The importance of this research

The importance of this research is that it should identify factors that lead to a high level of engagement with science and to high teacher confidence. This could help inform science teacher education for the training period and beyond. The main study for this research is a longitudinal one focussing on the development of teachers over three years. These three years include the training year. Few such studies have been undertaken before and so this research would make a useful contribution to the literature on teacher development.

Trainee teachers have to teach all aspects of science as required by the National Curriculum. Trainee teachers would be expected to teach science at least one and a half hours a week at Key Stage 1 (pupils aged 5-7 years) and two hours a week at Key Stage 2 (pupils aged 7-11). For the trainee teacher, who does not feel confident to teach science this would pose a significant problem. It is possible for trainee teachers to mask their inadequacies, real or imagined, but it is unlikely that they would enjoy success in the classroom, and this would probably lead to a diminution in confidence. If this research could identify what the trainees teachers' concerns were, these could be addressed during the trainee teachers' training year. I thought that if I could identify neglected aspects of engagement with science, I could share them with the mentors, class teachers and tutors, involved in assessing trainee teachers. This would enable them to provide subject specific feedback, to help trainee teachers improve their teaching of science. I would also be able to use the research findings with trainee teachers in science in university based sessions.

I chose to undertake a longitudinal study because I am interested in looking at change. I chose to follow a group of PGCE trainees, because their training course is only one year and I wanted to observe how their science teaching developed post qualification. I thought that these post qualification observations would help inform the content of the science teacher education that I provide for trainee teachers and the content of further training provided for NQTs by LEAs and schools.

I was also aware that there were not many pieces of longitudinal research in science education. A survey of longitudinal research projects (Arzi, 1988) listed projects carried out between 1963 - 1987, in four major science education research journals, European Journal of Science Education, Journal of Research in Science Teaching, Research in Science Education and Science Education. Of the 34 projects listed, only six were focussed on the teacher. One looked at the implementation of new science programmes following awareness conferences for elementary teachers and administrators (Sheldon, 1978). Three of the projects looked at teacher change following inservice training (Moon 1971, Lashier and Nieft 1975, Mayer, Disinger and White 1975). One project looked at teacher change following the adoption of a new science curriculum, (Orgren and Doran 1975:Orgren, 1977). The final project looked at the change in attitude to, and anxiety about, teaching science, in pre-service elementary school teachers (Westerback 1982). This research could be a significant addition.

2.6 Summary

This research originated in my work of training trainee teachers and observing experienced teachers teaching science in primary schools. I was interested initially in factors that contributed to both teacher confidence and teacher engagement with science.

It was necessary to distinguish 'confidence to teach' from 'confidence to teach science', because teachers could be confident in front of a class in a science lesson but fail both to explain the science properly and to ensure that children grasp key scientific ideas. They used strategies sometimes subconsciously, to 'side-step' the science. Feedback from teachers acting as mentors to trainee teachers also frequently side-stepped the science, focusing only on the development of generic teaching skills. What began to emerge was the need to consider the extent to which teachers engaged with science ideas during lessons and whether they helped pupils to engage with these ideas. 'Engagement with science' eventually became the focus of the research. Early research questions brought together these ideas of confidence, engagement and effectiveness,

An assumption was made that increased teaching experience would lead to an increase in personal confidence to teach science and this would in turn lead to higher level of engagement with science in lessons. An exploration of the factors that contributed to the feeling of confidence would be useful to the research. An early exploratory study revealed that trainee teachers regarded their own subject knowledge as a key factor in their feelings of confidence, but this was followed closely by whether or not they had taught the topic previously. They were more confident with biological topics than physical science topics, a finding echoed in research by Smith et al. (1992).

The initial research questions lacked the idea of development over time, which as a teacher educator, was a major focus of my work and interest. I wanted to find out if trainee teachers' engagement with science increased over time. This led to the research questions

1. How does the level of engagement with the content of primary science vary with the level of teacher confidence and how does this change over time?
2. What factors contribute to the level of engagement with science?
3. What factors contribute to teachers' level of confidence

The role of subject knowledge and understanding in relation to teacher confidence and effectiveness is explored in Chapter 3.

Chapter 3 The Role of Subject Knowledge and Understanding in relation to Teacher Confidence and Effectiveness - a literature review

3.1 Introduction

"If he had only learnt less, how infinitely better he might have taught much more"

Charles Dickens (1854), Hard Times

So thought Mr M'Choakumchild, the newly qualified teacher in Dicken's Coketown. Mr M' Choakumchild had, with many others, recently been turned out "like so many pianoforte legs" from college. He had successfully answered "volumes of head breaking questions" on a wide variety of subjects from algebra to the "Water sheds of all the world (whatever they are)".
But despite this learning, he did not feel that he was adequately prepared for the task of teaching the pupils of Coketown, there was clearly something missing from Mr M'Choakumchild's training.

This chapter examines the role of the teachers' own science subject knowledge and understanding in relation to teacher effectiveness. Shulman (1987) cited in Harlen (1999) lists the areas of knowledge that a teacher must grasp in order to teach science, these are

1. content knowledge - about science and of science
2. general pedagogical knowledge - about classroom management and organisation that transcends subject matter
3. curriculum knowledge - the guidelines, national requirements and materials available
4. pedagogical content knowledge - about how to teach the subject matter, including useful illustrations, powerful analogies and examples
5. knowledge of learners and their characteristics
6. knowledge of educational contexts
7. knowledge of educational goals, values and purposes, including the history and philosophy of education.

Shulman places content knowledge, that is, what the teacher knows and understands about science and of science, first. This is because as Harlen (1999), says, several of the others areas of teacher knowledge depend upon it. Shulman does not say that teachers need to know and understand every aspect of a subject in order to teach it successfully, but rather, that he needs,

> An understanding of what identifies science; how the discipline differs from other disciplines; what are its boundaries, its limitations and the different ways in which it can be conceived
>
> Shulman,1991

The surveys of trainee teachers (see Chapter 2,tables 2.2 and 2.4) show that they identify their own science subject knowledge and understanding as the most important factor in determining their confidence to teach science.

3.2 Reports from government agencies on the role of subject knowledge and teacher confidence

The importance of primary teachers' own subject knowledge and understanding in the successful teaching of science has been a central theme in documents from government agencies before and since the introduction of the National Curriculum in 1989. It is central to the DFEE (Department for Education and Employment) 1998 Initial Teacher Training National Curricula in England and Wales. In 1978, as shown in Chapter 2 teachers' lack of subject knowledge and understanding, was identified as the "most severe obstacle" to the improvement of primary school science.

In the year in which the National Curriculum was introduced in UK primary schools HMI (Her Majesty's Inspectors) report on primary science stated that opportunities were needed for teachers to:

> improve their own knowledge of science in relation to what children should know, understand and be able to do
>
> (DES 1989 para 100 p 25)

Nine years later this view was supported in the Ofsted (Office for Standards in Education) report of 1998, which stated that:

> steps need to be taken to enhance the science subject knowledge of teachers, especially those teaching older classes
>
> (Ofsted, para 1 p 5)

The Ofsted report suggested that teachers lacked knowledge and understanding of particular areas of science, especially the physical sciences, and that this lack of

understanding led to an overemphasis in their teaching on knowledge acquisition at the expense of conceptual development. In their report, Alexander et al (1992) recommended that in-service education and training (INSET) for teachers should be "more exactly targeted on the issue of improving subject expertise". The situation regarding teachers' confidence to teach science in the primary school appeared to have improved by 1998/9. Few teachers were said to lack confidence in science, but this was still identified as the reason for the small gains made by their pupils:

> Gains have been smallest where the few teachers who continue to lack confidence in science have relied on merely giving information and have not engaged the interest of pupils through lively exposition or stimulating practical work.
>
> (DfEE, 2000, para 16,p 4)

The underlying assumption that subject knowledge is the most important factor is treated as unproblematic in many contexts. A review of recent research into teacher subject knowledge and understanding, will show that whilst it is very important, it may not necessarily the most important factor in determining teacher effectiveness. Teacher subject knowledge and understanding is, to say the least, more uncertain than suggested by the official reports. The literature shows that even when teachers have a firm grasp in cognitive terms of the relevant subject knowledge and understanding, effective teaching is not automatically guaranteed. The picture is more complex. Whilst the research examined for this chapter concentrates mainly on primary science, research involving other areas of the curriculum such as music and mathematics, has also been explored.

3.3 The influence of subject knowledge and understanding on teacher effectiveness

Whitby (1993) and Osborne and Simon (1996) provide studies that explore the influence of subject knowledge and understanding on teacher effectiveness, by comparing the practice of two teachers teaching the same topic. Both studies show that the more effective teacher was the one with the higher qualification in science. Whitby (1993) examined the relationship between teachers' confidence to teach primary science and their knowledge and understanding of science subject matter. She showed that the teachers' confidence to teach science was determined by their own science subject knowledge and understanding, and that this in turn influenced their teaching style. Whitby observed the science lessons of two Key Stage 1 teachers, A and B, both

considered by their headteacher to be good practitioners. Teacher A had a science degree and expressed a confidence in teaching science to young children. Teacher B felt that her own science knowledge and understanding was very limited, and that this led to a lack of confidence to teach science to young children, but she regarded science as an essential part of the primary curriculum. The two teachers collaborated on their planning and both classes did the same activities. Whitby focussed on the questioning techniques of the two teachers. She found that teacher A asked more questions and that her questioning led to the problem being solved. Teacher B, on the other hand, asked fewer questions, her questioning led to confusion and she ignored suggestions made by the children. Teacher B said that she rushed the activity to prevent the children asking questions that she could not answer. Whitby concluded that it was teacher B's poor science subject knowledge and understanding, which led to her lack of confidence to teach the science content of the lesson, which undermined the learning in classroom B.

Whitby does not tell us how it was determined that both teachers were good practitioners, nor if what she observed during this one lesson was typical of how the two teachers taught. However, teacher B cited her lack of science subject knowledge and understanding as determining her teaching style, that is poor questioning and avoidance of the children's questions.

Brown and Simon (1996) cited in Osborne and Simon (1996), observed two primary teachers teaching the topic Light to lower Key Stage 2 children. Carol, a linguist, reported that she lacked confidence to teach science, saying of herself "I like science, but I am not a science person". She felt vague about her science teaching plan and was unsure about what she was trying to achieve. Carol used a variety of source materials to plan activities for the children and to extend her own subject knowledge and understanding. Fiona, a science graduate was confident in her knowledge of the topic Light, she was also the school's science coordinator. She set out to teach the same Programme of Study (PoS) as Carol that is 'light can be reflected and that reflection of light enables objects to be seen'. Carol's plan matched relevant activities for the children to the important concepts of the topic. The questioning style of the two teachers was different. Carol attempted to discuss how we see an object with her class, but her rapid questioning and hinting that the concept was difficult, rendered the children mute. Fiona had a more open style of questioning. Unlike Carol, she had a clear picture of the

direction of the discussion, but made use of the children's ideas. When asked 'how we see', seven out of ten of Fiona's children were able to give an acceptable answer. None of Carol's children were able to do so, although five out of nine of them could describe how they saw their reflections in a mirror. Brown and Simon concluded that the children's responses were linked to their teachers' level of confidence in their discussions of 'how we see objects'. Carol's children were able to describe how we see our reflection in a mirror, because she was confident in this area of knowledge and understanding.

In both studies, the teacher possessing a science degree and therefore having a higher level of subject knowledge and understanding in science was suggested to be a more effective teacher of science than the teacher without a science degree. Contrasting the success of science graduates against the poorer performance of teachers with little or no science in their backgrounds is not particularly helpful, as these two positions are the extremes in a primary school. As neither study indicated what science degree the successful teacher had, we can not be sure how relevant it was to the science topic that the teachers were teaching. We were not told if Fiona's degree was biology, chemistry or physics based. It is possible to study biology successfully to degree level, with no qualifications in physics. Fiona's effectiveness in teaching the physics based topic, Light, may have been more to do with how she understood what she knew, rather than how much she knew. As Shulman (1991) said, the effective teacher must be able to build bridges between their own understanding of subject matter and that which their pupils develop. Fiona may have had a good understanding of what her pupils already knew and so she was able to tackle their misconceptions and to ensure that the 'new' science that she was teaching allowed the pupils to challenge what they already knew. It is possible that a good general knowledge and a lively interest may have been sufficient to teach the topic Light successfully.

Several large-scale research projects have looked at the level of teachers' subject knowledge in science and its influence on teacher effectiveness, (Symington and Hayes 1989, Tobin and Garrett 1988). The findings suggest that teachers are deficient in subject knowledge and so are less effective teachers of science and support the views in the Ofsted (1989) and DfEE (2000) reports, namely that the lack of necessary content knowledge inhibited primary teachers' ability to improve their practice in primary science.

Bennett and Carré (1991) looked at the role of subject knowledge and understanding in PGCE trainee teacher effectiveness. They compared music lessons given by music specialists and non-specialists. The analysis of the lessons showed that "not only do the specialists maintain a much better balance between teaching and management, they do so at consistently higher levels of performance". Bennett et al. concluded "subject knowledge is a vital ingredient in high quality teaching and pupil learning, and that teachers "cannot teach well what they do not know". Bennett et al. (1993), continuing this area of work, wanted to find out if trainee teachers taught their specialist subjects to 7-11 year olds to higher levels of competence than their non - specialist colleagues. They looked at the performances of primary teachers whose specialisms were music, science or mathematics, and how well they taught their specialism and non-specialism. The researchers found that the music specialists taught music to a higher level of competence than the mathematics and science specialists taught mathematics and science. The music specialists had a higher level of subject knowledge and understanding in music, than the mathematics and science trainee teachers had in their respective specialisms. It was concluded that having a higher level of subject knowledge and understanding results in the trainee being able to teach to a higher level of competence. Hence the music specialists were more successful at teaching music than the science specialists were at teaching science, and the mathematics specialists were in teaching mathematics.

3.4 Primary teachers' perceptions of their competence to teach primary science

Carré and Carter (1990,1993) showed that primary teachers underestimated their competence to teach science. The project based at the University of Exeter, surveyed 901 teachers in 51 primary schools, to ascertain the teachers' perceptions of their competence and needs with respect to the new National Curriculum in the UK. Thirty four per cent of the teachers felt confident in their existing knowledge and skills, in science. This placed science eighth out of the ten primary subjects that the teachers felt competent to teach. These results are not unexpected, as only eight per cent of the teachers had specialised in science in their own higher education. The results for the other subjects followed a similar pattern. That is, the teachers' confidence was linked to their subject specialism. The authors were not attempting to verify the teachers' level of understanding; that is,

there may be a mismatch between what the teachers say that they know and understand and what they actually understand. Overall many primary teachers rated their competence to help pupils to achieve science process skills quite highly, but a large number indicated that they needed further training for the development of scientific knowledge especially in the physical sciences.

This research was followed up two years later in 1991, when the National Curriculum was in its second year. Of the 433 teachers surveyed for the project, forty one per cent now felt competent with their existing science knowledge and skills. Thus science moved from eighth place in 1989, to third place in 1991. What had happened in these two years to account for the rise? For Carré et al. (1993) the "precise reasons for these changes are beyond the scope of this enquiry". They concluded that "science teaching in primary schools will have been substantially enhanced by the advent of a national curriculum if these data can be generalised". Thus, teachers had taught National Curriculum science for two years, so experience led to increased confidence. In 1989, the teachers underestimated their competence with their existing science knowledge and skills. By teaching National Curriculum science they realised that they knew more science than in the pre-National Curriculum era.

3.5 The level of teachers' subject knowledge in science: the 'deficit' model

The deficit model is that, teachers are deficient in their knowledge and understanding of particular science topics and that this deficiency can be addressed by courses to enhance subject knowledge and understanding. Considerable research suggests that primary teachers lack conceptual understanding in specific areas of science (Smith et al. 1992; Kruger, Palacio and Summers 1990; Summers and Mant 1995). The response to this research has included the development teacher training materials, rather than to question the extent to which this lack matters. Others, however have argued that focusing on teachers' understanding of science subject matter exaggerates the extent of the problem. If teachers appreciate in a general sense the nature of science, then they can engage pupils in enjoyable science activities. Golby, Martin and Porter (1995) make this point in their critique of the work of (Mant and Summers 1993) on the lack of primary teachers' knowledge and understanding of 'the Earth's place in the universe'. They describe Mant

et al. as having a transmission view of teaching, with an implied reception view of pupil learning. For this mode of teaching the teacher must have a sound knowledge base to enable them to pass on their learning to the pupils. Golby et al. say "teaching is not principally about telling facts, but about finding meaning in experience". This position implies that teachers do not need such a high level of subject knowledge and understanding. The critique of Golby et al. is useful in indicating the complexity of the issue. However, they do not explore how the teacher is to select experiences in which the pupils will find meaning or how the teacher will help the pupils to find that meaning. Mant et al. refute this criticism of their work, they say that they have a constructivist view of learning in science and that their INSET materials reflect this. They strongly support the view that having a sound subject knowledge and understanding of science is an important condition for being able to teach it well (Mant and Summers 1995). McDiarmid, Ball and Anderson (1989) in their study of teacher knowledge reported that teachers' own subject knowledge and understanding was critical in determining their ability to pose questions, select tasks, evaluate their pupils' understandings and to make curriculum choices. Bennett and Carré (1991) support this view, saying that teachers need a sound subject knowledge and understanding in order to " frame accurate and high quality explanations, and they need it to diagnose accurately misconceptions".

3.6 The influence of attitude on teacher confidence

The influence of attitude on teacher confidence provides contrary evidence to the case for the importance of teacher subject knowledge and understanding as the most important factor in determining teacher effectiveness. Zuzovsky, Tamir and Chen (1989) for instance, looked at the difference in the attainment of fifth grade pupil in Israel, who were taught science by either specialised science or generalist science teachers. The pupils' achievement was measured using a science test comprising 45 multiple choice questions. In Israel one teacher, the homeroom teacher, taught all subjects to pupils in the lower grades (pupils aged 6-8). The homeroom teachers did not have a special subject. In the upper grades (pupils aged 8-12), specialised teachers taught specific subjects including science. Due to a shortage of specialist science teachers, the homeroom teachers sometimes taught science to the upper grades. This difference in pattern of staffing provided the context of the research. As Zuzovsky et al. said "it is commonly believed that specialist teachers (who only teach science) are better prepared, and are more familiar with professional literature and educational innovations in their

area than are the general teachers (who teach most subjects, including science)" and "so consequently specialised teachers are expected to be more effective teachers". This supports the view, that the "inferior scientific preparation of the general teachers accounts for the claimed low science achievement in the elementary school" (about half of the elementary school teachers were generalists). However, the researchers found that although the specialist teachers were judged to be better prepared and exhibited more adequate modes of science instruction, their pupils did not achieve any more than the pupils of the non-specialist teacher. This was because the generalist teachers had a more positive attitude to the study of science, which balanced out their poorer preparation and less adequate modes of science instruction. Thus, teacher attitude was found to be as important as preparation and science teaching skills in determining teacher effectiveness. An enthusiastic teacher can compensate for a lack in some of the areas of knowledge listed by Shulman (1987) see section 3.1.

3.7 The influence of teaching style on teacher effectiveness

Teaching style may also affect teacher effectiveness, as several studies have suggested. Effective teaching involves helping pupils to engage with and make sense of scientific ideas and concepts. McDiarmid et al (1989) looked at secondary science, saying that teaching is about helping pupils develop "flexible understandings"of the subject matter, which they define as:

> "the ability to draw relationships within the subject as well as across other disciplinary fields and to make connections to the world outside of school"
> (p 193)

This view is supported by Askew, Brown, Rhodes, Johnson and Wiliam (1997) who show that teachers, who are able to make connections between different branches of mathematics, are more effective than teachers who are unable to make these connections. They studied what 90 primary teachers knew, understood and were able to do in terms of numeracy, and the relationship between this and the outcome in terms of pupil learning. They found that the highly effective teachers had knowledge of and an awareness of conceptual connections between different areas of the National Curriculum, which they taught. The study found that, being a highly effective teacher of mathematics was not associated with having an 'A' level or degree in mathematics. This finding conflicts with those of Whitby (1993) and Brown et al. (1996) cited earlier.

Askew et al. (1997) found that some, but not all, of the less effective teachers of numeracy displayed knowledge that was "compartmentalised, and framed in terms of standard procedure, without the underpinning of conceptual links". This group included teachers who were highly qualified in mathematics. Effective teachers of numeracy were those who:

> used pupils' descriptions of teacher methods and their reasoning to help establish and emphasise connections and address misconceptions
>
> (p1)

Thus, it seems to be the interaction of a teacher's knowledge and understanding with that of his or her pupils' which is a crucial factor in the classroom, a point made by Golby et al. (1995). The ability of the teacher to highlight connections and address pupils' misconceptions was not linked to the teacher's level of mathematics subject knowledge and understanding. Askew et al. (1997) developed a model of teaching that shows the relationship and interplay between the teacher's beliefs, knowledge and classroom practices. Teachers' practices are determined by their own subject knowledge and understanding, how they see the role of the teacher, their understanding of how pupils learn best, and most importantly the pupils' response. The authors claim that it is "the interactions between teachers and pupils as they occur in lessons that will be the most significant influence that a teacher has on pupils' learning". Thus however well prepared a teacher is and however well informed, what actually happens in the lesson is the crucial factor. They describe three types of teacher, 'connectionist', 'transmission' and 'discovery' with regard to mathematics. Although, no teacher fitted just one of these beliefs frameworks, they found that

> those teachers with a strongly connectionist orientation were more likely to have classes that made greater gains over the two terms (of the project), than those classes of teachers with strongly discovery or transmission orientations
>
> (p 24)

This supports the view of McDiarmid et al. (1989) cited above. Askew et al. (1997) found that the orientation of the teacher was not linked to their subject knowledge and understanding, that is, having little subject knowledge and understanding did not mean that teachers were any more likely to have a particular teaching orientation. However, if a teacher believes that his role is to help pupils to accrue knowledge, then he is likely to

give importance to his own subject knowledge and understanding, that is the more he has, the more he has to give.

The Connectionist teacher emphasises the links between different aspects of the curriculum. A primary belief is that teaching is based on dialogue between the teacher and the pupils, so that the teacher can better understand the pupils' thinking and pupils can gain access to the teacher's subject knowledge and understanding.

The Transmission teacher places more emphasis on teaching than on learning. Thus teaching is believed to be most effective when it consists of clear verbal explanations of routines, procedures and concepts. Interactions between teacher and pupils tend to be question and answer exchanges in order to check whether or not the pupils can reproduce the routine, procedure or concept being introduced to them.

The Discovery teacher provides experiences for the pupils. The emphasis is on individual learning by the pupils; understanding is based on pupils working things out for themselves. Unlike the transmission teacher, the focus is on learning rather than teaching. The pace of learning is determined by the pupils.

The three teacher types listed above are not the only ones. The teacher as a 'co-learner' was found to be a popular idea with trainee teachers (Appleton 1995). He suggested that teachers' lack of confidence to teach science was attributed to their poor background knowledge. Appleton asked trainee teachers about their confidence to teach science at the start and at the end of their training course. Of the fifty five per cent of trainee teachers who completed the questionnaire, seventy one per cent were more positive about science; seventeen per cent were neutral and the rest negative. Appleton found that several trainee teachers felt that a small amount of knowledge was sufficient for the teacher, if the teachers viewed themselves as co-learners. The problem with this model is that if teachers are learning alongside the pupils or are only a few steps ahead of them, it is possible that the teachers would not be able to select appropriate experiences for them and identify their misconceptions. As Appleton said "teachers with limited science knowledge may not be aware of pupil misconceptions and cannot offer alternative, helpful explanations".

A further teacher type is the 'traditional teacher'. This type is characterised by a didactic teaching approach, where all of the pupils do the same activities at the same time. It is very similar to the transmission teacher. The following two studies show that teachers can adopt a traditional teaching style, but for different reasons. The first, by Lowden and Wallace (1994), compared the teaching style of two teachers, Malcolm and Susan. The second, by Tobin, Butler, Kahle and Fraser (1990), looked at Peter, who like Malcolm adopted a 'traditional' teaching style, but for different reasons.

Malcolm and Susan participated in a programme to increase the amount of interactive teaching in science. Both teachers taught in the same school and were willing participants in the project. Malcolm favoured a more traditional approach to teaching. The children worked individually and there was an emphasis on basic skills in mathematics and English. Susan organised her classroom around active learning centres for most of the day. Malcolm and Susan were both considered experienced and successful teachers, although the headteacher was keen for Malcolm to alter his teaching methods. Indeed Malcolm himself felt the need to examine his own teaching and said that he was "in danger of becoming too conservative". Malcolm tried out a 'group work activity', but found that he spent most of his time on management issues rather than problems of science understanding. Malcolm was not committed to this new teaching approach, although he was willing to try it. He felt more confident maintaining his former practice. It is difficult to assess the value of organising the classroom into active learning centres rather than in the more traditional approach of whole class teaching, as Lowden et al. do not indicate why this teaching style was considered better. They do not say if there was more learning in Susan's classroom compared to Malcolm's. So we do not know if Susan was a more effective teacher than Malcolm.
Peter described in, (Tobin et al. 1990), like Malcolm favoured a more traditional approach to teaching. Peter's lack of confidence in his own knowledge of science meant that he relied heavily on worksheets and textbooks for material.

Although Malcolm and Peter appear to have similar teaching styles, the reasons for their chosen teaching styles are different. Malcolm was confident in his own science knowledge and understanding, but was afraid that a less traditional approach would result in poor pupil behaviour and thus undermine his authority as a teacher. Peter, on the other hand, was afraid that his lack of science knowledge and understanding would be

exposed in a less traditional classroom and thus his authority as a teacher would be undermined. In both cases a change from a teaching style with which the teacher was uncomfortable, would not necessarily result in more effective teaching and learning. As Malcolm said "I need to be an individual and keep my own integrity, do what I know is right". For Malcolm to change his teaching methods, he must believe that a change would enable him to teach more effectively.

The study of Susan and Malcolm shows that one teaching style is not always more effective than another. A traditional teaching style, as in Malcolm's classroom can be effective. It is important to understand why a teacher has adopted a particular teaching style, as this might reveal some serious weakness. Peter might benefit from some further training that would help enhance his science subject knowledge and understanding. Malcolm might benefit from further training that would enable him to manage pupil behaviour more effectively.

In a study looking at effective practice in primary science, Murphy, Davidson, Qualter, Simon and Watt (2001) identified two models of effective practice, in terms of efficiency in achieving the goals of a teacher and of the National Curriculum and its assessment. They also identified the two views of knowledge underlying teachers' practice. As with the models identified by (Askew et al. 1997), only some of the teachers observed for the study fitted the two models However, the researchers were able to discuss the teachers in terms of their tendency towards one or other of the models.

The first model was labelled Model A : Linear Transmission. In this model, the teacher is the authority figure in the classroom, s/he supplies, controls and mediates the resources for learning. That is, teachers who fit this model have a view of knowledge, that it is, linear, sequential and fragmented. Murphy et al. (2001) used the metaphor of a petrol pump attendant or parent bird to describe the Model A teacher. Teachers with this view of knowledge use elicitation to check pupils' knowledge rather than understanding. They use discovery tasks and demonstrations, where interaction is focussed on the task and not on the learning. Model A is not unlike the transmission teacher described by Askew et al. (1997) where the teacher inputs knowledge and understanding into the pupils, whose output is their performance in assessment. For the transmission the focus is teaching rather than learning. Murphy et al. (2001), found that teachers who fitted this model,

taught knowledge as fragments that fitted into a hierarchy of knowledge. These teachers did not recognise connections between areas of knowledge and so did not make these explicit to pupils.

The second model was labelled Model B: Social Constructivist. In this model, the teacher is the guide and the modeler of ways of thinking and acting. The researchers use the metaphor of a sherpa guiding learners' exploration of an unknown terrain. Here the pupils as learners are active, reflective and purposeful. They are not empty vessels waiting to be filled with teachers' knowledge. In this model, making connections between knowledge is an essential part of becoming competent. Teachers who fitted this model, were concerned with pupils' understanding and ways of making sense, rather than the acquisition and retention of knowledge. Model B teachers, used investigations and explorations to develop pupils' procedural and conceptual understanding. Central to this model is that connections between areas of knowledge are seen as essential outcomes of learning. Pupils make connections guided by teachers and through interaction with others, including their peers. Model B, is not unlike the connectionist teacher described by Askew et al. (1997), where the focus is on dialogue between the teacher and pupils and pupils with others.

Where teacher effectiveness is judged in terms of pupil performance in national tests, which give priority to factual and descriptive knowledge, both types of teacher were found to be effective and their pupils achieved highly in these tests, (Murphy et al. 2001). However, if other measures were considered, that is, children's understanding, then model B was found to be more effective.

3.8 Findings from Inservice training in Primary Science

This section reports the findings from inservice training projects working with experienced primary teachers. Science educators would generally agree that teachers need at least some science knowledge and understanding in order to teach science effectively. Given that many primary teachers cite their lack of science knowledge and understanding as an important factor in determining their confidence to teach primary science, the matter of science INSET for primary teachers must be addressed. However, as Russell, Bell, McGuigan, Qualter and Schilling (1992) said

> The argument that a certain amount of science knowledge and understanding is *necessary* to teach the current curriculum is accepted. However, there is logical fallacy in the overstated version of the same case which attempts to suggest that such knowledge and understanding is *sufficient*.
>
> (p 81)

The Primary Science Processes and Concept Exploration (SPACE) Project began in 1986, that is, pre National Curriculum. At this time teachers did not have to teach primary science although there was considerable pressure to do so and every school was responsible for determining its own science curriculum. The orientation of the project was constructivist. The project concentrated on collaborative programmes of research into children's ideas in science and ways of helping the children to develop their understanding. The researchers worked closely with class teachers, meeting regularly to discuss concerns. They reported that

> these meetings enabled teachers to begin to appreciate the possibilities of learning in science as an interactive rather than isolated activity and the group sessions appear to have contributed significantly to the development in teachers' understanding
>
> (p77)

So, when given the opportunity to discuss their concerns and develop science understanding, the teachers made progress. Russell et al. (1992) quote some of these teachers:

> "I can put my knowledge into a framework to use with the children at their level"
>
> "Now I'll have a go, I feel a lot clearer in my mind where I'm going and why I'm doing things"
>
> (p 77)

Teachers mentioned that their confidence in their own science understanding had improved along with their teaching. This supports the findings of Carré et al. (1991, 1993), who found that the teachers' feeling of competence with their existing knowledge

and skills in science increased with teaching. Similar findings come from a study by Gooday, Payne and Wilson (1993). This study involved first and fourth year undergraduate primary trainee teachers who were given a list of science items. For each item they were asked to rate their own understanding of it, their ability to explain it to children and its importance for children. The trainee teachers were also asked about their confidence to teach science and their attitude towards science. The fourth year trainees were found to be considerably more confident in teaching science compared to the first year trainee teachers, they were more knowledgeable about classroom resources and how to use them. The fourth years also had a greater understanding of science processes. However, there was very little difference in the first and fourth year trainee teachers' understanding of basic science concepts. The trainees' content knowledge had remained unchanged, but there had been an increase in other areas of knowledge (Shulman 1987), for example, general pedagogical knowledge and curriculum knowledge. The trainee teachers had developed their general teaching skills through experience. In this study, teaching experience led to an increase in confidence. This might imply that a greater understanding of science subject matter is not necessarily important for a teacher's confidence to teach.

Harlen, Holroyd and Byrne (1995) surveyed 119 primary schools in Scotland. They used a questionnaire to find out teachers' confidence in their knowledge and teaching skills in different areas of the primary curriculum. They also explored teacher confidence in the knowledge needed to help develop pupil understanding of 26 'key features' of science and technology. The research arose from concerns about primary teachers' own understanding of science and technology concepts. This concern came from three sources;

- inspectors' reports
- research into children's learning and its implications for the knowledge and understanding needed by teachers
- research into teachers' perceptions of their own confidence and competence.

In all, 514 teachers responded to the questionnaire. The researchers found that having some science in their background that is a previous science qualification, made the

understanding of 'big ideas in science' by teachers more likely, but did not always guarantee it. The 'big ideas' came from both biological and physical sciences topics (Harlen et al. 1995 p 18 - 19). They also found that "the relative ease with which understanding of some 'big ideas' was developed by teachers suggested that there was latent understanding waiting to be awakened" (Harlen 1999, p 76). Although this did not apply to all of the ideas nor all of the teachers who participated in the project. Harlen et al. (1995) found that it was "sufficiently common to suggest that what holds back teachers' understanding is not ability to grasp ideas but the opportunity to discuss and develop them" (Harlen 1999, p 77). This has implications for teacher training programmes and INSET. Teachers may not need INSET to enhance their subject knowledge, but rather time to discuss and develop their ideas.

3.9 The types of knowledge teachers need in order to teach effectively

Teachers need a variety of knowledge types in order to teach effectively. Those identified by Shulman (1987) have been listed in section 3.1. Other writers have examined this area. Grossman, Wilson and Shulman (1989), looking at secondary teachers, describe the different types of knowledge that a teacher must have;

1) Content knowledge - which they use to refer to "the stuff of a discipline: factual information, organising principles, central concepts". For example a person who possesses content knowledge of biology "knows about RNA and DNA, theories of evolution and heredity, about ecosystems and nervous systems" they can "identify, define and discuss these concepts separately" and "identify relationships among concepts external to the discipline". So, content knowledge of ecosystems "involves understanding interrelations of trophic levels, energy flow, habitats, populations and niches".

2) Substantive knowledge - this includes the explanatory frameworks or paradigms that are used both to guide inquiry in the field and to make sense of data, (Schwab 1978).

3) Syntactic knowledge - this is knowledge of the "canons of evidence that are used by members of the disciplinary community to guide inquiry in the field. They are the means by which new knowledge is introduced and accepted into that community"

A teacher may have a high content knowledge, but know little of how the content of the subject has been constructed, and how to challenge it. Teachers who lack substantive knowledge and syntactic knowledge may be hampered by their ability to grasp new information in their field.
Primary teachers who do not know how science facts / theories are developed will not be able to guide their pupils' investigations effectively. Thus, syntactic knowledge may impact on pedagogy.

Morrison (1989) argued that other kinds of knowledge, other than subject knowledge were important for effective teaching, for example,

- knowing about children and how they learn,
- teaching strategies and
- communication.

Morrison supports the view of Calderhead and Miller (1985), who give an example of how a teacher uses different aspects of knowledge to teach about clouds. The teacher, they say, tailors his knowledge of the content to the context in which he is currently teaching, that is the teacher integrates his knowledge and understanding of clouds, with the pupils' needs and interests. This implies a grasp of the factors identified by Morrison which are listed above.

That primary teachers do need science subject knowledge and understanding is clear. Of particular importance is knowledge of how different areas of science are constructed and how science areas and ideas are interconnected. Subject matter knowledge and understanding must, however, go hand in hand with a sound grasp of the other aspects of teacher knowledge that is substantive and syntactic knowledge. The primary teacher needs to know and understand some science subject matter. They must also know and understand how to teach primary science. A university-educated physicist is not necessarily best able to explain an echo to Key Stage One pupils. The teacher's belief about his role, his personal subject knowledge and understanding, and subject specific pedagogy will determine his interactions with his pupils and therefore the effectiveness of his teaching.

The primary teacher, working with pupils who have little science to draw upon, must make connections with the pupils' experiences in school, at home and in both the real and imagined worlds. The effective primary teacher needs to know and understand how to make these connections. This does not necessarily result from having a high level of personal science knowledge and understanding, but in understanding how areas of science are related to one another (Khwaja 2001 p 50). The effective teacher must also be able to select teaching methods appropriate for the pupils in his class. As Askew et al. (1997), reported

> while a teacher may have a sound understanding of a mathematical idea, suitable teaching *approaches* need to be used in order to make the idea accessible to pupils
>
> (p 20)

3.10 Factors affecting teacher effectiveness - a complex picture

The Council for Science Technology report, on supporting and developing the profession of science teaching in primary and secondary schools, 2000, identified eleven hallmarks of top quality science teaching. The report states that the personal attributes, knowledge, skills and competencies of teachers are critically important and influential in the level of attainment of pupils. The effectiveness of teachers, the report claims, stems from

> their attitude, their confidence, their knowledge of the subject and how to teach it (pedagogy).
>
> para 11, page 9

The report claimed that effective science teachers had good subject knowledge (both substantive and syntactic), they needed this to develop the subject related pedagogical knowledge, skills and competence to present science topics to children, in comprehensible and stimulating ways. These teachers, as Shulman (1987) agrees, are able to draw on the best possible analogies, examples, illustrations, explanations and demonstrations to develop each child's existing level of understanding.

The literature explored thus far shows that the picture of the factors affecting teacher effectiveness is a complex one, with many factors, other than teacher subject knowledge and understanding emerging as significant. These other factors include a teacher's;

1. attitude to the subject,
2. ability to select appropriate and enjoyable experiences for the pupils, although this has been linked to the teacher's own subject knowledge and understanding,
3. ability to connect one area of subject learning with others,
4. view of his role as a teacher and hence teaching style,
5. interactions with pupils in the lesson, this includes identifying misconceptions, giving appropriate explanations.
6. view of what science knowledge is and how it is constructed

The third point above does not necessarily imply more subject knowledge and understanding, but rather a different way of organising existing knowledge and understanding.

There is a need to "question the dominance of subject knowledge as a professional base for teaching" (Carré and Carter 1990). However, a teacher's subject knowledge and understanding can influence other aspects of effective teaching, see points 2,3 and 5 above. Whilst most science educators would agree that subject knowledge and understanding is one factor in determining teacher effectiveness, how important is it, as we have seen, is debatable.

3.12 Summary

Much of the literature on teacher effectiveness in science teaching focuses on the necessity to have 'good' subject knowledge and understanding. Shulman (1987) who has written extensively on the knowledge which teachers need to teach a subject, puts understanding of the subject matter at the top of his list as all his other areas of knowledge emanate from it. There is, however, no consensus about *how much* and *what* science knowledge and understanding is needed to constitute 'good'. There is also no consensus that the higher the level of teachers' qualifications in a subject, the more effective teachers of that subject they will be. Askew et al. (1997) looking at the effective teaching of numeracy, suggests that the most effective teachers are those who help pupils to make connections between one area of mathematics and another. The ability to identify these connections was not found to be related to the teacher's level of qualification in mathematics. Teachers require a variety of types of knowledge; subject knowledge is one of these types. It may not be the most important. In this research finding out how teachers engaged with science and what factors determined their engagement were central themes.

Chapter 4 reports on a pilot study carried out with a small group of trainee teachers, exploring the ways in which they engaged with science. These aspects of engagement were used to develop an observation tool, which was intended for use in the main study. Chapter 4 also reports on why using this tool was unsuccessful and why it was decided to develop an engagement schedule, using an iterative approach.

Chapter 4 Pilot Study of 'engagement with science'

4.1 Introduction

A pilot study was carried out to identify how trainee teachers engaged with science. The purpose of the pilot study was to develop an observation tool that could then be used to score science lessons observed during the main study. An observation tool was developed and it was used to record and score engagement with science in two lessons. However, scoring level of engagement became non viable and so the approach for the main study moved away from a quantitative approach to a more qualitative approach, where engagement with science would be described and charted over time, rather than scored and plotted over time.

4.2 Defining 'level of engagement' with science

By engagement with primary science, I mean, those words and actions by the teacher, which have the potential to involve the pupils in the learning of science. The focus of this research is the teacher, and what the teacher says and does, in order to engage the pupils with science. I have not attempted to measure or comment on the effectiveness of the teaching, by measuring the pupils' learning. While it would not be possible to say that particular teacher actions / words necessarily result in particular learning, a positive engagement with science is more likely to involve the pupils in the learning of science. Therefore, level of engagement with science has a relationship with teacher effectiveness.

From my experience of observing trainee teachers, I was aware that engagement was more than teacher talk, as gesture and the use of secondary sources convey meaning. For example, it would be very difficult to convey to a class the structure and function of the eye without the use of a labelled diagram. Several modes of communication are needed to convey meaning in science (Jones 2000). She lists the following modes used in secondary science classrooms, visual - graphical representations, mathematical equations, charts, tables, photographs, actions and speech. Thus the four areas of teacher engagement that I thought would be worthy of noting were language, gesture, display and models. Definitions and examples of these four areas are shown in table 4.1. The context for each of the areas of engagement must of course be science.

Table 4.1 The four areas of engagement

Area of engagement	Definition	Examples
Language	This includes informing, questioning, explaining, chanting, singing, instructing, telling, writing (on the board, worksheets).	• Teacher and pupils sing song "Heads, shoulders, knees and toes" to name the external parts of the human body. • The teacher writes the instructions for an investigation on the board.
Gesture	This includes nodding /shaking the head, smiling/laughing, demonstrating an action, talking with hands.	• The teacher shows pupils how to make a string telephone. • The teacher makes a squeezing motion with his/her hands to demonstrate peristalsis.
Display	This includes passive and interactive displays, books, and a science corner.	• A frieze showing the solar system. • A large jigsaw of the human skeleton for pupils to put together.
Models	These include artefacts (commercial, teacher /pupil made), drawings, diagrams, role play (teacher and/or pupils representing the real thing)	• Pupils act out the movement of the planets around the sun. • Teacher shows pupils a 3D model of the human heart.

4.3 Developing a means of observing and recording 'engagement'

In order to describe and measure level of engagement with science and to compare one lesson with another an observation schedule or tool was needed. The purpose of the observation tool was to list those aspects, positive and negative, that contributed to the engagement of science in primary science classrooms. The tool would then be used to 'score' aspects of engagement with science in the lessons observed. Thus the lessons taught by one teacher could be compared over time, the second research aim. Lessons taught by different teachers could also be compared one with another. I was aware at the time of other observation tools and ways of describing what is going on in classrooms, both in the primary

and secondary sectors. These included, 'Describing and classifying the language used by secondary teachers in a range of subjects, including science', (Barnes, Britton and Torbe 1990), 'Teacher effectiveness' (Flanders 1970), 'An observation schedule for secondary science', (Eggleston, Galton and Jones 1976) and 'The effectiveness of questioning in primary science classrooms', (Elstgeest 1985). As the research developed I became aware of further tools and ways of describing what is going on in science classrooms. For example how secondary science teachers explain concepts to pupils in (Ogborn, Kress, Martins and McGillicuddy 1996), teacher effectiveness in Askew et al (1997) and teaching styles and teacher effectiveness in (Murphy et al. (2001). However, I wanted my observation tool to be rooted in what I actually observed happening in the primary science classrooms that were part of my research. I wanted to include only those aspects of engagement that I had actually observed, rather than adopt an existing schedule, which may not include all of the aspects that I observed and may include some that I had not observed. I wished to focus on what was happening in the lessons that I observed, rather than on what was not happening. The aim was to develop an observation tool during the pilot study that could be used to observe and analyse science lessons observed for the main study. For the pilot study I used aspects of the observation tools developed by Flanders (1970), Boydell (1974), Eggleston et al. (1976) and Elstgeest (1985) to help me to describe engagement with science. Thus the tool that I developed was rooted in those developed by others.

The "level of engagement with science" suggests that this is something that can be quantified. I had originally thought that I would be able to identify all of those aspects, both positive and negative, that contributed to engagement with science, and that these observations could then be used to construct an observation tool. Science lessons could be observed and 'scored' using the tool, thus the tool could be used to measure the engagement with science in primary science classrooms, and the scores of two lessons compared.

4.4 Pilot study to observe and record 'engagement'

This section describes the design of the pilot study; the trainee teachers selected for observation and the science lessons that were observed.

4.4.1 The design of the pilot study

For the pilot study, I observed three final year BA trainee teachers and one Primary PGCE trainee teacher teaching science to pupils in both Key Stages 1 and 2. At the time I was the 'School Experience' tutor for these trainee teachers; that is, I observed them teaching across the whole primary curriculum and was responsible, with the class teachers for the trainee teachers' summative School Experience assessment. For the pilot study, I made an additional visit to each of the trainee teachers in order to observe a science lesson. The trainee teachers knew that I was observing these additional lessons as part of my research and all agreed to be observed. At the end of the lessons I gave the trainee teachers feedback on their lessons as I would if observing them at any other time. The trainee teachers were assured that for these additional science lessons, I would only record positive aspects of their teaching for assessment purposes. All names are pseudonyms, in the lesson extracts, only the initial is used. The pupils are referred to as ch1, ch2 and so forth. W/C refers to all pupils, this could mean all of the pupils in the small group being taught, or to the whole class. The context is clear in the transcripts extracts.

4.4.2 The trainee teachers

Three of the four trainee teachers were in the final year of their BA Primary Education programme. In their final year, the trainee teachers were able to select the Key Stage for their School Experience. One of the trainee teachers Denise taught a Key Stage Two. Sarah and Carrie both taught Key Stage One classes. The PGCE trainee teacher, Bella, taught a Key Stage Two class. This was Bella's first School Experience. It was my intention to make PGCE trainee teachers the focus of the main study, these trainee teachers only teach in Key Stage 2 classes. However, for the pilot study I observed trainee teachers for whom I was the School Experience tutor, that is, those I would have been observing teach anyway. Thus, I observed trainees in Key Stage One classes. I was concerned that a one off visit to other trainees in Key Stage Two classes might be disruptive as they and their classes would not be used to me observing them. Also my time was very limited.

4.4.3 How the lessons were observed

I observed the four trainee teachers teaching science and noted what they said to the pupils. During the lessons, I sat at the back of the classroom and made notes as I observed. The only difference with this and my usual *modus operandi* when observing lessons as a School Experience tutor was that I did not interact with the pupils. This absence of interaction enabled me to focus fully on what the trainee teacher was saying to the pupils. The lesson in terms of time and character was determined by the trainee teacher, that is the length of the lessons observed was not uniform, two of the trainee teachers taught small groups of pupils and two taught the whole class. At this stage in the research my focus was on what the trainee teachers said (language element section 4.1). I recorded everything that the trainee teachers said to the pupils concerning the science aspects of the lesson. In the two lessons where the trainee teachers taught small groups of pupils, I did not record what the trainees said to the other groups of pupils, as these pupils were not doing science- based activities. I had thought about tape recording the lessons, as I was not sure how much of the lesson I could actually record by hand. However, I was also aware that introducing a tape recorder or indeed a video camera could interfere with the usual running of the class. By observing in my usual way, I thought that this interference would be minimised. Also, the trainee teachers were not keen to be taped, and one of the schools said that they would not allow any taping of the pupils. Although I had only intended to make notes on what the teacher and pupils said, I also noted other significant aspects of engagement, (the four areas of engagement table 4.1). I did not have any pre observation criteria for deciding what was significant, but simply recorded that which seemed to be significant to me at the time, for example (from Sarah's lesson);

S " Who can tell me what a push is"
ch1 " A push is when you push something like this" *pupil gestures pushing with hands*
S " Yes, we push things to make them move" *teacher gestures pushing with hands*

Here Sarah's and the pupil's gestures demonstrating pushing are significant. The gestures help the other pupils to match the concept with the word.

Within a few days of the lesson, I sent the trainee teachers a transcript of their lessons. The trainee teachers were asked to read the transcript and indicate whether or not they thought that this represented a true account of their lessons. In all cases the trainee teachers said that the accounts were accurate.

4.4.4 The lessons

The following are brief descriptions of the four lessons observed.

Sarah was teaching a year two class (pupils aged 6 -7 years); the science topic was Forces. Sarah was working with the whole class. The words PUSH and PULL were already written on the board. Sarah discussed what pushes and pulls were with the group, she showed them how to measure how much they could pull using a 'forcemeter' and how much they could push using bathroom scales. The pupils drew a picture of the forcemeter and wrote how much they could pull it. They then drew pictures showing a person pushing or pulling something. None of the pupils had completed the second picture.

Carrie was teaching pupils aged 6-7 years, about Electricity. Carrie also worked with a small group of three pupils. Of these three pupils, two had difficulties reading and writing in English, and one had behavioural problems. The rest of the class did literacy work, supervised by their class teacher. The science group was using a battery, a bulb and two wires to make a simple circuit. Once they were all able to do this Carrie left them to try to make circuits using more than one battery or more than one bulb. At the end of the lesson, the science group demonstrated how to make a simple circuit to the rest of the class.

Bella was teaching a year one class (pupils aged 7 - 8 years); the science topic was Materials. Bella taught a group of six pupils science, whilst the rest of the class did non-science related activities. Bella discussed what soft, hard, rough, bumpy and smooth meant with the science group. The pupils were then left on their own to classify a range of materials according to

gross observable features for example rough, smooth, hard and spongy. They then recorded their findings on worksheets. At the end of the lesson, Bella returned to the science group to check their work.

Denise was teaching a class of 8-9 year olds about Temperature. Denise explained what a thermometer was and showed the pupils how to use one. The pupils were then asked to investigate "how to make the temperature rise". Towards the end of the lesson, the pupils were asked how they made the temperature rise. Denise planned to complete the lesson later in the week.

4.4.5 Finding 'aspects' of engagement in four classes

The four lesson transcripts were used to identify aspects of engagement. They were read through as soon as the observation visit was over. The transcripts were word processed or handwritten in neat, to make them legible. The following extracts from Denise's lesson, show the first record (done during the lesson), and the word -processed version (done later on the day of the observation).

Figure 4.1 A sample of notes taken during a lesson

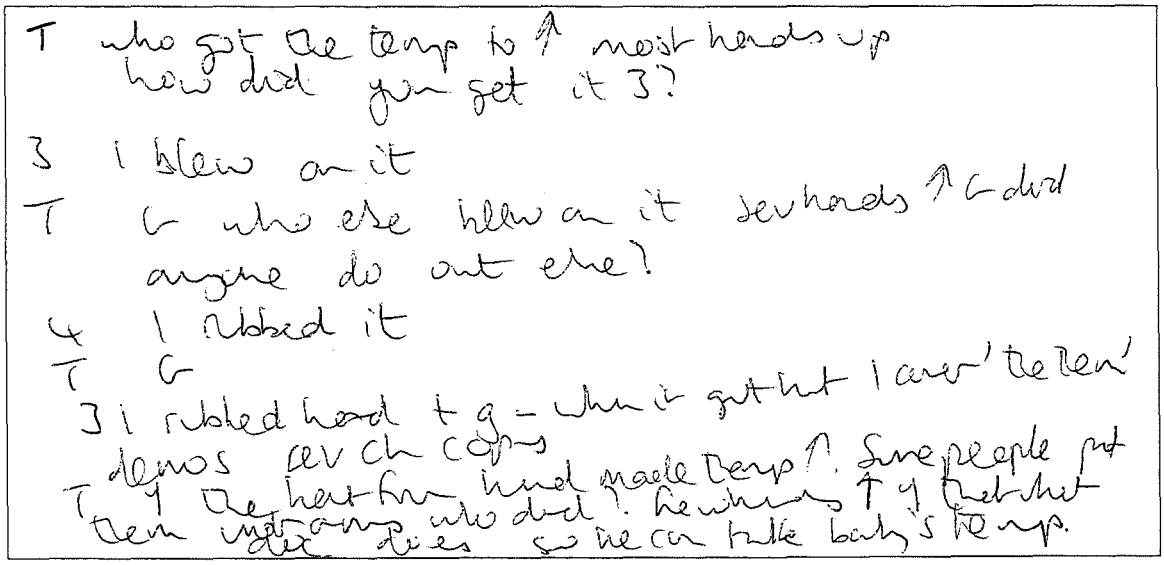

Figure 4.2 Rewrite of the lesson, done soon after the lesson observation

D "Who got the temperature to rise?" *most hands go up* "How did you do it ch3?"
Ch3 "I blew on it"
D "Good, who else blew on it?" *several hands up Good*, "did anyone do anything else? ch4 what did you do?
Ch4 " I rubbed it"
D "Good"
Ch7 "I rubbed my hands together and when they got hot, I covered the thermometer"*ch7 Demonstrates this, several ch copy him*
D "Yes, the heat from your hands made the temperature rise. Some people put thermometer Under their arms, who did?" *a few hands go up* " Yes, that's what the doctor does so that he can take the baby's temperature".

I read through the 'transcripts' of the lessons highlighting evidence of engagement with science, and describing in my own words what this engagement was. The following extract from Denise's lesson shows how this was done.

Figure 4.3 A lesson transcript extract, showing evidence of engagement with science

D "Who got the temperature to rise?" *most hands go up* "How did you do it ch3?"
Ch3 "I blew on it"
D "Good, who else blew on it?" *several hands up Good*, "did anyone do anything else? ch4 what did you do? asks ? what did you do
Ch4 " I rubbed it"
D "Good" affirms ch's response
Ch7 "I rubbed my hands together and when they got hot, I covered the thermometer"*ch7 Demonstrates this, several ch copy him* affirms, relates + gives information
D "Yes, the heat from your hands made the temperature rise. Some people put thermometer Under their arms, who did?" *a few hands go up* " Yes, that's what the doctor does so that he can take the baby's temperature".

I analysed all of the four lesson transcripts in the same way identifying aspects of engagement.

It was when I was reading the lesson transcripts that I became conscious of negative engagement with science, that is, the trainee teachers were engaging with science in ways

that were unlikely to lead to the pupils' increased knowledge and understanding of science. I was aware that I had been thinking of engagement with science as positive, that is, the trainee teachers would engage with science in ways that were likely to involve the pupils with science (Khwaja ,2001). Indeed, negative engagement with science might lead to further misconception. Thus, it was important to identify both positive and negative aspects of engagement with science. Table 4.2 shows the different aspects of engagement identified in the four lessons transcripts. Positive aspects are shown in plain text and negative aspects are shown in italics.

Table 4.2 Aspect of engagement with science in four lessons - a comparision

Aspect of engagement	**Denise**	**Sarah**	**Carrie**	**Bella**
1)Asks a factual question	*	*	*	
2)Affirms correct science answer	*	*		*
3)Affirms correct answer by restating it	*			
4)*Ignores pupil's answer*	*			
5)Gives 'new' information	*	*	*	*
6)Explains science task	*	*	*	*
7)Comments on pupils' work, science	*	*	*	*
8)Comments on pupils' work, not science	*			
9) Asks, "what will you do?"	*		*	
10) Asks, "what did you do?"	*	*		
11)Uses written word to support explanation	*			*
12)Uses written word to support understanding of concept		*		
13)Demonstrates concept with action	*	*		
14)Reviews previous learning	*	*		*
15) Asks, "what is happening?"		*		
16)Asks pupil to explain answer		*		*
17)*Asks a 'leading' question*			*	
18)Instructs				*
19)Explains task non-science	*	*		*
20) Asks, "can you find out?"	*			
21)Suggests answer to question posed			*	
22)Demonstrates correct answer with a model			*	

4.5 How 'aspects' of engagement were determined

The field notes from the four lessons were read and aspects of engagement were identified and described. I then used the ten -category system for coding all possible classroom interactions, developed by Flanders (1970) which he called Interaction Analysis Categories (FIAC) to refine my descriptions of engagement. The FIAC was organised into ten categories under three groupings, Teacher Talk, Pupil Talk and Silence. The categories were numbered 1-10, but there is no scale implied by the numbers 1-10, they are simply classificatory.

As the focus of my research was teacher led engagement with science, I did not include category 1, as it describes a social interaction between teacher and pupils, and does not describe engagement with a subject, in this case science. For category 9, my interest was the teacher response to pupils' questions. I did not record pupil- initiated conversations between pupils, which did not include the teacher.

In this section I will explain, with examples from the four science lessons, how the 22 aspects of engagement identified were described using the (Flanders 1970 p.34) categories. This is shown in the following two pages as table 4.3.

Table 4.3 How aspects of engagement were described using Flanders

Flanders Interaction Analysis Categories		**Aspect of engagement**	**Example from transcript**	**Explanatory notes**
Teacher Talk	1.Praises or encourages	7) Comments on pupils' work about science	S "What is he doing to the lead?" *ch10 has drawn a man taking a dog for a walk* ch10 "He has to pull it, cos the dog is getting away" S "Good"	Sarah acknowledges that the pupil's work is correct. This is very similar to (2), "Affirms correct science answer".
	2.Accepts or uses ideas of pupils	2) "Affirms correct science answer"	*D writes ^{O}F on board* D "What does this mean?" ch3 "Degrees Fahrenheit" D "Good"	The pupils know that ch3 has given the correct answer, this either confirms what they already knew or gives them new information.
		3) "Affirms correct science by restating it"	D "What do these numbers mean?" *D points to thermometer scale* ch5 "When it gets hot, the line *(coloured alcohol)* goes up to the higher numbers" D "That's right, the hotter it gets the higher up the blue liquid will move, so you can see how hot it is"	Denise is confirming that the pupil is correct, but she is adding to the pupil's explanation. By restating the pupil's answer Denise is emphasising how important it is.
	4. Asks questions	1) "Asks a factual question"	D "What is this?" *D holds up a thermometer*	The pupils either know the answer or they do not. The teacher expects only one answer.
		9) "Asks, What will you do?"	D "How are you going to make the Temperature rise?"	Here Denise is asking the pupil to say how they are thinking about answering the question posed in the investigation.
		10) "Asks, what did you do?"	D "Who got the temperature to rise? How did you do it?"	This is very similar to (9) but the difference is that here Denise is asking about something that has already happened. For this aspect, there could be an implication that only those pupils who have been successful in 'solving' the problem would answer.
		14) "Reviews previous learning"	S "What about pulling" ch5 "A train pulls coaches" S "What about when you went to the farm, did you see anything pulling and pushing?"	Here Sarah is reminding pupils of previous science learning. The class had visited a farm where examples of pushing and pulling were discussed.
		15) "Asks, What is happening?"	S "What have you drawn?" ch12 "A girl in the park" S "What is she doing?" ch12 "She is pushing the swing"	Here Sarah is asking the pupil to describe what they are doing; this could be the pupil's written work or practical activity.
		16) "Asks pupil to explain answer"	D "What can you see covering the bulb *(of the thermometer)*?" Ch1"A tiny metal cage" D "Why is the bulb *(of the thermometer)* covered in a Metal cage?" Ch1 "So it won't break"	Here Denise is asking a question that requires pupil understanding.
		17) "Asks a 'leading' question"	B "Can you find anything in the box that is smooth?" *ch2 takes out a stone* B "Is yours really smooth? It looks a bit rough to me. You feel it, doesn't it feel rough?" ch4 "Yes"	Here Bella is pointing the pupil towards the correct answer. It is not surprising that the pupil agrees with the teacher.
		20) "Asks, Can you find out?"	C "Now you try, with the other Batteries and bulbs, can you make two bulbs light up?"	Carrie poses a question that leads to an investigation. This links to (6) "Explains science task".

Teacher Talk	5.Lecturing	5) "Gives new science information"	S "Yes, we push things to make them move"	Here Sarah is 'telling' the pupils a science fact, that is, that pushes (forces) cause objects to move. This information may not be new to all of the pupils, but it has been presented as new.
		12) "Uses written word to support understanding of science concept"	*S has written PUSH and PULL on the board, she points to them when introducing the lesson.* S "Today we are going to do experiments to find out about pushing and pulling"	Here Sarah reinforces the concepts PUSH and PULL, by saying and writing them. This has links with (11) above; the teacher is using two modes, speech and the written word to give emphasis.
		13) "Demonstrates concept with action"	S "A push is when you push something like this" *S gestures a push with her hands*	Here Sarah is reinforcing the concept PUSH by showing the pupils the action of pushing. This is important for pupils for whom the word PUSH is new.
		22) "Demonstrates correct answer with an artefact"	*ch1 and C fix wires, battery and bulb to form a circuit to show to the class.*	Here Carrie explains what a circuit is, using an actual circuit. This links to (13) "Demonstrates concept with action.
	6.Giving directions	6) "Explains science task"	B "Now we are going to sort out all of the materials to find out which ones are smooth or rough or hard or soft, what you have to do is write your answers here on the sheet".	Here Bella is telling the pupils what the task is and explaining what the purpose of the task is.
		11) "Uses written word to support explanation of task"	*The pupils were given a worksheet to complete re the sorting materials task.*	Here Bella is using a worksheet to reinforce the explanation of the task, so this aspect relates to (6) "Explains science task".
		18) "Instructs"	B "Find something smooth"	Here Bella is simply telling the pupil what to do.
		21) "Suggests answer to question posed"	*C is helping ch1 to make a simple circuit. CH1 is thinking about where to attach a wire.* C " I think it might go here, try that" *ch1 does* C " Good, now what else?"	Here Carrie points the pupil towards the correct answer. It is not surprising that the pupil agrees with the teacher. This links strongly with (17) "Asks a leading question".
Silence		4) "Ignores pupil's science answer"	D "Why is the bulb in the metal cage?" *A metal cage protects the thermometer bulb.* ch4 "So it won't break" D "What is the blue liquid inside?"	Denise has ignored ch 4's response, so ch4 and the other pupils would not know if ch4 was correct or not. The reasons for Denise ignoring the pupil's answer are not clear from the transcript. It might have been that she simply did not hear the answer. She may have nodded or smiled assent, which I did not notice or she might have been more focussed on asking questions than listening to the answers.

Two aspects were not included in the observation tool, as their focus was not science. These aspects were (8) "Comments on pupils' work not about science" and (19) "Explains the task non-science". The example for (8) came from Denise's lesson, where the pupils drew thermometers;

D comments on pupils' drawings of a thermometer
D " Nice drawing"
D " That's really neat, well done"
D " That's not very neat is it? Rub that bit out"

Denise's comments are not clearly about the science aspect of the pupils' work. The comments are about the presentation of the drawings

The example for (19) came from Carrie's lesson;

C "Put the things back in the box
and leave your worksheets neatly on the table"

Here Carrie is giving the pupils a non-science task

For the purposes of my research the (Flanders 1970) instrument was limited. This instrument was developed to evaluate all possible classroom interactions. While it was useful in helping me to clarify what I had observed, it was too broad a brush to allow the detailed description of what was happening in primary science classrooms, that I wanted. For example, 'questions' category did not differentiate between different sorts of questions. So that "how many legs does a ladybird have?" has the same classification as "how can you make the sugar dissolve more quickly?" I was interested in the all the ways that teachers engaged with science and so needed to refine Flanders (1970) category on questions. To do this I looked at an observation schedule developed by Eggleston et al. (1976). This schedule was developed to be used in the evaluation of secondary science teaching methods, it was designed to code events as they happened in the classroom. A key feature for me of this schedule was that is allowed detailed records to be made of different kinds of questions. In my observation of the four trainee teachers I identified eight different types of questions.

In table 4.4, I show how the twenty two aspects of engagement that I identified in the four lessons could be coded using the (Eggleston et al. 1976) observation schedule.

Table 4.4 Describing aspects engagement using Eggleston et al (1976)

Eggleston et al observation tool descriptions of engagement with science			**Aspect of engagement identified in four lessons**
Teacher Talk	1a Teacher asks questions (or invites comments) which are answered by	a1 recalling facts and principles	1. Asks factual question
		a2 applying facts and principles	
		a3 making hypothesis or speculation	
		a4 designing of experimental procedure	9. Asks "what will you do" 10. Asks "what did you do?" 20. Asks "can you find out?"
		a5 direct observation	14. Reviews previous learning 15.Asks "what is happening?" 16. Asks pupil to explain answer
		a6 interpretation of observed or recorded data	
		a7 making inferences from observation or data	16. Asks pupil to explain answer
	1b Teacher makes statements	b1 of fact and principle	2.Affirms correct science answer 3.Affirms correct science by restating it 5.Gives new science information 7. Comments on pupils' work 12. Uses written word to support understanding of science concept 13. Demonstrates concept with action 17. Asks a leading question 21. Suggests answer to question posed 22. Demonstrates correct answer with an artefact
		b2 of problems	
		b3 of hypothesis or speculation	
		b4 of experimental procedure	6. Explains science task 11. Uses written word to support explanation of task 18. Instructs

Teacher Talk	1c Teacher directs pupils to sources of information for the purpose of	c1 acquiring or confirming facts or principles	
		c2 identifying or solving problems	
		c3 making inferences, formulating or testing hypotheses	
		c4 seeking guidance on experimental procedure	

Three of the aspects of engagement that I identified did not fit the Eggleston et al. tool. Two of these, aspect 8 "comments on pupils' work not about science" and aspect 19 "explains the task non-science" were for obvious reasons abandoned as descriptions of teacher engagement with science. The third, aspect 4"ignores pupil's science answer" did not fit into any the Eggleston et al. categories, but it was a significant aspect of teacher engagement with science. If using the (Flanders 1970) tool, this aspect would be coded under "silence", where the observer could not be sure if the teacher's ignoring of the pupil's answer was deliberate.

By using the Eggleston et al. tool, I could see how inadequate and sometimes misleading my own descriptions of teacher engagement were. For example, aspects which I had described as

"reviews previous learning" was in fact, the teacher reminding the pupil of an observation that s/he had made the previous day. I was interested to note the different ways in which the teachers made statements of fact or principle, which included, asking and responding to questions, demonstrations with actions and models, commenting on pupils' work and suggesting solutions to problems and of course, giving new science information.

Given that the Eggleston et al. tool was developed for secondary classrooms, I was not surprised to note that some aspects of teacher talk were not found in the four primary science lessons that I had observed. These included making and testing hypotheses and speculations and the teacher directing pupils to sources of information, as the primary lessons all involved more first hand experiences.

I was surprised that there were no examples for the 'Talk and activity initiated and /or maintained by pupils' section, as I would have expected that the pupils would ask the teachers questions for the purpose of seeking information and guidance. I have not included

this section in Table 4.4. as there were no examples from the lesson observations. However, as my focus was on the teacher, it is possible that I missed interactions between the teacher and pupils, which were pupil initiated.

In order to explore teachers' questions further, I looked at the descriptions by Elstgeest (1985). Here Elstgeest describes six types of questions that primary science teachers ask. In Table 4.5, I show how the eight types of question that I identified in the four lessons fit the Elstgeest classification.

Table 4.5 Using the Elstgeest classification of types of question to describe aspects of engagement in four lessons

Elstgeest classification of questions	**Explanatory note and examples**	**Question types identified in the four primary science lessons**
Attention-focusing questions	These questions focus the pupil's attention, by asking them to observe and describe, for example "have you seen?", "what is it?", "what happens?".	1. Asks a factual question 14. Reviews previous learning 15. Asks "what is happening?" 16. Asks pupil to explain answer
Measuring and counting questions	These questions ask children to count how many or measure - these have a quantitative aspect, for example "how many?", "how long?".	
Comparison questions	These questions are more qualitative, for example "how are these seeds the same?",	
Action questions	These require the pupil to carry simple experimentation, for example "what happens if?"	
Problem-posing questions	These questions pose real problems for pupils to solve, for example "can you find a way to?"	9. Asks "what will you do? 10. Asks "what did you do?" 20. Asks "can you find out"
Reasoning questions	These questions require pupils to explain their responses or an observed phenomenon, for example "why do you think?"	16. Asks pupil to explain answer

Two of the questions did not fit the Elgstgeest classification. The first, aspect 4 " ignores pupil's science answer" seemed to be a new aspect, as it has not been adequately described by Flanders either. In the second, aspect 17 "asks a leading question", Bella posed a two part question

> " Is yours really smooth? It looks a bit rough to me. You feel it, doesn't it feel rough?"

Here Bella suggests the 'correct' answer in the second part of the question. This aspect is better classified under the Flanders category "teacher make statement of fact or principle", because although Bella asks a question, she using this engagement to make a statement about the material.

Aspect 16"Asks pupil to explain answer" fits two of Elstgeest's classes of question. I coded this as one interaction, where in fact Denise has asked two questions.

> D "What can you see covering the bulb?" (*of the thermometer*) - 1
> ch 1 "A tiny metal cage"
> D "Why is the bulb covered with a metal cage?" - 2
> ch1 "So it won't break"

The first question (1) is an attention- focusing question, the second (2) is a reasoning question.

4.6 How aspects of engagement were developed into observation tool A

The aspects of engagement with science described in table 4.3 were collapsed into a shorter list to form observation tool A. This was done by combining two or more of the original aspects 1 - 22 if they were similar to make a 'new' aspect. The new descriptions for engagement came from the Eggleston et al. (1970) and Elstgeest (1985) descriptions of engagement with science. Table 4.4 shows the descriptions of the new aspects, and which of the original aspects were combined to form them. Negative engagement with science is shown in italics.

Table 4.6 How aspects of engagement with science from table 4.3 were combined to be redefined - Observation Tool A

Aspect of engagement with science		**Aspect from four science lessons**
A. Teacher gives factual information		2,3,5,7,12,13,17,21,22
B. Teacher explains the task		6,11,18
C. Teacher ignores pupil's science answer		19
D. Teacher asks Questions that	Demand factual recall	1
	Require observation	14,15,16
	Demand inference/reasoning	16
	Demand description of how to solve a problem	9,10,20

Aspect (8) and (19) from table 4.3 were not included in the new descriptions of engagement in table 4.6. Both aspects (8) "Comments on pupil's work not about science" and (19) "Explains task non science", do not constitute an aspect of engagement with science and so have been excluded.

4.7 Trial of Observation Tool A

The purpose of Observation Tool A was that it would be used to score the lessons observed for the main study. It was necessary to trial the tool before using it in the main study, to see if it could be used successfully. I therefore observed two further science lessons and used Observation Tool A to note aspects of engagement as they were observed.

4.7.1 Design of the trial of Observation Tool A

I observed two third year BA Primary Education trainee teachers, Naomi and Agnes, teaching science. Both were teaching magnetism to year four classes (pupils aged 8-9 years) in the same school. I was the School Experience tutor for both trainee teachers. As with the four previous trainee teachers, Naomi and Agnes knew that they were being observed for my research and agreed to this. At the end of the lesson I gave them feedback on their lessons, but I did not keep a record of it. The class teachers always planned together so that the

pupils had the same experience, so the trainee teachers also planned together. The pupils were asked to design and carry out experiments to find out which magnet (from a set of three different ones) was strongest. Both classes had pupils from across the whole ability range.

I asked Naomi and Agnes to tell the pupils not to speak to me during the lesson, as I was aware that if I was distracted I might miss an aspect of engagement. During the lessons I sat at the back of the room listening to what the trainee teachers said and observing what they did. I used Observation Tool A to record any aspects of engagement that I identified during the lessons. I did not record the lessons, so there were no transcripts. The purpose of Observation Tool A, was that I should be able to record aspects of engagement observed during the lessons. As with the previous lesson observations, I did not interact with any of the pupils and they ignored me.

4.7.2 Results from and evaluation of using Observation Tool A

From the results of the observation it would appear that the level of engagement with science was 'higher' in Naomi's lesson, that is, she had covered more aspects of engagement, see table 4.7. below. Each positive aspect of engagement with science was scored as +1, each negative aspects of engagement with science was scored - 1. Thus Naomi scored 6 and Agnes scored 3.

Table 4.7 Using Observation Tool A to compare two lessons

Aspect of engagement with science		Observed engagement	
		Naomi	Agnes
A. Teacher gives factual information		+1	+1
B. Teacher explains the task		+1	+1
C. Teacher ignores pupil's science answer			-1
D. Teacher asks Questions that	Demand factual recall	+1	
	Require observation	+1	+1
	Demand inference/reasoning	+1	
	Demand description of how to solve a problem	+1	+1

Before I could use this scoring, I had to decide whether it was valid, and if so, whether it was reliable. It was in fact becoming apparent that Observation Tool A, table 4.6 was not satisfactory, the reasons for this were that:-

i) The trainee teachers were engaging with science in ways that were not on Observation Tool A, so for each observation I was adding new aspects to the tool. These aspects were

a) "tells pupils why they are doing the task" (*we are going to find out which magnet is the strongest)*
b) "ignores pupil's question" *(how does the magnet do that - pick up paper clips)*
c) "ask, can we say that....?" *(the more paper clips the magnets picks up the stronger it is)*
d) How many.....? *(paper clips does the magnet pick up)*
e) Which is.....? *(is the strongest magnet)*

It is not possible to quote from the lessons, as no transcripts were written, the aspects were simply noted onto Observation Tool A as they were observed during the lessons, with brief explanatory notes (see italics above).

ii) It was sometimes difficult to decide what aspect was being covered. I had to think about what I was observing rather than simply observing it. As can be seen in section 4.5 above, even with a lesson transcript, it is possible to miscode an incident.

iii) Scoring the lessons was problematic. I had to decide whether or not to score an aspect of science if it was noted more than once. This would mean that a teacher, who asked a series of factual questions and affirmed correct answers, could be said to have engaged more with science than the teacher who covered a wider range of aspects of engagement. Also I had to decide whether or not every positive aspect of engagement was equally positive and that every negative aspect of engagement was equally negative.

My original intention in using a tool was to score the level of engagement with science. However, I was aware that Naomi asked more factual questions than Agnes. Agnes interacted with all of the pupils in her class, asking them what they were doing and why they were doing it. Naomi interacted with far fewer pupils. Naomi and Agnes were teaching the same topic and doing the same activities, with year 3 pupils. Naomi engaged *more* with

science than Agnes did, but Agnes engaged *more* with the pupils than Naomi did. Observation tool A did not show this difference and so I decided not to use it for the main study, for the following reasons:

i) Observation Tool A did not include all of the aspects of engagement identified in Agnes's and Naomi's lessons. Three 'new' aspects of engagement were identified during the trial of Tool A. It was therefore likely that more new aspects would be identified during the main study.

ii) In order not to miss anything, it was important that the lesson was recorded fully. It would be easier to read through a transcript and identify aspects of engagement at 'leisure' (as I had done for Denise, Carrie, Sarah and Bella), rather than attempt to decide what aspect was being met during the actual lesson. This links to (i) above, in that it would be difficult to decide if I had identified a new aspect of engagement during the lesson and attempt to define and describe it, whilst observing the lesson. Also, I could look back on previous transcripts to check if a 'new' aspect of engagement identified later, had not in fact occurred earlier.

4.8 Redesigning the research moving away from a quantitative approach

As already indicated measuring the level of engagement quantitatively, became non-viable. This section explains why that shift occurred. One of the original aims of the research was 'to see if and how the level of engagement with science in primary lessons varied over time'. This aim was eventually modified to become 'to see if and how the pattern of engagement with science in primary lessons varied over time'.

I thought that it would be possible to score lessons for engagement with science and thus enable comparisons between lessons to be made. Also I thought that it would be possible to plot the level of engagement with science against time, to see if there was an increase. I had hypothesised that with teaching experience trainee teachers would engage more with science. It would have been possible to show this quantitatively if lessons could be scored for engagement.

I had intended to use evidence from the post observation interviews in the main study to compile a list of factors that contributed to a high level of engagement with science. These factors could then be promoted as a list of desirable factors that would be of interest to those involved with primary science.

4.9 From observation tool to engagement schedule

The shift from *using* an *observation tool* to *developing and using* what I have called an *engagement schedule* accompanied the shift from measuring the level of engagement quantitatively to charting the pattern of engagement qualitatively. For the main study, therefore a single fixed observation tool was would not used to identify engagement. Instead an engagement schedule was developed throughout the period of the main study. As new aspects of engagement were identified these were added to the schedule. The schedule was used to chart each of the main study's participants' patterns of engagement with science over the period of the main study. The patterns of engagement would also have a quantitative element, in that the number of the participant's engagement with the various aspects of engagement with science would be noted. The participants' patterns of engagement would not only show how they engaged with science in terms of what aspects of engagement they were involved with, but how many times that aspect was engaged with. Flanders (1970) used a similar approach to show an example of a lesson in which, 54.2% of the interaction were in category 5, *Lecturing* and just 6.7% were in category 6, *Giving directions*.

4.10 Summary

Engagement with science comprises those words and actions, which have the potential to involve the pupils in learning science. Engagement with science constitutes more than just what a teacher says, so any description of engagement should not simply refer to the spoken word. Engagement with science includes teachers giving information, explaining, asking and answering questions, using first hand experience and secondary sources. In observing lessons in order to describe that nature of engagement, I found it necessary to develop the concept further by identifying negative engagement as well as positive engagement.

There was no 'ready made' measure of engagement with science in primary classrooms that I could find in the literature. This had to be developed as an intrinsic part of the research, from observations of science lessons. The definitions of engagement would be rooted in the theoretical frameworks of other researchers.

A pilot study to develop an observation tool was carried out. This was the start of a method of analysis of the data from lesson observations. Aspects of positive and negative engagement with science identified were elaborate using extracts from the lesson transcripts.

The observation tool was used to 'score' two further science lessons. However, it was soon clear that the observation tool did not list all of the aspects of engagement identified in the two lessons. Problems of placing a value on aspects of engagements were identified. This meant that measuring level of engagement became non-viable, so did the possibility of conducting a quasi experiment, where level of engagement could be plotted against teaching experience (time).

Thus there was a shift from a quantitative study to a qualitative one, where an attempt to *measure* level of engagement with science was replaced with finding ways of *describing* different teachers' patterns of engagement with science. It was therefore decided that rather than develop an observation tool to be used for the main study, the development of an engagement schedule that would be used to chart the pattern of engagement of teachers would become a part of the main study.

The aim of the research at the end of the pilot study moved towards, seeking changes in patterns of engagement over time for the ten participants.

Chapter 5, the methods chapter, reports on the three-year longitudinal study, which identified the patterns of engagement with science, for the ten participants. This chapter describes how the participants were selected, along with the dilemmas that I faced as a researcher, who was also the participants' tutor. The decision to report the findings of the main study as case studies of the ten participants is explained. Chapter 5 also explains the iterative approach adopted for the main study.

Chapter 5 The main study - a longitudinal study over three years

5.1 Introduction- research questions redefined

Following the pilot study the research questions were redefined. The intention to measure level of engagement with science was abandoned and the decision was made to describe the pattern of engagement instead. The trial of the observation tool developed during the pilot study showed that the use of the observation tool was not viable, as further aspects of engagement not listed in the observation tool, were identified in the two trial lessons. Thus the development of an engagement schedule that would both identify aspects of engagement with science and be used to analyse lessons for evidence of engagement with science became a major feature of the main study. The purpose of the engagement schedule was to identify all aspects of engagement with science over the three years of the main study, so the engagement schedule had to be developed using an iterative approach. I decided to explore the factors that contribute to teachers' patterns of engagement with science is a more general way, rather than focus on 'confidence'. Thus the original research questions, see section 2.4, were changed to

1. How does the pattern of engagement of new teachers with the content of primary science develop over their first three years of teaching?
2. What factors contribute to the teachers' patterns of engagement with science?

These revised research questions led to the following revised aims:

1. to explore, describe and define engagement with science
2. to develop an engagement schedule that be used to describe engagement with science and to chart a teacher's pattern of engagement with science
3. to see if and how the pattern of engagement with science in primary science lessons varied over time
4. to identify the factors that affect teacher engagement with science
5. to identify the participants in terms of the teacher types described in Chapter 3.

I wanted to tell the 'stories' of the first three years in the teaching life of the participants. There was no other way that I could tell these stories, other than by writing them as case studies. By describing in detail what was happening in primary science classrooms and questioning the participants to begin to find out why it was happening, I hoped to tell stories of the participants that other readers could relate to when thinking about their own experiences.

In this chapter, I define case study approaches, explain why I chose it and how my research meets its requirements. I also explain the iterative approach that I used to develop the engagement schedule.

5.2 The case study approach

In this section I define the case study approach, explain the rationale for its use and how this research meets its requirements.

5.2.1 Why I chose the case study approach

I chose the case study approach, because I wanted to tell the stories of the development of primary science teachers from their training year to their first few years of teaching. I wanted to describe who the participants were, their thoughts about the role of science in primary schools, their engagement with science and their reason for their engagement with science. I did not believe that it would be possible to tell these stories using any other research methods. I chose to write separate case studies on each of the participants, but also looked at the group as a whole, in order to identify any common trends.

The aim of case studies is to

> probe deeply and to analyse intensively the multifarious phenomena that constitute the life cycle of the unit with a view to establishing generalisations about the wider population to which that unit belongs
>
> Cohen and Manion (1994) p.106 - 107

The participants had different science backgrounds, different feelings about teaching science, and they taught in different schools. This gave the opportunity to tell ten very different stories, which might resonate with the wider population.

5.2.2 Defining the case study approach and showing how this research meets its requirements

Robson (1995) defines the term case study as

> "a strategy for doing research that involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence"
>
> (Robson 1995, p5)

In this research the contemporary phenomenon is *teacher engagement with science*, the real life context is *primary science classrooms* and the multiple sources of evidence are *questionnaires, lesson observations, interviews* and *the analysis of lesson transcripts.*

Case studies can produce both quantitative and qualitative data. The qualitative data for this research came from the lesson observations, where patterns of engagement were described and from interviews with the participants, which were used to help explain the pattern of engagement. The quantitative data came from plotting how many incidents of engagement with science identified for each participant over the three years of the main study.

A case study is the preferred method when examining contemporary events, when the researcher cannot manipulate the behaviours. These behaviours are numerous, see section 4.9, and include the participants' own subject knowledge and understanding, teaching style, the science topic taught and the participants' confidence to teach science.

The central idea of Yin's (1981,1989) approach to case studies is that each case is studied in its own right, not as a sample from a population. In this research there are ten case studies that is, the ten participants. The ten participants were selected so that there was a mixture in terms of gender, confidence to teach science and pre course qualifications. A range of participants was selected so that a variety of readers could identify with the variety of *participants.* There was no intention that the participants represented any particular type or group. The idea that aspects of a category of teachers' practice, *engagement with science*, can be observed across teachers *participants* in different settings *primary classrooms* fits with a case study approach to data collection, Murphy et al. (2001).

A drawback of the case study approach is that it may not be possible to generalise from the case studies. The case studies cover ten teachers in different primary schools, teaching different topics to different aged pupils. However, the findings in one case study can be applied to interpret another study in similar situations, in what Stake (1995), cited in Murphy et al. (2001) called *naturalistic generalisation*. As with the Murphy et al. (2001) research project, my research is also exploratory in nature and has a complex phenomenon to capture, namely, engagement with science, a case study approach was the most suitable approach.

The participants' practice, as we shall see in Chapter 7, was not independent of the contexts in which they worked. The age of the pupils and the participants' feelings of well being in their schools affected their patterns of engagement. It is generally accepted that in case study research that rich, 'thick' descriptions of phenomena are necessary, Murphy et al. (2001). In my research, I observed a number of participants over a period of three years, in which I looked at engagement with science in depth.

5.3 An iterative approach

An iterative approach was the second method used for this research. Here the rationale for it is explained.

5.3.1 Why I chose an iterative approach

An iterative approach allows a description to emerge from the phenomenon being studied, in this case engagement with primary science. The Engagement Schedule could only be developed using an iterative approach. This approach is different grounded theory, as I will explain.

Glaser and Strauss first introduced grounded theory in 1967. Later, Strauss and Corbin (1990) outlined what grounded theory is, its procedures, canons and how grounded theory should be evaluated. They describe it as a

> qualitative research method that uses a systematic set of procedures to develop an inductively derived grounded theory about a phenomenon. The purpose of grounded theory method is, of course, to build theory that is faithful to and illuminates the area under study
>
> (Strauss and Corbin 1990, p 24)

It is important to emphasise that I was not attempting to generate a theory for explaining why teachers engaged with science in the ways that they did. I was attempting to provide some insight as to how the pattern of engagement is different for different teachers and why this might be. However, the iterative approach that I have used, does have some similarities with the grounded theory approach.

Grounded theory has two principles. The first principle applies to change, since the phenomena are not static, but are continually changing in response to evolving conditions. In this research the phenomena engagement with science was expected to change over time, as the participants gained teaching experience. An important part of the grounded theory method is to build change, through process, into the method. Aspects of engagement with science identified on each School Experience were added to the engagement schedule, which was then used to analyse what was happening in the lessons.

The second principle applies to the participants having the means of controlling their destinies. That is, the participants were able to make choices about the options they encountered for example how to teach and how to manage pupil behaviour. The participants could choose to improve their subject knowledge and understanding of the topics they taught

by reading. They could choose how to make the best use of the resources available to them. They could not however, choose what science topics and age groups they taught. Although the participants were not consciously determining their patterns of engagement with science, the choices that they made helped determine these patterns.

In order to describe how the participants engaged with science and to explain their patterns of engagement, it was necessary to collect any data that would shed light on the research questions. In this research the sources of data were questionnaires, lesson observations and interviews.

It is important that for the engagement schedule to be accepted as reliable, that its development is explicit and shown to be grounded in the lesson observations. Chapter 6 charts the development of the engagement schedule over the three years of the main study.

Coding was the fundamental analytical process used in the development of the engagement schedule. The three basic types of coding open, axial and selective, used in the grounded theory approach, were all considered in the development of the engagement schedule, using an iterative approach. The three types are explained below. References to my own research are shown in italics.

A) Open coding

Open coding is the process of interpreting the data analytically. Its purpose is to give the researcher new insights by breaking through standard ways of thinking about the data. Wicker (1985) talks about the analyst "breaking out of conceptual ruts". Events, incidents and interactions are compared to others for similarities and differences; these are then given conceptual labels. Once identified, concepts (which can be formed to make categories) become the basis for sampling on theoretical grounds. *I analysed the lesson transcripts by interpreting what I had observed. I did not analyse the data using an existing observational tool, as I did not want to be constrained by another researcher's ways of interpreting the data. However, the scrutiny of my data by others meant that their interpretation inevitably influenced mine.*

B) Axial coding

In axial coding categories are related to their sub categories and the relationships tested against the data. *All of the categories of engagement were related to aspects of engagement.* As soon as the researcher identifies a category, the data should be scrutinised to determine the conditions that gave rise to it, the context in which it occurred, the action/interaction through which it occurred and its consequences. *Once I had identified the aspect 'teacher avoids pupils' questions', I found out, by interviewing the participant, why the pupils' questions had been avoided.* Alternatively the researcher must collect and analyse data, because the analysis focuses the next batch of observations and interviews. A hypothesis can only be verified or discarded if indicated by the data repeatedly. *As previously said I did not intend to discard any data, even if it only occurred once.*

C) Selective coding

In selective coding all categories are unified around a core category. The core category represents the central phenomenon of the study. Poorly developed categories are most likely to be identified during selective coding. A poorly developed category is one that has few examples and so may be discarded. *I did not use selective coding for this research. In this research the core category would be 'engagement with science'. In the event I choose six categories, for example, 'The Teacher Asks Questions' each made up of several aspects of engagement. Each of the aspects of engagement was made up of several incidents of engagement; thus each category was very well developed. A less well- developed category would not be abandoned, as I wanted the engagement schedule to represent all aspects of engagement identified during the research.*

5.4 Practical considerations for planning the main study

In planning the main study the following decisions had to be made: -

- how to select the participants
- when to observe
- how to observe and record the lessons

- what questions to ask the participants post observation
- how to verify what had been observed
- how to identify engagement with science
- how to chart pattern of engagement with science

In this section, I will describe how each of these decisions was made.

5.4.1 Selecting the participants

Ten PGCE trainee teachers were selected and observed teaching science twice a year for three years, their training year and the two succeeding years. It was decided with my supervisor that ten participants would be a manageable group size for a lone researcher. If a couple dropped out, the group size would still be viable. These participants were interviewed after each lesson observed and their written science schemes and lessons plans, where available, viewed.

A Primary PGCE group was chosen, as opposed to a BA Primary Education group, because of the length of the course, that is, one year. This meant that the participants would be in their second year of teaching by the end of the observation period, thus enabling me to investigate the range of support available to newly qualified teachers and teachers in their second year. Primary PGCE trainees are graduates, so there was a possibility that some would have a degree in science. I taught science to all of the PGCE trainees and so had a greater opportunity to develop a rapport with them, which I felt would enable me to maintain their interest and participation in the research when they were no longer trainee teachers.

In September 1995, I had a meeting with all but one, of the PGCE trainee teachers. The absent trainee was observing a religious holiday. I met with this trainee separately to discuss the research. This trainee was not subsequently selected to be in the main study, as she was not planning to teach in London after qualification. In the meeting with the group I briefly outlined the purpose of my research. I told the trainees that I wanted to follow a group of ten of them throughout their training and for two years after qualification, to see how the way in which they taught science changed over time.

The trainees were given a questionnaire (Appendix 4.1), to complete individually within the session. I decided to use a questionnaire rather than interview the trainees for the following reasons: -

a) Economy of time. The questionnaire took about forty minutes to complete, so it would have taken at least twelve hours to complete a set of interviews instead. This time would have to be fitted around the trainees' course commitments, which would have proved difficult. I was keen that participation in the research would not seem onerous to the trainees.

b) I wanted the trainees to have time to think about their responses and thus give a considered response. If I had interviewed the trainees they might have given brief responses, as I did know them and they may have found being interviewed rather intimidating.

c) Tuckman (1972) cited in Cohen and Manion (1994), states that questionnaires have a poor return rate, but as the trainees completed them in the session, this was not a problem.

d) The questions I wanted to ask were relatively straightforward and unlikely to require follow up questions.

The purpose of the questionnaire was to find out: -

i) The trainees' preferred subjects from a given list. The list reflected those aspects of the curriculum that are commonly taught at primary level, namely, English, mathematics, science, design technology, information technology, physical education, religious education, history, geography, art and music being National Curriculum subjects. Dance and drama, although not separate subjects at primary level, are both commonly taught in primary schools.

ii) The trainees' feelings about teaching science.

iii) The trainees' confidence to teach science, compared to the other subjects, (see the subject listed in point (i) above).

iv) The trainees' recollections of school science.

v) The trainees' attitude towards science as a core subject, that is, did the trainees think that it ought to be a core subject and why?

vi) The trainees' first degree.

vii) The trainees' pre - course qualifications in science.

vii) Where the trainees were likely to apply for their first teaching posts.

For questions 1 and 4 (see questionnaire 4.1) the trainees were given a set of cards with the names of the subjects commonly taught at primary level. They were asked to place the subjects in order of preference (question 1) and on order of 'confidence to teach' (question 4). This allowed the trainees to 'play around' with their lists before committing them to paper. I wanted their responses to be considered, and not simply their first thoughts. I observed that the trainees did spend time altering their lists before recording their final versions.

Using data collected from the questionnaire the following criteria was used to select ten participants: -

a) An equal number of male and female participants, so that any conclusions made could be generalised to all trainees rather than male or female only, unless such differences were identified during the research. Thus five male and five female participants were selected. The PGCE group consisted of fifteen female and eight male participants.

b) Participants from a variety of first degree backgrounds.

c) Participants with no science qualifications and participants with qualifications in science.

d) Participants with little confidence to teach science and participants with a lot of confidence to teach science. Those who rated it first to fourth out of thirteen were considered to have a lot confidence to teach science. Those who rated science ten to thirteenth were considered to have little confidence to teach science, the rest, fifth to ninth has some confidence.

e) Participants who were likely to take up teaching posts in north London (where I lived). As a full time science education tutor there was a limit on the time that I would have available to visit schools.

The participants selected reflected the diversity in the group. I was aware that the participants' assessments of their own confidence to teach science at this stage were not necessarily based on any experience of having taught it. One of the pre-course requirements for the PGCE course was that the participants had to have had some experience of working with primary aged pupil, including a week in a primary school. However, this does not mean that they would have taught science or even seen science taught. Following the concern with the questionnaire sent to BA Primary Education trainees about their confidence, that the trainees might not all share the same understanding of confidence (Chapter2, section 2.1.2), I discussed the idea of confidence with the PGCE trainees. We agreed on the following definition

> a happy willingness to teach it, no worries that I won't teach it well

An analysis of the questionnaires enabled me to select the ten participants, shown in Table 5.1. It was agreed at the start of the research that no participant or school involved in the research would be named, hence all of the names of the participants are pseudonyms.

Table 5.1 Participants selected for the main study

Participant	Gender	Previous Science Qualification		First Degree	Confidence to Teach science
		'O' level	'A'level		
Veronica	Female	B	None	Humanities	Little
Mary	Female	None	None	History	Some
Esther	Female	C,P,B	None	Photography	Some
Ruth	Female	C,P,B	None	Computer Science	A lot
Rachel	Female	C,P,B	None	3D Design	A lot
James	Male	P	None	Eng Lit	Some
Thomas	Male	None	None	History	Some
Peter	Male	P,C,B	PCB	Eng Lit	A lot
Mark	Male	G,P,C,HB	P	Economics	Some
Luke	Male	G	None	Political History	Some

The following codes have been used in Table 5.2;
P (Physics), C (Chemistry), B (Biology), G (General Science), HB (Human Biology), Eng Lit (English Literature).

Once the selection had been made the participants were notified by post, outlining their expected commitment to the research. I decided that participation in the research was voluntary, as the participants would be committing themselves to a three- year study. I was aware that as one of the science tutors for the PGCE course and therefore involved in the trainees' assessment, some of them might have felt obliged to participate in the study. I assured them, that their participation was entirely voluntary. Fortunately, no trainee declined to be involved; indeed several of those not selected had expressed disappointment. I held a brief meeting with the whole group to explain the selection procedure, assuring those who had not been selected that this did not mean that they had been rejected. I then met with the ten participants to outline the research.

5.4.2 Outlining the main study

The meeting was held with the ten selected participants in December 1995. The purpose of the meeting was to explain the research in more detail and to explain my role as a researcher.

The participants were told that the aim of the research was to see how the level of engagement with science by teachers changed over time, through their training year and beyond. At this stage 'level of engagement' was defined by me to the participants as 'how much science the teacher actually teaches during the lesson'. The participants were told that they would be observed teaching science twice a year for three years and be interviewed after each observed lesson. These lessons would be tape recorded for analysis by my supervisors and me only. Several of the participants expressed firm reservations about being tape recorded, and two refused to be. So it was agreed that the lessons would be recorded in note form only. This seemed to me at the time to be very unsatisfactory, as there was a danger that aspects of the lesson would be missed. But I felt that for fairness, the observation and recording should be the same for every lesson, and so agreed not to tape record the lessons. Later when asked for permission to observe the lessons for my research, three

Headteachers agreed provided that no lessons were tape-recorded.

5.4.3 The tutor as researcher

As I was a science tutor on the PGCE course, I needed to establish the differences between my roles as a researcher and as a tutor, to avoid any tension between the two roles.
The role of the tutor as researcher was explained to the participants in the December 1995 meeting. I told them that during the observation period, that is, the lesson and the interview, my focus would be my research, and that the data collected would not form any part of their assessment. The participants knew that I was not involved in the assessment of their school experience. However, some were concerned that if the lesson that I observed was below their usual standard and I mentioned it to their School Experience tutor, it might alter the tutor's perception of them and thus have a negative effect on the assessment of their School Experience. I assured them that I would not discuss my observations with the participants' School Experience tutors. However, several of the participants said that they would like positive things reported to the Primary PGCE programme leader, as he was responsible for writing the participants' references for their first teaching posts. In light of the participants' concerns about the lesson observations and my role, the following were agreed by them and me: -

i) Observations would be confidential between the participant and me. I would not report anything to the school / university, unless it was harmful to the pupils. The participants' request that positive things should be reported back was agreed.

ii) Participants could see anything that was written by me about them.

iii) Observations about the lesson would be shared with trainees orally as I would if I were their School Experience tutor. In order to minimise my potential influence on the trainees' engagement with science, I ensured that the feedback I gave was about their generic teaching skills.

iv) I would give participants advice about their teaching as I would if I were their tutor, (*this advice would be generic*).

v) Participants would only speak to me about their school experience in a professional manner, as they would to a tutor.

I suggested items (iii) and (iv) above, as I thought that it was fair that the participants who were contributing their time, got something out of the research that is, additional feedback. The next stage in the research was to contact schools about the research and ask for permission to observe the participants.

5.4.4 Contacting the schools

A letter was sent to the schools where the participants were placed for School Experience and to those where they taught after qualification, (Appendix 5.3). The letter briefly described the research and invited Headteachers to contact me to discuss the research further if they wished to. Three Headteachers contacted me on receipt of the letter to say that they did not want their pupils tape-recorded. No Headteacher refused permission for their school to be involved in the research, and no Headteacher sought further explanation of the research. I was unable to observe two participants during their second School Experience placements, as the schools were inspected by Ofsted.

5.4.5 Lesson observations

My decision to record, transcribe and then subsequently analyse whole lessons using the engagement schedule, rather than using an observational tool has already been referred to. I decided upon this approach for the following reasons: -

i) I attempted to use an observational tool during the lesson observations for the pilot studies (see Chapter 4 section 2.1.2), but with little success. During the trial of Observation Tool A, I observed aspects of engagement that were not on the tool, and so the tool would have to be altered after every observation, thus it became an engagement schedule, which developed over time.

ii) A full transcript of the lesson could be reread, checked and analysed further beyond the actual lesson being observed. Evidence of engagement with science not observed by the researcher at the time of the lesson, could become apparent at a later date. This iterative process meant that each participants' pattern of engagement was as accurate as possible. As the lessons were not tape - recorded it was necessary to have a written record that the participants could read, to verify accuracy. Also other

researchers needed access to the transcripts to see if their understanding of engagement was consistent with mine. The transcripts of participants' lessons in their training year and first two years of teaching might be useful for research beyond this.

iii) Although the results of the lesson observations would be in table form showing the pattern of engagement over time, having the lesson transcripts meant that the lesson could be revisited, so that the lesson 'observation' was not limited to the actual lesson.

Later in the research I became interested in identifying 'critical moments' in the lessons and I was able to return to the lesson transcripts to pinpoint the moment. Critical moments are described and discussed in detail in Chapter 8.

The participants were to be observed teaching science in the spring and summer terms of 1996, 1997 and 1998.These observation periods were called School Experience (SE), that is SE1, SE2, SE3, SE4, SE5 and SE6, respectively. SE1 took place in the second term and SE2 took place in the third term. I decided to maintain these timings for the second and third year of fieldwork, to allow the participants time to establish a relationship with their classes. So SE3 and SE5 took place in the second term of the two subsequent years and SE4 and SE6 took place in the third term. These timings also suited my own teaching commitments.

Whenever possible, before observing the participants teaching I spoke to them informally about the class and what they were planning to teach. These pre - observation conversations were not recorded, but notes were made at the time. These conversations only took place if there was time before the lesson started. The participants were given questionnaires to complete before the start of SE1 (Appendix 5.2) and SE2 (Appendix 5.4). The purpose of these questionnaires was to find out what the participants concerns were before teaching the topic.

Each of the participants was observed teaching a whole science lesson. The length of the lesson was determined by the participant / school. During the lesson I was a non- participant observer as in the pilot study. I asked the participants to introduce me to the class, as a

"science researcher who had come to find out what we are doing in science"; the pupils were told to "pretend she's not there". As I was not tape recording the lessons, it was important that I was not distracted from note taking, as there was a danger that I would miss parts of the lesson. I avoided making eye contact with the pupils, so that they would not feel welcome to talk to me. This was more difficult during the observations for SE4 and SE6, as these were second visits to the same classes observed for SE3 and SE5 respectively. During the second visits many of the pupils remembered me from the first visits, and were keen to speak to me. On these occasions I spoke to them briefly before the lesson, or told them that I would speak to them after the lesson. In most cases the pupils ignored my presence.

During the lesson I wrote down everything that was said and recorded how it was said and what gestures were used. The observation notes were written in a shorthand of my own devising. These notes were transcribed before the next participant was observed, and usually this was within two days. It was important to complete the observation notes for one participant, so that those of the next participant were not contaminated. During the lessons, I sat where I could easily hear the adult participant talking, moving when necessary to facilitate this. I recognised the importance of this because, when observing Denise's lesson for the pilot study, I missed part of the lesson because I was too far away from her. My focus was recording all oral interactions involving the adult participant. I did not record pupil / pupil interaction, unless it was directly linked to an interaction with the participant. I did not record in detail any interactions that were unrelated to the lesson, but noted that they had occurred, as they may have influenced the lesson. The following extract was taken from my notes written for James's SE4 lesson.

> *There has been a disturbance prior to the lesson, several ch have been with the head, class rather restless, James a bit stressed, he has spoken to six children about this.*

I did not record what James said to the pupils as it was not relevant to the lesson. However that a disturbance had occurred may have been relevant when discussing with James what had affected his teaching, but the detail of the incident was not relevant. I noted any interruptions to the lesson, as they may have affected the participants' teaching. The following extract is taken from the transcript for Rachel's SE1 lesson.

11.15 HT (Headteacher) interrupts to talk about choir & give out letters -- about 2 mins.

I also noted the tone in which the participant and / or pupil spoke. The tone in which a person speaks conveys meaning, and can tell the reader something of the relationship between the participant and their class. The following extract is taken from my transcript of Peter's SE3 lesson. The class was discussing the results of a questionnaire that they had completed at home on the harmful effects of smoking.

P	"Tell your parents you'll smack them if they smoke, no don't say I said that *laughs*, have you got any people who didn't smoke? Did they smoke when they were young? I remember a teacher who said "remember if you don't start you don't have to stop" *scary voice.* I remembered that so I've never started smoking"
ch1	"don't you smoke?" *surprised*
P	"no"
ch1	"oh!"

As explained in Chapter 2, engagement with science includes aspects of language, gesture, and the use of display and models. The following extract taken from the transcript of Rachel's SE1 lesson shows the importance of gesture as a means of engagement. The pupils were trying to find out if temperature affects the rate at which salt dissolves in water. Rachel was working with a group of four low ability pupils. The group was discussing how to make the test fair.

R	"What else have I done to make it fair? What else is the same?" *W/C look a bit puzzled*
R	"the amount of .....?" *points to salt*
W/C	"salt"
R	"Yes and the same amount of .....?" *swirls water in cup*
W/C	"water"
R	"yes, what is different?"

Here Rachel's actions were important because they led the pupils to the correct answer, that is, Rachel told the pupils the answer, albeit non verbally. Without the notes about Rachel's gestures, the engagement with science would be positive. As shown above the engagement

with science is negative, because nothing has been said or done by Rachel to aid the pupils' understanding of a fair test.

I collected copies of any worksheets used by the participants to illuminate the lesson transcripts. I also decided to collect copies of the participants' lesson plans and schemes where available in case they were useful when I was analysing the transcripts. Not all of the participants wrote full lesson plans, in these cases I collected copies of their lesson notes. The participants were required to write evaluations of their lessons, as part of the assessment of SE1 and SE2. I asked the participants to send me copies of these, where available. I also noted any displays and artefacts the participants had in their classrooms, relating to science. Where participants used posters and diagrams, these were noted. The timings of the three sections of the lessons, that is, introduction, development and conclusion were noted, as were any interruptions to the lesson. After the lesson, the participants were interviewed.

5.4.6 The Interviews

I interviewed the participants following each lesson. The purpose of the interview was to find out what the participants thought were the factors that might have contributed to their patterns of engagement with science. The interviews also gave the opportunity to spend time with the participants. I thought that this contact would help keep the participants in the research.

The interviews were planned to last for about ten to fifteen minutes, as that is the length of 'playtime', that is, when the participant would be available for interview. I decided to interview the participants, rather than send a questionnaire for the following reasons: -

a) Some of the participants may have not returned the questionnaires.
b) For SE1 and SE2, the participants were on School Experiences, which were assessed. I did not wish to add to their workload, by asking them to complete and return questionnaires.
c) The questions that I wanted to ask were likely to require follow up questions, which could easily be asked in an interview situation.

d) A longer response could be coaxed from the participants if necessary.

e) At the end of the lesson observation, I spoke to the participants about the lesson. I did not want their reflections on their lessons to be influenced by their lesson transcripts.

The interview consisted of a set of prepared questions, which I asked the participant and wrote down their answers. I often asked unprepared supplementary questions to encourage the participant to give a fuller answer, or to explain an initial answer. These supplementary questions were also recorded. The questions were not the same for each SE (Appendix 4.5), as the questions were not solely related to the lesson observed. The questions related to the lesson, remained the same in content, although the wording altered slightly. These questions were:

- What were you trying to teach?
- Did the children grasp the concept? How do you know?
- What was your main concern when preparing for this lesson / topic?

Other questions were added, to enable me to find out if the participants' views about teaching science changed over time, and to allow the participants to compare their performance over time. I also asked the participants questions that arose from my observations of their lessons, so these questions were different for each lesson observed.

At the end of each of the School Experiences the transcripts of the lessons were analysed using the developing engagement schedule. The interview transcripts were analysed to provide reasons for the pattern of engagement with science.

5.4.7 Giving feedback to the participants

As already mentioned (see section 5.4.3), I thought that it was necessary to give feedback to the participants, as I would if I had been their School Experience tutor. Thus, after the interview was completed, I spoke more informally to the participants, giving them feedback about their lesson and talking about any general teaching and school matters that they asked for my opinion on. The participants often asked about the performance of the others. I had

not anticipated this question. When asked this question, I decided not to answer it, as I did not want the participants to feel that they were in competition with each other. I stuck to this policy throughout the research.

5.4.8 Analysing the lessons

After each School Experience, the lessons were analysed using the most recent version of the engagement schedule. Any 'new' aspects of engagement identified during the analysis of the transcripts were added to the schedule. All lesson transcripts prior to the identification of the 'new' aspect of engagement were checked to see if this 'new' aspect was indeed new, and the aspect was then added to that participant's pattern of engagement chart. For the final analysis, all of the lesson transcripts were analysed using the final version of the engagement schedule. It was important that the transcripts were also analysed by others, to check that their understanding of, and identification of, engagement with science was consistent with mine. This was done in seven ways, namely;

i) All transcripts were analysed by my colleague, a science tutor using the engagement schedule

ii) A sample of transcripts was analysed by my supervisor.

iii) A group of ten research students and tutors at the Institute of Education, University of London, attending a research seminar that I gave after SE3, worked in pairs to identify aspects of engagement with science. The seminar participants were given extracts from three of the science lessons observed for SE3. I explained what engagement with science meant in terms of language, gesture and the use of displays and models. The seminar participants were then free to decide what they thought constituted an engagement with science; that is, I did not show them a copy of the engagement schedule, until after they had completed their analysis of the transcripts. The results of this exercise were variable. Some of the seminar participants' written comments were useful in helping me to develop the engagement schedule. Other seminar participants did not write any comments, so it was not possible to ascertain what they thought.

iv) The participants, were asked to comment on their engagement with science for a sample of the lessons that I observed, see question (B) below.

v) My own BA Primary Education and Primary PGCE trainee teachers at Middlesex University analysed sections of lesson transcripts to identify aspects of positive and negative engagement with science.

vi) I presented aspects of my research, including the discussion of lesson transcripts at two doctoral summerschools at the Institute of Education, so that other research students could comment on my interpretation of the data.

The lesson transcripts were seen by the participants to verify that they were an accurate reflection of what had happened. The participants were sent a copy of the transcripts with the following set of questions.

A) Is the transcript an accurate record of your lesson?

B) What evidence is there in the transcript that you have engaged with science in the lesson?

C) What are your feelings about (B) above?

D) Are there any further observations that you would like to make?

The purpose of this exercise was primarily to check the transcripts for accuracy. But I was also interested to probe the participants' thinking about their teaching following reflection and the opportunity to see the transcript of the lesson.

5.4.9 Using the post lesson interviews and informal conversations

The post lesson interviews and informal conversations were used to try and explain the participants' pattern of engagement with science over time.

The lesson interviews and relevant aspects of the informal conversations were recorded by note taking (as for the lessons), and written up as soon as possible after the lesson, usually within two days. As with the lesson transcripts, the interview responses were also sent to the participants so that they could verify that they were accurate.

When writing the case studies and reflecting upon them (Chapters 7 and 8), I used the data collected in the interviews and informal conversations to help make sense of my observations of the participants' patterns of engagement with science.

5.5 Summary

The main study was a longitudinal study carried out over a three-year period. Ten participants were viewed as ten separate case studies, but with the hope that the findings could be applied to interpret another study in similar situations.

Ten participants were selected from a PGCE group for the study, as a manageable number for a lone researcher. The participants were selected in terms of gender, pre course qualifications in science and confidence to teach science. This generated eight possible teacher types, six of which were present in the PGCE group.

The participants were observed teaching twice a year for the three years of the main study. The theoretical framework about engagement with science had to be developed as a component of the research. This framework evolved from an iterative process, using observations of successive lessons to form an engagement schedule.

The participants were interviewed after each lesson observation to find out what factors they thought contributed to their pattern of engagement for that lesson.

The reliability and validity of the data was checked by:

- the participants checking transcripts of their lessons, to see if they accurately what had happened in the lessons.
- reanalysing previous lesson transcripts for evidence of aspects of engagement.
- other people analysing extracts of the transcripts for evidence of engagement.
- the participants checking the accuracy and reliability of the interview data, form the interview transcripts.

Chapter 6 provides a detailed account of the development of the engagement schedule over the three years of the main study. It describes, with illustrations from the lesson transcripts, how incidents of both positive and negative engagement with science were identified, from the first set of lesson observations to the end of the observation period three years later. These Incidents were sorted to form Aspects and these Aspects were then sorted to form the six Categories of engagement of the Engagement Schedule.

Chapter 6 The development of the Engagement Schedule

6.1 Introduction

The Engagement Schedule was developed as part of the research. Its purpose was to help me to answer the first research question;

1. How does the pattern of engagement of new teachers with the content of primary science develop over their first three years of teaching?

The schedule was developed over a period of three years, during which the participants were observed teaching science. After each of the six sets of observations, SE1 - SE6, the lesson transcripts were analysed for both positive and negative Aspects of engagement with science. These Aspects were sorted into Categories, against which the participants' engagement with science would be charted. New Aspects were added after each SE and where necessary a new Category was formed. Thus the engagement schedule did not reach its final version until after all new Aspects and categories had been added. In the event, this happened when the fourth set of transcripts were analysed, because no new Aspects and therefore no new Categories of engagement were identified during the analysis of the fifth and sixth set of lesson transcripts.

During the three-year observation period, samples of, and extracts from, lesson transcripts were analysed by other people, including the participants, my science colleague, my supervisor and fellow research students. This ensured that the participants verified my observations and others supported my analysis of the transcripts. The engagement schedule was used both to describe and classify the positive and negative Incidents, Aspects and finally Categories of engagement with science, identified in the participants' lessons. It was also used to analyse the patterns of engagement with science by the ten participants over a three-year period. An engagement schedule established *before* the main study phase would not have included any further Aspects or Categories of engagement and thus would have given an incomplete picture of how the participants engaged with science. This chapter describes how the engagement schedule was developed.

6.2 How the observation data was analysed

The procedure for each of the SEs was the same. Each lesson transcript was read at least three times. All Incidents of positive and negative engagement with science were noted on the transcripts. I noted how many times each of the different Incidents of engagement with science occurred. I was interested in not only whether the participant asked a question that demanded factual recall but also how many times the participant asked this type of question during the lesson.

The Incidents of engagement were underlined and labelled with a tag comprehensible to the researcher. This tagging was done after the lessons had been transcribed, for example;

> "asks ? drf " meant that the teacher asked a question that demanded factual recall by the pupils, in order to answer it correctly
>
> "asks? das" meant that the teacher asked a question that demanded that the pupils had to apply science in order to answer it correctly

Each of the different Incidents of engagement with science, both positive and negative, were written on POST IT notes and stuck on a large piece of card. These descriptions were physically moved and stuck with those that were similar. Where I had written the same description more than once, only one was kept. I then read through the set of transcripts again, to check that all of the Incidents noted on the transcripts had been noted on the POST IT notes.

Where there were similar descriptions or use of a single word, a new description encompassing all similar descriptions / words was written. For example, words used by the participants in response to pupils who answered questions correctly for SE1 were *good*, *yes*, *well done*, *right* and *excellent*. These Incidents were labelled 'Affirms pupils' correct response'. Thus all five Incidents were treated the same. Of course the participants might not have meant the same thing when saying *good* and *excellent*. An answer that receives the response *excellent* might be deemed to be a better answer than one that receives the response *good*. The participants might have used the same word, for different meanings; for instance,

excellent could mean *that is a really good answer* or *that is a good answer coming from you.* The use of words might not be consistent for individual participants and also, it is unlikely that there would be consistency between ten participants. Although I had no way of knowing what a particular participant's meaning was, I decided to treat these Incidents as meaning the same thing, because in all cases correct responses were affirmed and so they all formed the same Incident namely, 'affirms correct response'.

This was not the only way that the participants affirmed correct responses. In the following example taken from James, SE1, he affirmed a pupil's answer and then repeated it,

J "If the bridge is straight, what happened to the pencil?" *placed pencil on top of the bridge*
ch5 "It stayed on it"
J "Yes, it stayed on it"

In the example above, James has emphasised the pupil's response by repeating it; that is, he is giving it importance. This Incident although closely related to 'Affirms pupils' correct response' is different, so it is a new Incident and was written 1(b) 'Affirms pupil's correct response and emphasises it by repeating it'.

The following example from Rachel's SE4 lesson, shows that analysing Incidents of affirming pupils' correct responses can be complex. Rachel had asked the pupils to describe some apples that had been left to go mouldy. As the pupils called out answers, Rachel wrote some of them on the board. The pupils later used this list when doing their written work. Although Rachel did not say *yes, good, well done, right, lovely* and *excellent* in response to all of the pupils, that they were correct was implicit, as she only wrote some of their answers on the board.

R "Look at the apples, think of words that you could use you describe these apples"
R writes down some of the pupils' responses, those underlined.
ch1 "Mouldy" (i)
ch2 "Hard"
ch3 "Juice"
R "Juicy, good" (ii)

ch4 "Decay"
R "Decay, lovely" (iii)
ch5 "Brown"
ch11 "Filthy"
R "What do you mean by filthy?"
ch11 "Disgusting"
ch2 "Spotty"
ch7 "Melting"

Incident (i), is labelled 1(c) 'Affirms pupil's correct response and emphasises it by writing it on the board'.
Incidents (ii) and (iii) could both fit both 1(b) as Rachel 'Affirms the pupil's correct response and emphasises it by repeating it' by saying *good* and *lovely*. However, she also wrote the pupils' correct answers on the board, so they fit 1(c) 'Affirms pupil's correct response and emphasises it by writing it on the board.

It was decided that the Incidents, 1(a), 1(b) and 1(c) could be classified together to form the Aspect "Teacher affirms pupils' correct response. These Incidents were not identical, but were sufficiently similar to form a single Aspect.

After the analysis of the SE1 transcripts, 24 different Aspects of engagement were identified. These Aspects were then written on to POST IT notes and sorted into five Categories. These Categories and how they were developed is described later in section 6.2.3. The Engagement Schedule was made up of these five Categories for example, **The Teacher Explains.** Each Category contained a set of related Aspects of engagement. The hierarchy of engagement with science is shown in table 6.1.

Table 6.1 The hierarchy of engagement with science

Engagement classification	Definition
Category	Collection of similar Aspects of engagement. These Aspects are collated to form a Category. The Category is given a label that encompasses all of the Aspects that make it up.
Aspect	Collection of similar Incidents of engagement. These Incidents are collated to form an Aspect. The Aspect is given a label that encompasses all of the Incidents that make it up. Where there is only one Incident, that is, there are no other similar Incidents, then this single Incident will form an Aspect on its own.
Incident	Single act of engagement (positive or negative). In some cases the Incident is a collection of very similar 'events'.

In the following sections I describe the Aspects of both positive and negative engagement with science identified on each SE. Only the first appearance of each Aspect is described, that is, after SE1, only Aspects of engagement not identified on previous SEs are described. In the event the bulk of the engagement schedule was written based on the SE1 transcripts, with increasingly smaller additions with each subsequent SE. Examples were taken from the transcripts of all participants in each SE, for the purposes of writing the Engagement schedule, but the observations for each SE are treated as a whole. To assist the reader, the individual Incidents of positive engagement are written in plain text, with single quotation marks for example, 'Teacher affirms correct response and emphasises it'. Aspects of positive engagement are also written in plain text but with double quotation marks for example, "Teacher affirms correct response". Similarly, the individual Incidents of negative engagement are written in italics, with single quotation marks for example, *'Doesn't pay*

attention to pupil's response, while Aspects of negative engagement are written in italics but with double quotation marks for example, *"Teacher ignores pupil response"*. Where an Aspect is made up of just one Incident, the Aspect and Incident both have the same label for example, Aspect 12 "Teacher asks question that demands factual recall" has the same label as the Incident that made it up 'Teacher asks question that demands factual recall'. Categories are written in bold for example, **The Teacher Asks Questions**.

6.3 Stage 1-using data from observations in SE1

All Incidents of positive and negative engagement with science identified in the SE1 lesson transcripts are described. These Incidents were then sorted to form positive and negative Aspects of engagement with science, see sections 6.3.1 and 6.3.2. These Aspects were then sorted to form five Categories of engagement with science, see section 6.3.3. Nine of the ten participants were observed for SE1. The version of the engagement schedule developed after the analysis of the SE1 transcripts is shown in figure 6.1.

The Categories are shown in **bold**, the positive Aspects of engagement (1-21) are shown in plain script and the negative Aspects of engagement are shown in *italics*.

Figure 6.1 The version of the Engagement schedule developed after SE1

Category	Aspects
The Teacher Instructs	Teacher instructs pupils about the task (3)
The Teacher Gives Information	
Direct	Teacher affirms correct response (1)
	Teacher gives science information (5)
	Teacher gives science labels (6)
	Teacher highlights health and safety (7)
	Teacher answers pupil's question (15)
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)
	Teacher rewords pupil's answer to make it more scientific (16)
	Teacher exploits unforeseen occurrences in lesson (18)
	Teacher overrides pupil response (E)
	Teacher leads pupils to answer, but not necessarily understanding (F)
The Teacher Asks Questions	
Factual	Teacher reviews pupils' prior learning (2)
	Teacher encourages the pupils to observe (11)
	Teacher asks questions that demands factual recall (12)
	Teacher asks 'how many?'(19)
Reasoning	Teacher encourages the pupils to think (10)
	Teacher asks questions that demand an explanation (13)
	Teacher asks questions that demand application of science (14)
	Teacher asks 'what happens if?' (21)
Open	Teacher asks pupils to describe what they will do (17)
	Teacher asks questions that demand comparison (20)
The Teacher Explains	Teacher uses representations of the real thing (4)
	Teacher uses pupil's answer as a basis for explanation to the class (9)
Not Teaching	*Teacher gives wrong information (A)*
	Teacher misleads the pupils (B)
	Teacher ignores pupil's question (C)
	Teacher ignores pupil response (D)

6.3.1 Identifying positive Aspects of engagement from SE1

Eighteen Aspects of positive engagement with science were identified during the analysis of SE1. These have been labelled 1 to 21. Some Aspects, were made up of more than one Incident. The different Incidents were labelled 1(a) and 1(b) etc. Each new Aspect is illustrated with an extract taken from a SE1 lesson transcript. The Incident in each interaction is underlined.

1) **Teacher affirms correct response**

This Aspect was seen in three Incidents, 1(a) 'Affirms pupil's correct response' and 1(b) 'Affirms pupil's correct response and emphasises it by repeating it' and 1(c) 'Affirms pupil's correct response and emphasises it writing it on the board'. These three are Incidents of the same Aspect, because they are so closely related. This Aspect has been fully described in section 6.2.

2) **Teacher reviews pupils' prior learning**

This Aspect arose in Incidents, 2(a) and 2(b). Participants drew on the pupils' previous knowledge to give a context to the current lesson's learning. 2(a) 'Teacher links today's lesson to a previous lesson' was identified in James's lesson. The class was reviewing what they had previously learned about bridges in readiness for a practical investigation. James started the lesson by posing the following question,

J	"What did we say about bridges?"
ch1	"They must be strong"
J	"Good, what else?"
ch2	"Quite flat"

The second Incident, 2(b) 'Teacher relates learning to pupils' everyday experiences' was identified in Rachel's lesson. The pupils had investigated whether or not the temperature of water affects dissolving. During the conclusion this discussion occurred,

ch20	"I think warm water, because we have Ovaltine at home and it dissolves in warm milk"
R	"What about with hot water? Have you tried it?"
ch20	"No"
R	"What about cold?"
ch20	"No"
ch25	"I was making hot chocolate in cold milk by accident, it was horrible"
R	"What was it like?"
ch25	"It was like when we put talc in water"

3) **Teacher instructs pupils about the task**

Six Incidents generated this Aspect. In each case the participant told the pupils what they must do. This could be done orally as an instruction, by demonstration, or by questioning. 3(a) 'Instructions on board, worksheets and/or poster' was identified in all lessons as all participants used at least one of these three items to convey instructions to the class. In all cases writing and pictures/ diagrams were used. 3(b) 'Teacher explains / describes the task' was also identified in all of the lessons. All participants told the pupils what the task was and how to carry it out. For example in Mary's lesson this task was set,

M "This afternoon I want you to make an electrical circuit"

3(c) 'Teacher summarises what the pupils should do / have done' was identified in James's lesson. Towards the end of the lesson James reviewed what the class had done, before asking the pupils to draw a conclusion.

J "We tried out these different shapes, to make it strong. Does anyone want to tell me which one of these shapes was strongest?"

3(d) 'Teacher demonstrates action/s to show pupils what to do' was identified in most of the lessons and always when there was a practical activity. For example in Peter's lesson, he demonstrated how to set up the equipment and told the pupils what to do as he did it.

P "I know some of you have seen this before, but I want to go through it again quickly. See this board, if I put it here why doesn't it move?" *P has set up a small plank against a pile of books, he holds a block of wood at the top of the plank.*

3(e) 'Teacher checks that pupils know what to do' was identified in Mary's lesson. Mary showed the class an electrical circuit, described the task and asked the pupils if they all knew what to do.

M "Look here is a simple circuit. *Holds up a completed circuit.* When you want to test different materials, you need to unclip the wire from the bulb and clip it onto say this coin and touch the screw of the bulb holder with the coin. Does everyone get that?" *exaggerated weary voice*
W/C "Yes!!"
M "Good, I don't expect anyone to ask me what to do now"

3(f) 'Teacher asks pupils to report what they have done' is similar to 3(e) above, but here the participant was checking what had been done, not that the pupils knew what to do. For example in Thomas's lesson, pupils were making compasses using magnetised sewing needles. By asking the pupils what they had done, Thomas was able to identify those pupils who didn't know what to do.

T *to small group* "What have you done?"
ch14 "We don't know what it's about"
T "You've magnetised the needle and then you use the equipment to make a compass. You've got ten minutes to do it"

4) **Teacher uses representations of the real thing**

Two Incidents 4(a) and 4(b) formed this Aspect. 4(a) 'Use of drawings, diagrams, photographs to represent the real thing'. This Aspect was identified in all lessons. These representations were found on the board, posters, information books and worksheets. For example in Mary's lesson on electricity I found:-

M *holds up a poster of Blackpool Tower* "Who can tell me what they can see? What can you see in the poster?"
ch1 "A big building"
ch2 "A seaside"
ch3 "A tower, the Effiel tower"
M "Actually it's the Blackpool tower. There's something the Victorians invented"
ch3 "Electricity"
M "Excellent"
ch4 "You can't see electricity"
M "No, you can see the lights that are powered by electricity".

Esther's lesson generated the second Incident 4(b) 'Teacher uses a model to represent the real thing'. The class was discussing human digestion. Esther used a marble and piece of rubber tubing to demonstrate peristalsis.

E *puts a marble into a piece of narrow rubber tubing* "The food is slowly squeezed along the food tube like this *squeezes the tube above the marble* and takes it down to the stomach"

5) **Teacher gives science information**

Two Incidents 5(a) and 5(b) formed this Aspect, where participants imparted 'new' subject knowledge to the class. 5(a) 'Teacher describes new information' includes the participant telling the pupils new information and giving new information using the written word, drawings, diagrams and photographs on the board, in books and on worksheets and by video. For example in Mark's lesson a group of pupils complained that their buzzer wasn't working:-

M "You can test it by using the first switch. The buzzers only work one way round. Don't automatically think that they don't work. I've tested them all myself"

5(b) 'Teacher summarises what the pupils were to supposed to have learned' generally occurred at the ends of lessons. For example in Mark's lesson, pupils investigated making an electrical circuit using a pressure pad switch. During the lesson conclusion Mark summed up the lesson's learning objective:-

M "So what happens when he stands on the pad, ch14?

ch14 "The circuit is complete and the buzzer goes off"

M "Yes, the completed circuit makes the buzzer go off. To make it, work there must be a complete circuit. Electricity only travels when the circuit is complete.

6) **Teacher gives scientific labels**

Aspects 5 and 6 are closely related. The labels were given as factual information, so there was no explanation. The participant matched an item to a label. The item may be the real thing, a model or pictorial representation. For example Mark drew the standard symbols for parts of an electrical circuit on the board, each symbol was labelled.

M "When we draw a circuit we are using those symbols" *points to electricity symbols on board*
ch23 "I don't like doing it like that"
M "Your's is a lovely way of drawing it, but we must do it the more scientific way. All of you must use the correct symbols"

7) **Health and safety**

Two Incidents formed this Aspect. 7(a) 'Teacher identifies a health and safety issue' and 7(b) 'Teacher asks the pupils a question about health and safety'. In both cases health and safety issues were highlighted. For 7(a) Luke demonstrated what happened to steam when it cools down.

Some pupils trying to put hands over kettle

L "Steam is very hot, stay away from it"

An example for 7(b) Mary discussed with the class why bulbs were not included in the envelope of equipment that the pupils were given to make an electrical circuit.

M "Why isn't there a bulb in here?" *holds up envelop*
ch3 "It can break easily"
M "Why is it dangerous if the bulb breaks?"
ch3 "Glass can cut you"

8) **Teacher uses pupils' answers as exemplars**

This Aspect comprised two Incidents, (8a) 'Teacher uses pupil's work as an example of what pupils should achieve'. In James's lesson pupils were making paper bridges.

ch9 "Sir, look mine can hold two cars!!!"
J *to whole class* "Everyone, ch9 has made a bridge that can hold up to two cars, show them your bridge ch9" *ch9 holds up bridge, class cheer, ch9 bows*
J "Yes, yes, we know you're a genius *all laugh* I want everyone to try ch9's shape" *a triangle*

The example for 8(b) 'Teacher uses pupil's answer as the explanation to whole class' comes from Mark's lesson.

M *to whole class* "How can you describe how the burglar would set off the alarm if he came into your house?"
ch10 "Or she did" *AP laugh*
M "Or she did" *smiles*
ch12 "Sir, I know. The burglar stands on something say a piece of carpet and when he treads on it, it connects with the bit under the carpet so it switches on the alarm and the buzzer goes off"
M "Excellent, you've got it. Did everyone hear that? Good"

Here the participant ensured that the whole class hears the pupil's answer, thereby giving it importance. This Incident is closely related to 1(a) and 1(b), both of which cover the participant affirming a pupil's answer.

9) **Teacher uses pupil's answer as the basis for an explanation to the class**

Two Incidents form this Aspect, both are closely related to (8b). But in these Incidents the participant in 9(a) 'Teacher uses the pupil's answer, but rewords it to make it more scientific' and in 9(b) the participant 'Teacher uses the pupil's answer, but expands it'. For example in Mark's lesson he discussed how a burglar alarm worked with an individual pupil, in front of the whole class.

M "Does it work? Describe the events where does the burglar come in?"
ch18 "He comes in here and stands on that switch but we'll cover it up, so it goes on that and the alarm goes off" *ch18 points to parts of circuit as he speaks*
M "So this is a pressure mat, so when the burglar comes in, it connects the

circuit *lifts pressure mat to show the paper clip of the pressure mat touching the circuit so that thecircuit is completed and the buzzer sounds* and the alarm goes off"

In Esther's lesson the class was discussing what happens to food before it is swallowed:-

ch8 "What happens if the food is too big?"
ch7 "That's why you swallow it before"
E "Yes, you chew it to make it smaller and easier to swallow"
ch7 "Yeah, that's what I mean you have to chew it first of all"

10) **Teacher encourages the pupils to think**

Five Incidents formed this Aspect, where the pupils are encouraged to think about possible answers for themselves. 10(a) 'Teacher asks "what do you think?' the participant could ask the pupils explicitly "what do you think?" or less explicitly "what will happen?" In both cases the participant wanted the pupil to think before answering. For example Rachel's lesson she posed a question before the pupils started an investigation:-

R "What do you think we are going to do? Don't tell me yet"

The example for 10(b) 'Teacher tells pupils to discuss their ideas' was also taken from Rachel's lesson. Most of the class was working in pairs to plan an investigation.

ch2 "I haven't got a partner"
R "Work with ch3"
ch4 "Can you talk?"
R "Yes, I want you to discuss your plans with your partner"

For example 10(c) 'Teacher facilitates discussion' James's class was discussing which shape made the strongest bridge:-

J "We tried out these different shapes, to make it strong. Does anyone want to tell me, which one of these shapes was strongest?" *J draws shapes on the board. Several pupils point to the second shape.*

J "The second one. You think this one was strongest *points to second shape* was strongest? Does everyone agree? What do you think? Does anyone think anything differently?"

W/C *Pupils point to other shapes on the board, shouting* "That one"

This sounds similar to (3e) 'Teacher checks that class know what to do' in that in both James and Mary used similar phrases "Does everyone get that?" and "Does everyone agree?" In Mary's case she was not expecting the pupils to offer an alternative method. She was checking that they understood her instructions. In James's case, he was looking for alternative answers. He made this explicit saying, "Does anyone think anything differently?"

The example for 10(d) 'Teacher questions the pupil's answer' comes from Esther's class's discussion about what three items were essential for survival on a desert island.

ch1 "We need a musical instrument for entertainment"
E "Would you choose it as one of your three things?"
ch1 "No"
E "What would you choose?"
ch1 "Fresh water, food and a TV"

Here Esther was asking the pupil to think again. Although the question "What do we need to survive?" does not have a *right* answer, clearly some answers are more scientifically accurate than others.

10(e) 'Teacher tells pupil to check work / answer' was identified in Mary's lesson, where the class was making simple circuits; several pupils were having difficulty.

ch10 and ch11 "Our circuit's not working"
M *to whole class* "Some children say that their circuit isn't working. You need to find out why. You need to find out. What would you do, anyone?" *no response*
M "Check the wires, the battery and the bulb"

Here Mary did not tell the pupils what to do; she wanted them to find out for themselves. However, on getting no response, she gave the pupils a clue.

11) **Teacher encourages pupils to observe**

Two Incidents formed this Aspect. 11(a) 'Teacher asks pupils to compare items / outcomes' was identified in Rachel's lesson. The pupils were finding out what temperature is *best* for dissolving salt:-

R	"This one is?"
ch6	"Hot" *R gives cup to each pupil to feel, all agree that it is hot.*
R	"What about this one?" *passes cup of warm water around group*
ch9	"Warm" *R holds up cups of hot and warm water.*
R	"Which one is hotter? Feel them" *pupils do this*

11(b) 'Teacher asks what happened' was identified in Luke's lesson, where he asked for an observation not an explanation as the pupils watched him collect steam in a cold glass bottle.

ch4	"Ah!!! smoke is coming out" *steam from the kettle. L places the bottle over the kettle*
L	"What is happening?"
ch2	"It's going cloudy, it's melting, it's hot" *L lets pupils at front feel the bottle*
ch8	"It's wet" *amazed*

Here Luke asked the pupils to describe what was happening and he gave them the bottle to observe by touch.

12) **Teacher asks question/s that demand factual recall**

This Aspect "Teacher asks questions/s that demand factual recall" was found in all lessons. Participants asked pupils questions that demanded factual recall. The knowledge that the pupils had to recall had been covered in a previous lesson (not necessarily taught by the participant) or covered earlier on in the lesson.

This example from James's lesson required the pupils to recall knowledge covered in a previous lesson. The class was discussing which shape was the strongest.

J "Which ones are strongest?" *points to triangles and squares on board*
ch1 "Square"
J "Are you sure? Can you remember what you did with Mrs. Jones?" *classteacher*
ch1 "It was a triangle"

This example from the conclusion of Mary's lesson shows Mary questioning pupils about simple circuits.

M "What components do we need to make a simple circuit?"
ch14 "A battery, a bulb and two wires"
M "What is the most important thing needed to make the bulb light up?"
ch4 "Touch the wires and the bulb holder"

13) **Teacher asks questions that demand an explanation**

Four Incidents where explanations are required form this Aspect. 13(a) 'Teacher asks, why?' This example from Esther's lesson shows the class discussing the first stage of human digestion.

E "What happens to food in your mouth?"
ch3 "We chew it"
E "Why?"
ch3 "So it can mix with saliva and so you can swallow it"

If Esther had not asked why, then this would have fitted Aspect 12.

The example for 13(b) 'Teacher asks pupils to tell, how' is from Mark's lesson. The class was discussing how a burglar alarm works.

M "Why didn't it, the electricity, cross over when the switch was open? Why won't it jump?"
ch2 "It isn't a circuit"
M "It is not a circuit, there's a break in the circuit. Tell us how this alarm works, what happens?"
ch2 "The burglar stands on the pressure pad and that connects the circuit so the electricity can go round and the alarm will go off"

The example for 13(c) 'Teacher asks, why did that happen?' is from James's lesson. A small group of pupils were asked to explain an observation as they tested their paper bridges.

J	"Can you think of why it dips in the middle?" *the paper bridge*
ch7	"Cos, the heaviest bit is there on it?" *points to weights in centre of bridge*

The example for 13(d) 'Teacher asks how do/will you know?' is from Rachel's lesson. Rachel was discussing the design plan for the 'dissolving investigation' with a pupil.

R	"Are you only using hot water?" *reading ch11's work*
ch11	"Yes"
R	"So how will you know if it dissolves more quickly in hot water?"
ch11	"You stir it"
R	"What is ch12 doing? He is using hot and cold water, he is comparing them" *ch11 looks bemused*

14) **Teacher asks questions that demand the application of science**

For this Aspect the participant required the pupils to give a generalised explanation for an observed phenomenon. The pupils were expected to use their prior knowledge and understanding of science to explain what will happen that is, to predict. Rachel's lesson provided the example for this Aspect. Rachel asked the group to predict what would happen to the salt in water.

R	"Which one is going to dissolve the most salt?"
ch6	"The hot one will"
R	"Why? Why the hot one? Why is the hot one going to dissolve more salt? Can anyone tell me?"
ch6	"Because hot milk makes chocolate"

Here the pupil applied his science knowledge of an everyday occurrence to the answer the question.

15) **Teacher answers pupil's questions**

Two Incidents formed this Aspect. 15(a) 'Teacher confirms pupil's answer to his own question', here the pupil asked the participant to confirm an answer that the pupil suggests.

This example is from Esther's lesson. The class was completing a cloze procedure exercise, where pupils were required to complete sentences by adding the missing words.

ch9 "Is the answer churned?" *points to w/s*
E "Yes"
ch9 "Does churned mean mushed up?"
E "Yes, that's right"

Here ch9 knew the correct answers, but sought reassurance from Esther, who gave it.

15(b) 'Teacher answers pupil's questions with a science explanation' was also identified in Esther's lesson, when she demonstrated peristalsis using a marble and piece of rubber tubing.

ch8 "What happens if the food is too big?"
ch7 "That's why you swallow it before"
E "Yes, you chew it to make it smaller and easier to swallow"

16) **Teacher rewords pupil's answer to make it scientific**

In this Aspect the participant adds to or alters what the pupil has said in order to make the pupil's answer fuller and therefore more scientific. The example for this Aspect is from Mary's lesson. The class was discussing what electrical conduction and insulation mean.

M "What does it mean, to conduct electricity?"
ch14 "Electricity can pass through it"
M "Excellent, electricity can pass through it. What does insulate mean then?"
ch14 "It can't let it through"
M "Insulators don't let electricity pass through, well done"

Here ch14 knew what insulation means, but Mary expanded his answer, changing the word *it* for *electricity.*

This is an example of what Wellington and Osborne (2001) call rephrasing. Here the teacher uses more scientific language to rephrase what the pupil has said, as seen in this example from Ogborn et al. (1996)

Teacher: As the sound goes *speaking in* a *low pitch voice* lower, what happens?
Student: They get wider
Teacher: They get spread out

Here the teacher uses the correct language to describe what happened to the sound waves, that is, *spread out* is correct, the waves do not *get wider*. However, as the teacher did not ask the student what he meant by get wider, we cannot be certain if the issue is be one of *language* not *science*.

17) **Teacher asks pupils to describe what they will do**

This Aspect was identified in most of the SE1 lessons where the pupils did practical work. In this Aspect the pupils were simply asked to describe what they will do, are doing or to report what they have done. This is different from (3f), because, here the pupils have to make their own decisions.

The following example is from Mary's lesson. The class had made simple circuits, the pupils were asked to report their findings;

M *to whole class* "Can anyone tell the class how they made the light bulb light up?"
ch7 "Yeah, we got the bulb holder and fixed two wires and crocodile clips in it"
M "In it?"
ch7 "Yeah. you had to unscrew these bits" *screws in the bulb holder*
M "So you had two wires and unscrewed the screws on the bulb holder"
ch7 "Yeah and then we put the switch in"

Here Mary did not ask ch7 to explain why he had unscrewed the screws in the bulb holder, or why a complete circuit was needed. The pupil was simply required to describe what he had done.

18) **Teacher exploits unforeseen occurrence in lesson**

This Aspect was identified in Veronica's lesson. Veronica exploited an unforeseen occurrence to support science. Whilst the pupils were supposed to be looking at their reflections in the polished spoons, three pupils were doing their own investigation.

Three pupils 'catching' light from outside and reflect it onto the ceiling.

V "Where is the light coming from?"
ch4 "The lights"
V "And?"
ch5 "The mirror"
V "And?"
ch4 "Outside?" *points to window*
V "It is coming from outside and reflecting from the mirror onto the ceiling"

Several pupils now reflect light onto ceiling

V "Okay, that's enough, do the experiment"

19) Teacher asks 'how many question'

This Aspect was identified in Rachel's lesson. The pupils were asked to count how many teaspoons of salt dissolved in water at different temperatures. The pupils had carried out the investigation and recorded the results as a tally chart.

R "How many teaspoons (of salt) dissolved in the cold water?"
ch1 "Two"
R "And in the hot water"
ch1 "It was three"

20) Teacher asks a comparison question

This Aspect was identified in Peter's lesson. The pupils were sliding blocks of wood down a slope, which was covered in different materials.

P "what are the differences between the different materials?"
ch1 "is that the paper?"
P "yes, paper is a material"
ch1 "the sandpaper is more rougher"
ch2 "the cloth is cleaner"
P "what else? what does it feel like"
ch2 "soft"

21) Teacher asks 'what happens if.....?'

This Aspect was also identified in Peter's lesson. The pupils were asked to predict what would happen to the blocks of wood before they did the investigation.

P	"What do you think will happen when you try to slide the block down the sandpaper"
ch1	"It will slide down it"
P	"What about the bathroom tile?"
ch1	"Slide as well"

6.3.2 Identifying negative Aspects of engagement from SE1

Incidents of negative engagement with science are those that would not, or were unlikely to, involve the learning of science. Six Aspects of negative engagement with science were identified during the analysis of SE1. These have been labelled A to F. Where an Aspect is made up of two or more Incidents, these have been labelled A(i) and A(ii) etc. Each Aspect is illustrated with an extract from the lesson transcripts, the key section in each example underlined. A suggestion for how the negative Incidents could have been made positive is given for at least one Incident per Aspect. I have used the term 'critical moment' to describe Incidents where an example of negative engagement could have been turned into a positive one. I believe that this is an important development in my research, that is, it was not one of the original research aims, because analysis goes beyond describing and explaining how things are, to describing and explaining how things could be improved.

(A) ***"Teacher gives wrong information"***

This Aspect was identified in Veronica's lesson. Pupils were looking at their images in concave and convex mirrors to see if there was any difference.

V	"What you saw depends on how you hold your mirror. In the concave it makes your face smaller, in the convex mirror it spreads your face out. Basically that's what happens"
ch1	"Mine was the other way round"
V	"Yeah, that's what happens sometimes" *laughs. The pupils start writing*
V	"Oh dear" *to me*

Here Veronica gave the pupil the wrong information. The pupil's conclusion supported by Veronica conflicts with the diagrams and explanations that he had been asked to copy from the board. Veronica would have to review the whole lesson in order to rectify this error. However, one might question how appropriate ray diagrams are for Key Stage 2 pupils. At Key Stage 2, the National Curriculum requires that pupils are taught that "light is reflected from surfaces [for example, mirrors, polished metals]". At Key Stage 2, pupils do not need to know or understand how the images in concave and convex mirrors are formed or what happens to light when it hits concave and convex mirrors. It might have been better if Veronica had focused on the pupils' observational skills, rather than try to explain what they saw using ray diagrams.

(B) ***"Teacher misleads pupils"***

This Aspect was identified in Thomas's lesson. Pupils were investigating how to make a compass using a sewing needle, polystyrene circle, masking tape and a bowl of water. One group made a compass with the needle stuck vertically through the circle.

ch10 "We've done it. We think we've done it, but we don't know what this is for?" *holds up masking tape*

T *to whole class* "You have two minutes left, then we will look at your results. I'm hearing some interesting things"

a few minutes later

ch10 "What about this?" *points to group's solution*

T "That's very interesting, we'll talk about it in a minute"

ch10's group look pleased and stop working

a few minutes later

T *to whole class* "You've all come up with some interesting ideas, but none of you have made a compass"

The pupils, who interpreted *interesting* as meaning *correct*, ch10's group, stopped investigating believing that they had solved the problem. Thomas could have commented positively on the group's efforts, whilst encouraging them to continue by saying;

T "That's very interesting, but I think you should think again"

(C) ***"Teacher ignores pupil's questions"***

This Aspect was identified in James's lesson. The class made and tested paper bridges for strength. They then discussed their findings.

J "Excellent, we folded it, when we folded it, it made it...?"
ch3 "Strong"
J "Excellent, strong, it made it strong. We folded it into a shape, these ones *gestures towards diagram on board.* What made it strong?"
ch12 "Triangle"
J "Yes, the triangles. After lunch you will write it up like you know you always write up science"
ch5 "I have never seen a triangular bridge" *tone suggests a question*
J "I will explain it to you after lunch"
ch5 shrugs

Here James had no intention of following up the discussion (he said this in the post observation interview). There were at least five minutes left of the lesson; so James could have answered ch5, instead James read a poem to the class. The pupil ch5 would not have known during the lesson that he had been ignored, but would, if James did not answer the question after lunch. The situation of pupils asking a teacher a question that the teacher is unable to answer is not uncommon. James could have made this Incident positive asking the pupil what he meant by a triangular bridge; it could be that James and the pupil were talking a cross purposes. If James wanted to allow himself time to think, he could have said one of the following:

J "That's a very good question. We'll discuss it after lunch"

J "That's a very good question. What does anyone else think?"

In order to encourage pupils to ask questions, their questions should be received positively. The questions should be answered, although not necessarily by the teacher or immediately.

(D) ***" Teacher ignores pupils' responses"***

This Aspect arose from two Incidents. D(i) *'Teacher asks a question but does not respond to pupil's answer',* was identified in Luke's lesson, where the class was discussing what steam is.

L	"Who can tell me what steam is?"
ch2	"Out of water"
ch5	"Ice"
L	"What is steam? Water which is very.....?"(1)
ch3	"Hot"
L	"The water has to be very hot to get steam"
ch2	"The water has to be very hot"

Here Luke ignores ch2's and ch5's responses. The pupils had seen a block of ice left out in the classroom, so ch5 might have observed vapour apparently coming off it. The class had just observed steam coming from heated water and being collected as water in a cool glass bottle. The pupil, ch2, may have been saying that steam comes out of water, but Luke did not know, because he did not pursue either ch2's or ch5's response. Luke indicated that they were both wrong by repeating the question and then inviting the pupils to fill in the blank, that is, oral cloze procedure, (Wellington and Osborne 2001), to which ch3 gave a response that Luke accepted and affirmed. At this point ch2 rejoined the discussion, by affirming Luke's definition of steam. Luke could have made this engagement positive by asking the ch2 and ch5 to expand their responses or by rewording their answers to make them more scientific, that is, Aspect 16.

The second Incident D(ii) *'Teacher doesn't pay attention to pupil's responses'*, was identified in Rachel's lesson. The pupils carried out an investigation to find out if more salt dissolved in hot water than in cold water. During the lesson's conclusion Rachel asked the pupils about their predictions.

ch18	"When it's hot and you have an ice cream. If it falls in the sea, it dissolves quite fast and so does the salt"

R not listening, she is looking at her lesson plan

R "The sun melts ice cream"
ch18 "No, I thought it might be the cold water, because salt at the beach dissolves in the sea"
R "Right" *hesitant*

Here because she was distracted, Rachel did not understand ch18's response, hence she wrongly summarised it. Rachel introduced the term melt, when ch18 was talking about dissolving. Many pupils have difficulty understanding the difference between these two phenomena, so Rachel's response may have added to this misconception. Rachel's response to ch18's further explanation was hesitant and she did not attempt to find out what ch18 meant. As in Peter's case, Rachel asked a question, but ignored the pupils' responses.

(E) ***" Teacher overrides pupil's answer"***

This Aspect was identified in Rachel's lesson. Rachel and a small group discussed what happened to salt when it was put in warm water.

R "Now I'll do the warm water"
R stirs a teaspoon of salt into a cup of warm water
R "Does it dissolve?"
ch6 "No"
R "Well it does a bit, put a question mark in that column *points to w/s*
What about hot water?"
ch6 "Nearly"
R "Yes it does, so put a tick in that column" *points to w/s*

In this short exchange Rachel overrode ch6's answer on two occasions. Rachel asked the group for their observations, but negated ch6's observations and told him the *correct* answer. Rachel should have asked the pupil to describe what was happening, that is, she have used Aspect 11 "Teacher encourages the pupils to observe". It may have been that the salt had not fully dissolved in the hot water or that the pupil may not have known what the term dissolve means.

(F) ***"Teacher leads pupils to the answer, but not necessarily to understanding"***

This Aspect was made up of four Incidents. F(i) *' Teacher uses the village idiot voice'* was identified in James's lesson. The class discussed what shape is strongest for making a paper bridge.

J	"Which ones are the strongest?" *points to squares and triangles drawn on the board*
ch1	"Squares"
J	"Are you sure? Can you remember what you did with Ms Jones?"*classteacher*
ch1	"It was a triangle"
J	"Yes, a triangle is the strongest (1) *village idiot voice* so which ones are the strongest?" (2) *points to squares and triangles on board*
W/C	"Triangles"(3) *chanting voice*
J	"Yes, these ones, we (4) know that it's these three *points to triangles on board* because they are triangles"

Here James told the class the answer (1) and then asked them the question (2) and they repeated it (3). I have characterised this as *repeat and you will understand.* The pupils used a chanting voice, but we cannot be sure if they are simply parroting the correct answer, teasing James or if they understood. By using a 'village idiot voice' he was letting the pupils know that he thought that anyone who did not know or understand that a triangle is the strongest shape, was an idiot. By using the term 'we' (4), James was indicating that the pupils and he share a common understanding, but this is not necessarily the case. Instead of telling the pupils the answer, James could have asked:

J	"Why is the triangle the strongest shape?"

If no one were able to offer an explanation, then James would know would know that he had to revisit this concept. However, it is likely that James had already made this assessment and decided against pursuing the concept in that lesson, but he wanted the pupils to leave the lesson with the correct answer.

F (ii) *'Teacher indicates the answer by gesture'* was identified in Rachel's lesson. Rachel and a small group discussed what made a dissolving test fair.

R	"Why do we have ten stirs for this one, and this one and this one?" *taps cups*
ch6	"It won't be fair"
R	"Oh, you genius you're right, it wouldn't be fair. What else have I done to make it fair? What else is the same?" *points to the salt*
ch8	"Salt"
R	"Yes and the amount of?" *swirls water in cup*
ch8	"Water"

Here, albeit subconsciously, Rachel told the pupils the correct answer.

F (iii) *' Teacher tells pupils the answer and then poses the question'* was identified in Peter's lesson. The class discussed what would make the wooden block slide down an inclined plank.

P	"If it *the plank* is rough will the friction be higher or lower?"
ch6	"Higher"
ch7	"Lower"
ch6	"No higher"
P	"Higher, okay, well we're going to test it"

A few minutes later, Peter gave out a prediction sheet, where the pupils were asked to rank the materials in order of which one had the most friction.

Here Peter told the pupils that the rougher the material was the greater the friction, he then asked them to predict that which he has just told them.

F (iv) *'Teacher sounds out answer to the class'*, was identified in Luke's lesson. The class was discussing the answer to a question in the crossword that Luke had written.

ch8	"What's three down?" When water gets very hot it turns to a _ _ _"
L	"It's a new word, it begins with a g"
ch8	"Steam"
ch4	"Water"
L	"Gaaaa"
ch8	"Gas!!"
L	"Yep"

Here the pupils did not know the correct answer. Luke did not give any science-based clues to help the pupils. Instead he gave a language clue, by sounding out the word, gas. This is an example of what Wellington and Osborne (2001) call oral cloze procedure, where the pupils are required to fill in the blanks. They cite the following example from Ogborn et al. (1996).

Teacher	Which of these things on the periodic table might be joined together to make hydrocarbons?
Student	Hydrogen
Teacher	Hydrogen and ……?
Student	Carbon
Teacher	Carbon, right

Here the teacher pauses (…..), to indicate that a word is missing, which the student then supplies. In Luke's case this was more overt, he gave the pupils the first letter of the missing word and when they failed to guess correctly, he sounded it out.

In all four Incidents above the participants tell the pupils the science answer, but there is no explanation. The pupils are simply told the answer, even though this may not have been deliberate. Thus they fit into the Aspect "Teacher leads pupils to answer, but not necessarily understanding".

6.3.3 Combining all Aspects from SE1 to form an engagement schedule

Eighteen Aspects of positive engagement with science and six Aspects of negative engagement were identified in SE1. Each of the Aspects was written on a separate POST IT note, for ease of sorting. These Aspects were sorted into groups of similar Aspects. After several attempts at sorting the Aspects, five groups, based on those for Observation Tool A (section 4.6), emerged. These groups became the five Categories that formed the Engagement Schedule. The five Categories were;

The Teacher Instructs

The Teacher Gives Information

The Teacher Asks Questions

The Teacher Explains

Not Teaching

Each of the five Categories encompassed those Aspects of engagement that I considered to be similar, or to lead to the same outcome. The first Category, **The Teacher Instructs**, was made up of all of those Aspects where the teacher is simply telling the pupils what to do, that is Aspect 3.

The second Category, **The Teacher Gives Information** was made up of all of those Aspects where the teacher *tells* or describes rather than *explains*. This category had the most Aspects, some of which were questions. I divided this Category into two sub-sections. The first I labelled direct and the second indirect. I read the section of the transcript to find out what the purpose of the participant/pupil interaction was. Those classified as direct, are those where the participant is intending to give information. Those classified as indirect, are those where the participant gives information, but may where the purpose of the interaction, in terms of giving information, is less clear. This does imply that indirect information is of any less value than information that is given more directly. The following example taken from Rachel's lesson shows her giving information indirectly.

Rachel and a small group discussed what happened to salt when it was put in warm water.

R	"Now I'll do the warm water"
	R stirs a teaspoon of salt into a cup of warm water
R	"Does it dissolve?"
ch6	"No"
R	"Well it does a bit, put a question mark in that column *points to w/s*
	What about hot water?"
ch6	"Nearly"
R	"Yes it does, so put a tick in that column" *points to w/s*

This is different to a participant giving information directly, in that Rachel has asked two questions, but she has not treated them as questions, that is, she does not discuss or question the pupil's response, she simply gave him the correct information.

Thus Aspects, 1,5,6,7 and 15 are classified as **The Teacher Gives** direct **Information**. Aspects, 16,18, E and F are classified as the **Teacher Gives** indirect **Information**.

The third Category, **The Asks Questions**, was made up of those questions whose purpose was to elicit a response from the pupils, not for the participant to give information. The Aspects in this category were, 2, 10,11,12, 13, 14, 17, 19, 20 and 21. The category was divided into three sub-sections, factual, reasoning and open. This classification comes from Barnes (1990). Questions are difficult to categorise or classify, as they exist as parts of sequences of talk and so their functions are often dependent on the context, (Mitchell 1992), as we can see from the example, above, taken from Rachel's lesson. In determining which questions to classify as questions, I read whole interaction to see how the participant treated the pupil's response.

In the first sub-section, factual, these were questions that the pupils could answer by factual recall or direct observation that did not involve interpretation, (Eggleston et al. 1975; Boydell 1974). Thus this section included what Elstgeest (1985) called the counting questions. These questions could also be thought of as closed questions, that where there is a correct answer, (Wellington and Osborne 2001).

The second sub-section, reasoning, these were those questions that require the pupil to think, that is to apply facts and principles to problem solving, interpreting and making inferences, (Eggleston et al. 1975). Both open and closed questions could fit into this sub- section. For example, a "what happens if" question could have several responses, but requires the pupil to predict, that is, to think about possible outcomes based on prior experience or knowledge, (Elstgeest 1985; Barnes 1990). A reasoning question such as what is the effect of insulating material on the temperature of a hot- water bottle. There is a *correct* answer, but the question requires the pupil to interpret the data and infer. This is what Barnes (1990) called 'closed' reasoning - not recalled.

It is not always the case that questions that appear to demand an explanation do so, as this example from James's SE4 lesson shows.
The class was discussing different types of bridges.

J "What is the simplest form of bridge?"
ch1 "A causeway"
J "Explain it. It's a new one on me"
ch1 "A simple one, just straight"
J "Do you mean one like this?" draws a beam bridge over water
ch1 "yes"

Here ch1 was required to describe the bridge not to explain anything about it.
This is a further example, of why at times analysing the lesson transcripts line by line would have led to the misclassification of Incidents/Aspects.

The third sub-section, open, these were those questions that did not require any reasoning and for which there could be many acceptable responses. For example, in Peter's lesson, he asks the pupils to identify differences between the materials to be tested, there are several *correct* responses. Similarly, when pupils are asked to report what they have done, there could be several acceptable responses.

Barnes (1990), includes a fourth sub-section of question, which he called Social, which is made up of 'control', 'appeal' and 'other' questions. I have not included 'control' and 'other' in my classification, as these do not relate specifically to the engagement with science. I identified two types of 'appeal' questions, one in Mary's lesson and the other in James's lesson.

Mary's lesson

M "Look here is a simple circuit. *Holds up a completed circuit.* When you want to test different materials, you need to unclip the wire from the bulb and clip it onto say this coin and touch the screw of the bulb holder with the coin. Does everyone get that?" *exaggerated weary voice*
W/C "Yes!!"
M "Good, I don't expect anyone to ask me what to do now"

Here Mary's tone indicates that she wants the pupils to agree with her that they know what to do. Hence this sequence fitted Aspect (3), Teacher instructs pupils about the task.

James's lesson

J "The second one. You think this one was strongest *points to second shape* was strongest? Does everyone agree? What do you think? Does anyone think anything differently?"

The first part of the sequences of three question 'does everyone agree?' is an appeal question, but James, then invites the pupils to disagree. Hence this incident fitted Aspect (10), Teacher encourages the pupils to think.

Thus Aspects 2, 11, 12 and 19 fitted the category **The Teacher Asks** *factual* **Questions**. Aspects 10, 13, 14 and 21 fitted the category **The Teacher Asks** *reasoning* **Questions** and Aspects 17 and 20 fitted the category **The Teacher Asks** *open* **Questions**.

The fourth Category, **The Teacher Explains**, was made up of those Aspects of engagement where the participants explain, that is, Aspects 4 and 9. In both examples, the participants do more than give information, they explain how and/or why.

Example 1

E *puts a marble into a piece of narrow rubber tubing* "The food is slowly squeezed along the food tube like this *squeezes the tube above the marble* and takes it down to the stomach"

Example 2

M "Does it work? Describe the events where does the burglar come in?"
ch18 "He comes in here and stands on that switch but we'll cover it up, so it goes on that and the alarm goes off" *ch18 points to parts of circuit as he speaks*
M "So this is a pressure mat, so when the burglar comes in, it connects the circuit *lifts pressure mat to show the paper clip of the pressure mat touching the circuit so that thecircuit is completed and the buzzer sounds* and the alarm goes off"

In both cases the participants do more than tell the pupils what happens they show them how the phenomenon works and says how/why it does.

The fifth Category, **Not Teaching**, was made up of those negative Aspects of engagement that did not fit any of the other four categories, that Aspects, *A, B, C and D*. Here the participant is neither directly or indirectly teaching.

6.4 Stage 2-using data from observations in SE2

In this section all Incidents of positive and negative engagement with science identified in the SE2 lesson transcripts are described and labelled. Where relevant Incidents were fitted into existing Aspects, others formed new Aspects. These new Aspects were fitted into existing Categories. Eight of the ten participants were observed for SE2.The version of the engagement schedule developed after the analysis of the SE2 transcripts is shown in figure 6.2. Those Aspects identified during SE2 are shown with a single asterisk.

Figure 6.2. Those Aspects identified during SE2 are shown with a single asterisk *.

Category	Aspects
The Teacher Instructs	Teacher instructs pupils about the task (3)
	Teacher acknowledges pupils' suggestions (23) *
	Teacher invites questions from pupils (26) *
The Teacher Gives Information	
Direct	Teacher affirms correct response (1)
	Teacher gives science information (5)
	Teacher gives science labels (6)
	Teacher highlights health and safety (7)
	Teacher answers pupil's question (15)
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)
	Teacher rewords pupil's answer to make it more scientific (16)
	Teacher exploits unforeseen occurrences in lesson (18)
	Teacher overrides pupil response (E)
	Teacher leads pupils to answer, but not necessarily understanding (F)
	*Teacher reveals doubt negatively (G)**
	Teacher anticipates future learning (25)*
The Teacher Asks Questions	
Factual	Teacher reviews pupils' prior learning (2)
	Teacher encourages the pupils to observe (11)
	Teacher asks questions that demands factual recall (12)
	Teacher asks 'how many?'(19)
Reasoning	Teacher encourages the pupils to think (10)
	Teacher asks questions that demand an explanation (13)
	Teacher asks questions that demand application of science (14)
	Teacher asks 'what happens if?' (21)
	Teacher asks questions that demand interpretation (22)*
Open	Teacher asks pupils to describe what they will do (17)
	Teacher asks questions that demand comparison (20)
The Teacher Explains	Teacher uses representations of the real thing (4)
	Teacher uses pupil's answer as a basis for explanation to the class (9)
	Teacher explains (27)*
Not Teaching	*Teacher gives wrong information (A)*
	Teacher misleads the pupils (B)
	Teacher ignores pupil's question (C)
	Teacher ignores pupil response (D)
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*
	Teacher reveals doubt positively (28)*

6.4.1 Identifying positive Aspects of engagement from SE2

In this section the seven new Aspects of positive engagement with science, identified for the first time during SE2 are described. Two of these Aspects formed a new category, **The Teacher directs pupil to secondary sources.** The new Aspects were labelled 22, 23, 24, 25, 26, 27 and 28. New Incidents of four existing Aspects, 4,5,7 and 13, first identified during SE1 are also described and so have the same number as those from SE1, but a new letter for example, 4(c). As with the analysis of the SE1 transcripts, the key section/s in each example is underlined.

4) **Teacher uses representations of the real thing**

A further Incident 4(c) 'Teacher mimes/ acts the real thing', was identified for this Aspect in Esther's lesson. Esther was observing two pupils labelling a drawing of a snail.

E "What are these?" *mimes antennae*
ch9 "Feelers"
ch18 "Antennae"

5) **Teacher gives science information**

Two further Incidents were added to this Aspect. 5(c) 'The teacher defines a new science word or concept', was first identified in Esther's lesson. Esther was discussing the characteristics of minibeasts with the class as they worked through an identification key.

E "See if you can take this bug (*picture of bug on card)* through the key"
ch1 "Does it have legs? Does it have pincers? Is it filmy?" *reading from key*
E "Filmy, that means transparent like film"

5(d) 'Teacher summarises what the pupils have discussed/agreed', was identified in Mary's lesson. A small group of pupils discussed how they would set up a test to find out the best conditions plant growth and how they would record their findings. The pupils had made several suggestions, including drawing and writing.

M "I wouldn't want to draw three plants every day"
ch1 "You could take a photograph"
M *laughing* " We haven't got a camera. Let's recap. You decided to keep the amount of soil the same and water it the same every day. ch2 said that drawing was not a good idea"

7) **Teacher highlights health and safety**

A further Incident was added to this Aspect. 7(c) 'Teachers encourages pupils to care for / respect living things', was identified in Esther's lesson. The class was discussing how to handle minibeasts.

E "I'm also giving each group a paintbrush, why?"
ch15 "To push the minibeasts into the container"
E "Yes, minibeasts are delicate and you need to use the paintbrush to gently push them into the container, so that you won't hurt their little legs"

13) **Teacher asks questions that demand an explanation**

A fifth Incident (13e) 'Teacher asks pupil to clarify answer to make it more scientific', was identified for this Aspect. This example from Rachel's in lesson, where the class discussed electrical circuits.

R "Will it work? What do you think?" *a circuit with one battery*
ch11 "Yes"
R "What would the bulb be like?"
ch18 "It would be better with two"
R "What do you mean better?"
ch11 "He means brighter"
R "Do you ch18?"
ch18 "Err, yeah"

22) **Teacher asks questions that demand interpretation**

This new Aspect was first identified in Mary's lesson. The pupils were investigating the best conditions for growing plants; they were using different soils to represent the different climates.

M "Here is gravel *shows gravel*, it's tiny pebbles but no soil. What climate does it represent?"
ch1 "Dry"
M "Dry? Well it could be, but we've already got sand for dry"

Here the pupils were required to interpret what climate the gravel represented.

23) **Teacher acknowledges pupil's suggestions**

This new Aspect was identified in Peter's lesson. Peter was showing the class how to make an electrical buggy and was having difficulty pushing a piece of wire through a tin can.

P "Now I'm going to make the axle cuts two pieces of wire coat hanger put the wire through here *a card disc it's* pretty hard"
ch8 "Sir, why not put it *the wire* in the small end *of the can* first?"
several pupils "Yeah!"
P "Good, perhaps you better take over" *laughs*

Here the pupil had not been asked to intervene, but because Peter thought ch8's suggestion was helpful, it was acknowledged.

24) **Teacher tells pupils to pose questions for research**

This new Aspect was identified in Esther's lesson. Here the pupils were asked to pose questions about minibeasts that they or other pupils could answer by referring to information books. In the following example, Esther asked a pupil what her questions were.

E "What are your questions?"
ch7 "Why do we have ladybirds? How do we tell how old a ladybird is? How many ladybirds are there in the whole universe? How can you tell if it is a girl or a boy? How can you tell where its head is?" *reading from notes*

25) **Teacher anticipates future learning**

This new Aspect was made up of two Incidents. 22(a) 'Teacher sets up next learning step' was identified in Esther's lesson. The pupils were discussing their questions about the minibeasts they had collected. Two pupils had posed the following questions *What does it*

eat? and *Does it drink?* After collecting several questions, Esther returned to those to do with eating and drinking, as this was to be the focus of a future investigation.

E "What about if they drink?"
ch8 "Put a cup of water and see if it drinks"
ch10 "You could do lots of different fluids and see what it drinks"
E "We will find out what? You asked, what does it drink? What is the investigation?" *no response*
E "Watch this space, we'll find out soon"
lesson ends

25(b) 'Teacher suspends discussion until a more appropriate time', was first identified in Thomas's lesson. The class was discussing how night and day occur, when a pupil asked a question about eclipses.

ch6 "So what is an eclipse?"
ch10 "Have you seen one?"
T "Yes, I've seen one lunar eclipse"
ch9 "I have a few mouths ago"
T "Yes, in January"
ch4 "How did it happen?"
T "Can you hang onto these questions until next week"

The pupil probably asked *So what is an eclipse?* because Thomas had talked about one side of the earth being in darkness while the other side is in light. Thomas allowed some time for a brief discussion, but then asked to pupils to suspend their questions *until next week*, when he was planning to explain what eclipses are. The question could not be given a brief answer, so Thomas judged that it was better to leave it until a future date.

26) **Teacher invites questions from pupils**

This new Aspect was identified in Peter's lesson. Peter had demonstrated how to make an electrical buggy and just before the pupils made their own he asked

P "any questions so far?"

From the other transcripts it can be seen that the participants all respond to pupils' questions, but Peter was the first participant to explicitly invite questions from pupils.

27) **Teacher explains**

This new Aspect is similar to Aspect (5) "Teacher gives science information", but is different in that here, the participant explains rather than describes new science information. This Aspect was identified in Thomas's lesson. The class was discussing the role of the sun as a powerhouse.

T "The sun is very hot, we call it a powerhouse. Because it is so hot. It gives energy to the whole solar system, like we eat food for energy.

This explanation is analogous to a story, Ogborn et al (1996). Thomas likens the sun to food, both of which give energy.

28) Teacher reveals doubt positively

This new Aspect was identified in Esther's lesson. Here the teacher reveals to the class that she does not know the answer. This was a positive Incident of engagement with science, as it encouraged her and the class to consult an information book.

ch12 "We found caterpillars under a stone"
E "Really, perhaps there is some kind of caterpillars that hatch under stones"
ch12 "We found ours under a stone"
E "Well I thought caterpillars could only be found on trees and things, so we'll have to look at some books"

6.4.2 Identifying negative Aspects of engagement from SE2

In this section the single new Aspect of negative engagement with science, identified for the first time during SE2 is described and labelled G. New Incidents of existing Aspects, A and F, are also described. As with the analysis of the SE1 transcripts, the key section/s in each example is underlined.

A) ***"Teacher gives wrong information"***

A further Incident was identified for this Aspect. This Aspect first identified in SE1 was made up of just one Incident 'Teacher gives wrong information', so the new Incident identified in SE2 *'Teacher affirms incorrect response'* was labelled A(ii). It was identified in Mary's lesson. The pupils were discussing what a *fair test* is.

M "What do we have to do to make it fair?"
ch3 "All have a go"
M "That's fair, everyone having a turn"
ch1 "All the same"
ch2 "Check everything"
M "All the same except the thing you're testing"

This example is slightly ambiguous. Mary does not say that a *fair test* is everyone having a turn, but she does imply this, partly because she posed the question *What do we have to do to make it fair* rather than *What do we have to do to make it a fair test*. From Mary's answer, ch3 might assume that his answer was correct, even though Mary goes on to explain what a *fair test* is.

F) ***"Teacher leads pupils to the answer, but not necessarily to understanding"***

Two new Incidents were added to this Aspect. F(v) *'Teacher asks a question, but immediately gives clue'*, was first identified in Ruth's lesson. Ruth was discussing how pupils could measure muscle strength.

R "How could we measure it? What about pushing?"
ch1 "I know, lie down....."
R "Yes, we will lie down, we could put it *the scales* against the wall and push on it *interrupting ch1* what are we going to do ch1?"
ch1 "Push it"

Here Ruth did not give the pupil an opportunity to answer the question even when she had given a clue. Ruth interrupted ch1, telling him the answer, which she clearly wanted the group to accept.

F(vi) '*Teacher implies an answer, without a reason',* was first identified in Rachel's lesson. A group of pupils was making an electrical circuit.

ch17	"Miss we need more wire"
R	"Why"
ch17	"To go there" *points to w/s showing circuit that group is building*
R	"I don't think you need any more wire" *leaves group, group shrug*

In this example, Rachel did not tell the pupils why she thought that they did not need any more wire, neither did she pose a question or give a clue to help the group to work out why they did not need any more wire. The group's response, a collective shrug, indicates that they were none the wiser.

G) *"Teacher reveals doubt negatively"*

This new Aspect was first identified in Thomas's lesson. This Aspect is similar to (25) "Teacher reveals doubt positively", but here the teacher's doubt, does not take the pupils' learning further. The class was discussing the characteristics of the Sun.

T	"The Sun is very hot, we call it a star. It gives energy to the whole solar system, like we eat food for energy"
ch9	"Why?"
T	"I don't know why, it is hot, it just is"

Here Thomas, closes the discussion, by saying *it just is*. Also it is not clear what question ch9 is actually asking, he could be asking about the temperature of the Sun, why it gives energy to the solar system or why we eat food. Thomas's reply does not invite a further question from ch9. Thomas could have made the Incident positive by asking ch9 to expand his question and either answering it or helping the pupil to find the answer using a secondary source.

6.4.3 Combining Aspects from SE2 to modify the engagement schedule

Following the analysis of the SE2 transcripts, eight new Aspects were added to the engagement schedule, namely,

(22) "Teacher asks questions that demand interpretation"

(23) "Teacher acknowledges pupils' suggestions"

(24) "Teacher tells pupils to pose questions for research"

(25) "Teacher anticipates future learning"

(26) "Teacher invites questions from pupils"

(27) "Teacher explains"

(28) "Teacher reveals doubt positively".

(G) "*Teacher reveals doubt negatively*"

Seven were Aspects of positive engagement and one was negative. New Incidents were identified for four existing positive Aspects, namely,

(4) "Teacher uses representations of the real thing"

(5) "Teachers gives science information"

(7) "Health and safety"

(13)"Teacher asks questions that demand an explanation".

New Incidents were identified for two existing negative Aspects, namely,

(A) "*Teacher gives wrong information*"

(F) "*Teacher leads pupils to the answer, but not necessarily to understanding*".

Six of the new Aspects were easily fitted under the existing five Categories of the Engagement Schedule. A new Category **The Teacher Directs Pupils to Secondary Sources,** was formed for Aspects 24 and 28, as these both required the pupils to consult secondary sources for information. This fits the Eggleston et al. (1975) section, *Teacher directs pupils to sources of information for the purposes of acquiring or confirming facts or principles*. Aspect (22) " Teacher asks questions that demand interpretation" fits into the Category **The Teacher Asks** *reasoning* **Questions**. Aspects (25) "Teacher anticipates

future learning" and (G) "*Teacher reveals doubt negatively*" both fit the category "**The Teacher Gives** indirect **Information**". Aspect (27) "Teacher explains", fitted into the Category **The Teacher Explains**, as the teacher is not simply giving information, but is explaining it. Aspects (23) "Teacher acknowledges pupils' suggestions" and (26) "Teacher invites questions from pupils" both fit into the Category **The Teacher Instructs,** because in these instances the teacher was checking that the pupils knew what to do.

6.5 Stage 3a-using data from observations in pre - SE3

Mark was observed in each of the three terms of his first year of teaching, and so he was the only participant observed for 'pre SE3'. I decided to analyse this single transcript, to see if there were any new Aspects or Incidents of existing Aspects.

6.5.1 Identifying positive Aspects of engagement from pre SE3

No new Aspects were identified from Mark's pre SE3 transcript, but two new Incidents were identified for an existing Aspect, namely (10) "Teacher encourages the pupils to think". The first 10(f) 'Teacher questions pupil's response by a non committal statement'. The class was discussing why pulse rates alter with exercise.

ch22 "I thought it would get faster, but some got slower"
M "That's interesting?"
ch22 "Yes, when ch21 was hopping his pulse went slower"

Here Mark does not say explicitly that the pupil is wrong, but his statement which was posed as a question, implies that the pupil was wrong. 10(g) 'Teacher questions pupil's response by gesture', is very similar to 10(d) 'Teacher questions pupil's response' and 10(e) above. Mark was discussing the pupils' results about their investigation.

M "What about after exercise?" *pulse rate*
ch25 "A hundred and ten"
M "In what?"
ch25 "Thirty seconds" *M raises eyebrows*
ch25 "In one minute" *laughs*
M "That's more like it. After star jumps?"

Again Mark does not say that the pupil is wrong, but his gesture questions ch25's answer, ch25 recognises the gesture and so alters his answer.

6.4.2 Identifying negative Aspects of engagement from pre SE3

No new negative Aspects or Incidents of existing negative Aspects of engagement were identified from the pre SE3 transcript of Mark's lesson.

6.4.3 Combining Aspects from pre SE3 to modify the engagement schedule

Although two new Incidents were identified in Mark's pre SE3 lesson, no new Aspects or Categories of engagement were identified, so, the Engagement Schedule, see figure 6.2, was not modified.

6.6 Stage 3b-using data from observations in SE3

In this section the Aspects of engagement with science, identified for the first time during SE3 are described. New Incidents of existing Aspects are also described and labelled accordingly. Nine of the ten participants were observed for SE3. The version of the engagement schedule developed after the analysis of the SE3 transcripts is shown in figure 6.3. Aspects identified during SE3 are shown with a double asterisk **.

Figure 6.3 Engagement Schedule (developed after the analysis of the SE3 transcripts).

Category	Aspects
The Teacher Instructs	Teacher instructs pupils about the task (3)
	Teacher acknowledges pupils' suggestions (23) *
	Teacher invites questions from pupils (26) *
The Teacher Gives Information	
Direct	Teacher affirms correct response (1)
	Teacher gives science information (5)
	Teacher gives science labels (6)
	Teacher highlights health and safety (7)
	Teacher answers pupil's question (15)
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)
	Teacher rewords pupil's answer to make it more scientific (16)
	Teacher exploits unforeseen occurrences in lesson (18)
	Teacher overrides pupil response (E)
	Teacher leads pupils to answer, but not necessarily understanding (F)
	*Teacher reveals doubt negatively (G)**
	Teacher anticipates future learning (25)*
	Teacher and pupils chant/sing and do actions (30)**
	Teacher tells pupil his answer is incorrect (31)**
The Teacher Asks Questions	
Factual	Teacher reviews pupils' prior learning (2)
	Teacher encourages the pupils to observe (11)
	Teacher asks questions that demands factual recall (12)
	Teacher asks 'how many?'(19)
Reasoning	Teacher encourages the pupils to think (10)
	Teacher asks questions that demand an explanation (13)
	Teacher asks questions that demand application of science (14)
	Teacher asks 'what happens if?' (21)
	Teacher asks questions that demand interpretation (22)*
	Teacher asks pupils to report a judgment (29)**
Open	Teacher asks pupils to describe what they will do (17)
	Teacher asks questions that demand comparison (20)
The Teacher Explains	Teacher uses representations of the real thing (4)
	Teacher uses pupil's answer as a basis for explanation to the class (9)
	Teacher explains (27)*
Not Teaching	*Teacher gives wrong information (A)*
	Teacher misleads the pupils (B)
	Teacher ignores pupil's question (C)
	Teacher ignores pupil response (D)
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*
	Teacher reveals doubt positively (28)*

6.6.1 Identifying positive Aspects of engagement from SE3

In this section three new Aspects of positive engagement, identified for the first time during SE3 are described and labelled 29,30 and 31. No new Categories were identified. New Incidents of existing Aspects 1,4 and 5 are also described. As with the analysis of the SE1, SE2 and pre SE3 transcripts, the key section/s in each example is underlined.

1) **Teacher affirms correct response**

Two new Incidents were identified for this Aspect. 1(d) 'Teacher affirms pupil's correct response by gesture', was identified in Mark's lesson, is very similar to 1(a) 'Teacher affirms pupil's correct response', but with 1(d) it is not done orally. The class was discussing what happens to materials when they are frozen.

ch6	"My dad put a bottle of water in the freezer and it expanded and burst the bottle" *M nods*
M	"Why do we make predictions?"

In this case, the pupil's intervention has been acknowledged and Mark has indicated that what ch6 said was correct.

1(e) 'Teacher suggests that pupil's response maybe correct', was identified in Rachel's lesson. The class was discussing what substances might be taken up by plants,

R	"Plants take up water in their stalks, it takes up water and things that are dissolved in it. Would it go up if it was in orange juice"
W/C	"Yes"
R	"Biscuits, crushed up? No"
ch4	"It might if it went sloppy"
R	"Maybe, what about gravel?"

Here Rachel does not say that ch4 is correct, but she implies that he may be, by saying *maybe.*

4) **Teacher uses representations of the real thing**

A new Incident was identified for this Aspect. 4(d) 'Teacher uses pupils as representations of real thing', was first identified in James's lesson. James was demonstrating to the pupils that the earth moves and the sun stays still.

J	"Yes, the sun stays still, if you look at the sun it has different stars behind it, so it appears to move, hesitantly. Can I have someone, right ch10 you're the sun and I need someone ch15 you're the earth and I need five stars, *chooses five pupils.* We're going to pretend that ch15 the earth, ch15 you look up at the sun, what do you see?"
ch15	"Three stars"
J	"So ch15 orbits the sun, do it and look up, what do you see now?' *ch15 walks around ch10*
ch15	"Two stars?"
J	"If you're on the earth what does it look like?"
ch9	"They're moving"
J	"Who's moving?"
ch9	"ch15 and ch10"
J	"There's only one person moving and it's ch15"

5) **Teacher gives science information**

A new Incident was identified for this Aspect. 5(e) 'Teacher gives new information hesitantly', was first identified in Peter's lesson. The class was discussing what people do to give up smoking and what the harmful affects of smoking are. The following two examples show this.

Example one

P	"What did people do to give up?"
ch8	"Willpower"
ch3	"Chewing gum for smokers"
ch2	"Cigarette patches"
P	"Had you heard of them?"
ch2	"Patches"
P	"I think that they give you a bit of nicotine"

Example two

ch15 "Sir can you get breast cancer from smoking?"
P "Yes, all types of cancer"
ch8 "I thought it was only lung cancer"
P "I think it is all types of cancer"

In both cases, Peter's use of *I think* could imply that he is unsure of the answer. However, as example two shows, it could be that Peter did not tell ch8 that he was incorrect, because he was in fact partially correct. Also some people use the frame *I think* so as to appear less forceful.

29) **Teacher asks pupils to report a judgment**

This new Aspect was first identified in Peter's lesson. The class was discussing what they thought about smoking.

P "We've talked about pressure from friends, what is your own opinion of smoking?"
ch3 "Refreshing, I can't wait to try"
P "Don't be silly, don't try to sound cool, let's have a sensible discussion"
ch4 "It's really bad"
P "Does anyone think it's okay?" *Four pupils put up hands*
P "It's interesting to see which children who have put up their hands. How can you help your parents give up?"

Here Peter was not asking the pupils why smoking is or is not harmful, as he did not ask ch4 why he thought that smoking is *really bad* or the four pupils who indicate that smoking is *okay*. Peter was asking the pupils to make a judgment, although it is not clear what he wants them to base their judgments on. Once the pupils had indicated what they believed, by a show of hands, Peter asked the question;

P "How can you help your parents give up"

The pupils could infer from this question that Peter thought that smoking was wrong/ bad for one.

30) **Teacher and pupils chant/sing with actions**

The new Aspect was first identified in Thomas's lesson. At the start of a lesson on Forces, the class was discussing what made things move.

T "You remember pushing and pulling. Bring me a toy that moves and you pull it" *ch1 brings a toy dog on wheels*
T "Can you show me how to pull it?" *ch1 demonstrates this*
T "Everyone push, pull, push, pull" *Pupils join in chanting the words several times. T and AP doing pushing and pulling action as they chant.*

At the end of the lesson, after the class had done an investigation about pushing and pulling large objects, the class sang two songs.

T "Now we're going to sing the popcorn song"
pupils sing song and do actions involving pushes and pulls
T "Push, pull, push, pull, use your arms and legs"
Pupils do actions as T calls them out
T "Find a partner and holds hands"
Pupils in pairs holding both of each others hands
T "Push, pull, push, pull"
Pupils do actions as T calls them out
T "Now let's play the bendy song"
T plays tape of song. T and AP do the actions as they hear them "bends, stretches make shapes with your body, push,pull"

This Aspect was only identified in Thomas's lesson. The pupils were year one pupils (aged five or six years), all of the other participants, except Esther, taught pupils aged 7-11years.

31) **Teacher tells pupils his answer is incorrect**

This new Aspect was first identified in Mary's lesson. Here the participant is explicit in telling the pupil that his answer is incorrect. The class was naming the parts of a flowering plant.

M "What is this bit sticking out?" *touches stigma*
ch5 "Is it the stamen"
M "No, not the stamen. These are the stamens" *touches anthers*

6.6.2 Identifying negative Aspects of engagement from SE3

No new Aspects of negative engagement were identified during SE3. In this section new Incidents of existing Aspects *D* and *F* are described. As with the analysis of the earlier transcripts, the key section/s in each example is underlined.

D) **Teacher ignores pupil response**

Two new Incidents were identified for this Aspect. D(iii) '*Teacher acknowledges pupil's suggestion, but doesn't act on it'*, was first identified in Peter's lesson. The class was discussing the health-related problems of smoking.

P	"Who can tell me some diseases caused by smoking?"
ch6	"Cancer " *P writes cancer on board*
ch15	"Breast cancer"
ch8	"Wrinkles" *P writes wrinkles on board*
ch9	"That's not a disease"
P	"No, it's not a disease, I know we'll put diseases and health problems *P adds to title on board*, not that wrinkles are a health problem" *laughs*
ch12	"Sir, put body health"
P	"That's a good idea" *P doesn't alter the title.*
ch4	"Asthma" *P writes asthma on board*
ch10	"Tonsillitis"
P	"No, not from smoking" *P doesn't write tonsillitis on board*

Peter wrote all of the *correct* answers on the board. Although he said that ch12's idea was *good*, he did not write it on the board. The ch12's idea was acknowledged, but then ignored. D(iv) '*Teacher dismisses pupil's response'*, was first identified in James's lesson. The class was discussing that the sun does not move. James invited the pupils to ask questions.

J	"Good, and what's not moving?"
ch16	"The sun"
J	"Good, any questions?"
ch1	"Yes sir, the sun is moving because the universe is expanding"
J	"Yes, do you know the word pedantic?"
ch1	"No"
J	"Well that's a new word for you *sarcastic tone*, you're right the sun is moving as the universe expands, but everything is moving in relation to each other, so we still things in the same way, okay?" *usual tone, but very fast*
ch1	"Okay" *shrugs*

James had invited the pupils to ask a question, but he was clearly not pleased with ch1's intervention. Although James responded to ch1's intervention, he spoke very quickly, ch1's response, a shrug, indicates that he did not understand it, or he had not paid attention, having been put off by James's manner.

F) **Teacher leads pupils to answer, but not necessarily to understanding**

A new Incident for this Aspect was identified in Ruth's lesson. F(vii) '*Teacher suggests silly answer'*. Ruth was discussing the pupils' plans for their investigations to find out the strength of carrier bags. Two examples show this;

Example one

R	"What are you going to do, put in ten books straight away?"
ch14	"no, one at a time" *laughs*
R	"Yes, one at a time and then what?"
ch14	"See if they break"

Example two

R	"How are you keeping it safe?"
ch1	"We're going to be careful"
R	"How? You're not going to dangle it over your feet?"
W/C	"No!" *laughing*
R	"Good"

In both cases it is unlikely that the pupils would have disagreed with what Ruth had suggested as her questions were clearly meant to be silly. Thus in neither case, could Ruth be sure that the pupils understood, they may just have been agreeing with her.

6.5.3 Combining Aspects from SE3 to modify further the engagement schedule

Following the analysis of the SE3 transcripts, three new Aspects of positive engagement with science were added to the engagement schedule, namely,

(29) "Teacher asks pupils to report a judgment"

(30) "Teacher and pupils chant/sing and do actions"

(31) "Teacher tells pupil his answer is incorrect"

New Incidents were identified for three existing positive Aspects, namely,

(1) "Teacher affirms correct response"

(4) "Teacher uses representations of the real thing"

(5) "Teachers gives science information"

Following the analysis of the SE3 transcripts, no new Aspects of negative engagement with science were added. But, new Incidents were identified for two existing negative Aspects, namely

(D) "*Teacher ignores pupil response*"

(F) "*Teacher leads pupils to the answer, but not necessarily to understanding*"

Aspects (30) "Teacher and pupils chant/sing and do actions" and (31) "Teacher tells pupil his answer is incorrect" were placed in the Category **The Teacher Gives** direct **Information**, because the participant was not explaining what s/he said. The new Aspect (29) "Teacher asks pupils to report a judgment", was placed in the Category **The Teacher Asks** reasoning **Questions**, because the pupils were asked to say what they thought.

6.7 Stage 4 -using data from observations in SE4

In this section Incidents of positive and negative engagement with science, identified for the first time during SE4 are described. Where relevant these Incidents were fitted into existing Aspects, others formed new Aspects. These new Aspects were fitted into the existing Categories. Eight of the ten participants were observed for SE4. The version of the engagement schedule developed after the analysis of the SE4 transcripts is shown in figure 6.4. Those Aspects identified during SE4 are shown with a triple asterisk ***.

Figure 6.4 Engagement Schedule. (This, the final version was developed after the analysis of the SE4 transcripts).

Category	Aspects
The Teacher Instructs	Teacher instructs pupils about the task (3)
	Teacher acknowledges pupils' suggestions (23) *
	Teacher invites questions from pupils (26) *
The Teacher Gives Information	
Direct	Teacher affirms correct response (1)
	Teacher gives science information (5)
	Teacher gives science labels (6)
	Teacher highlights health and safety (7)
	Teacher answers pupil's question (15)
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)
	Teacher rewords pupil's answer to make it more scientific (16)
	Teacher exploits unforeseen occurrences in lesson (18)
	Teacher overrides pupil response (E)
	Teacher leads pupils to answer, but not necessarily understanding (F)
	*Teacher reveals doubt negatively (G)**
	Teacher anticipates future learning (25)*
	Teacher and pupils chant/sing and do actions (30)**
	Teacher tells pupil his answer is incorrect (31)**
The Teacher Asks Questions	
Factual	Teacher reviews pupils' prior learning (2)
	Teacher encourages the pupils to observe (11)
	Teacher asks questions that demands factual recall (12)
	Teacher asks 'how many?'(19)
Reasoning	Teacher encourages the pupils to think (10)
	Teacher asks questions that demand an explanation (13)
	Teacher asks questions that demand application of science (14)
	Teacher asks 'what happens if?' (21)
	Teacher asks questions that demand interpretation (22)*
	Teacher asks pupils to report a judgment (29)**
Open	Teacher asks pupils to describe what they will do (17)
	Teacher asks questions that demand comparison (20)
The Teacher Explains	Teacher uses representations of the real thing (4)
	Teacher uses pupil's answer as a basis for explanation to the class (9)
	Teacher explains (27)*
Not Teaching	*Teacher gives wrong information (A)*
	Teacher misleads the pupils (B)
	Teacher ignores pupil's question (C)
	Teacher ignores pupil response (D)
	*Guess what I am thinking (H)***
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*
	Teacher reveals doubt positively (28)*

6.7.1 Identifying positive Aspects of engagement from SE4

No new Aspects of positive engagement with science were identified during SE4.This section describes the new Incident of Aspect 4 and the further event of Incident 1(d). As with the analysis of the earlier transcripts, the key section/s in each example is underlined.

1) **Teacher affirms correct response**

A new further event of Incident (1(d) 'Teacher affirms correct response by gesturing' was first identified in Peter's lesson. Peter clapped a pupil who had given the correct answer, but this did not form a new Incident, as it was similar to 1(d).

4) **Teacher uses representation of the real thing**

A new Incident of this Aspect was identified in Ruth's lesson. (4e) 'Teacher mimes a science concept'. The following three examples show Ruth describing how electricity moves in a circuit;

Example one

R "How does it work? The electricity is flowing round *draws a circle in the air* without the battery there would be nothing to push it around"
ch20 and ch21 nod
R "That's how electricity works, it travels round in a circuit"

Example two

R "Does it mater how you connect it?"
ch12 "Yes"
R "What must you allow the energy to do?"
ch12 "Move"
R "Yes, in a ....." *draws a circle in the air*
ch12 "Circuit!!!"
R "Yep"

Later in the lesson, Ruth uses circle as an analogy for a circuit

Example three

R "How is it working?"
ch22 "Dunno"
R "The energy is going from the battery along the wire to the bulb back along the wire to the battery is a ....." *draws a circle in the air*
ch22 "Circle"
R "A circuit, yes like a circle"
ch22 "Okay"

From the three example above, it is not clear if Ruth meant that a circuit was like a circle, that is, all of the parts are connected up to form a circle, or if the word circle sounds like the word circuit.

In the post lesson interview with Ruth it was clear that she meant the former, that is, that electricity moved round in a circuit, like moving round in a circle.

6.7.2 Identifying negative Aspects of engagement from SE4

In this section the single new Aspect of negative engagement with science is described and labelled *H*. No new Incidents of existing Aspects were identified. As with the analysis of the earlier transcripts, the key section/s in each example is underlined.

H) ***"Guess what I am thinking"***

The new Aspect was first identified in Mark's lesson. The class was discussing how to record the findings of an investigation. Mark wanted the pupils to record part of their results as drawings.

M "How could you use this grid *points to w/s on easel to* record the type of sound. I've done the hard bit, I've drawn the table"
ch6 "We could write the sounds"
ch7 "Otherwise there'll be no point doing it, we won't remember"
M "Do we have to always write things? What about the fact that there is a group of pupils outside?"
ch7 "To compare them"
M "Yes, but we can share them, but how could we record the sound we made? How could we record it?"
ch8 "Record it"
M "How"

ch9 "Write it"
ch11 "I pinged it"
M "Yes you could write it in words (1), how else, that is not writing?"
ch8 "Use a radio?" *I think the pupil meant a cassette*
M "Yes (2), but that's not what I'm thinking of" (3)
ch10 "Draw it?"
M "Yes that's what I'm thinking of.(4) Yes draw the things that you used. How will you describe the sounds made"

Even though Mark asked an open-ended question "how could you use this grid to record the type of sound" it was clear from his response (4) that he had a specific response in mind. Mark acknowledged that writing and tape recording were acceptable responses, (1) and (2). Mark was unintentionally explicit in wanting the pupils to guess what was in his head (3). This Aspect is different from (*F*) "*Teacher leads pupils to answer, but not necessarily to understanding*", in that Mark made no attempt to explain why drawing the results would be preferable to writing about them or tape recording them. There is an element of (*B*) "*Teacher misleads the pupils*", in that at least one of the pupils now thought that the way to record for the investigation was by drawing (5) as the rest of the example shows;

M "How will you describe the sounds made?"
ch9 "Draw it" (5)
M "No"
ch10 "Write it is a few little words?"
M "Yes, you could write that bit"

However, I decided to make the new Aspect (H) "*Guess what I am thinking*", because, the only way that the pupils could have found the *correct* answer was by guesswork, as Mark rejected acceptable answers, without explanation.
This is what Barnes (1990); Wellington and Osborne (2001) have called 'pseudo - questions'. Although the question is framed as an open question, that is, there are several acceptable responses, the teacher will only accept one response as correct. The pupils can only find the *correct* answer by 'guessing what is in the teacher's head'.

Mark could have made this Incident positive by allowing the pupils to choose their own method of recording, which may have included drawing and then discussed which method was best for which situation. Mark could have presented the pupils with alternative ways of recording for the pupils to evaluate and decide which method of recording was most suitable in what situation. As it was, ch9 simply guessed what method to record the description of the sounds (7), he had no learning to apply.

Aspect (H) did not fit any of the sub-sections of the category The Teacher Asks Questions, as the correct response did not require factual recall, reasoning, nor was it open.

6.7.3 Combining Aspects from SE4 to modify the engagement schedule still further

Following the analysis of the SE4 transcripts, one new negative Aspect was added to the engagement schedule, namely,

(H) "*Guess what I am thinking*".

Two new Incidents were identified for two existing positive Aspects, namely,
(1) "Teacher affirms correct response"
(4) "Teacher uses representations of the real thing"

The new Aspect (H) "*Guess what I am thinking*" fitted into the Category **Not Teaching**, as the pupils were none the wiser about how to record results following the exchange described in section 6.52.
This new Aspect was added to the engagement schedule to form a new version, figure 6.4.

6.8 Stage 5 -using data from observations in SE5

No new Incidents, Aspects or Categories of engagement were identified during SE5. Seven of the ten participants were observed for SE5. Thus the engagement schedule at the end of the analysis of the SE5 transcripts was the same as for the analysis of the SE4 transcripts, that is, Figure 6.4.

6.9 Stage 6 - using data from observations in SE6

No new Incidents, Aspects or Categories of engagement were identified during SE6. However, a further event for Incident 1(c) 'Affirms pupil's response and emphasises it' was identified. Six of the ten participants were observed for SE6. Thus the Engagement Schedule at the end of the analysis of the SE6 transcripts was the same as for the analysis of the SE4 transcripts, that is, Figure 6.4.

6.9.1 Identifying positive Aspects of engagement from SE6

A further event for 1(c) 'Affirms pupil's response and emphasises it', was identified, in Peter's lesson. Peter's class was suggesting items for food chains, Peter drew the *correct* answers on the board and ignored the *incorrect* answers. This was not a new Incident, as it was not different enough from 1(c) 'Affirms pupil's response and emphasises it'.

6.10 Categories, Aspects and Incidents

All of the transcripts were analysed using the version of the tool developed by the end of the SE4 analysis. No new Aspects of positive or negative engagement were identified during the analysis of the SE5 and SE6 transcripts. Figure 6.5 presented on the following two pages shows all the Incidents, Aspects and Categories that made up engagement with science.

Figure 6.5 Engagement Schedule showing all the Incidents, Aspects and Categories of engagement.

Category	Aspects	Incidents
The Teacher Instructs	Teacher instructs pupils about the task (3)	a) Instructions on board, worksheets and on poster b) Teacher explains/describes the task c) Teacher summarises what the pupils should do d) Teacher demonstrates action to show pupils what to do e) Teacher checks that pupils know what to do
	Teacher acknowledges pupils' suggestions (23) *	a) Teacher acknowledges pupil's suggestion
	Teacher invites questions from pupils (26) *	a) Teacher invites questions from pupils
The Teacher Gives Information		
Direct	Teacher affirms correct response (1)	a) affirms correct response b) affirms correct response and emphasises it by repeating it c) affirms correct response and emphasises it by writing it on the board d) Teacher affirms correct response by gesture e) Teacher suggests that pupil's response maybe correct.
	Teacher gives science information (5)	a) Teacher describes new information b) Teacher summarises what the pupils were supposed to have learned c) Teacher defines a new science word or concept d) Teacher summarises what the pupils have discussed/agreed e) Teacher gives new information hesitantly
	Teacher gives science labels (6)	a) Teacher gives science labels
	Teacher highlights health and safety (7)	a) Teacher identifies health and safety issue b) Teacher asks pupils a questions about health and safety c) Teacher encourages pupils to care for/respect living things
	Teacher answers pupil's question (15)	a) Teacher confirms pupil's answer to his own question b) Teacher answers pupil's question with a science explanation
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)	a) Teacher uses pupil's work as an example of what pupils should achieve b) Teacher uses pupil's answer as the explanation to the whole class
	Teacher rewords pupil's answer to make it more scientific (16)	a) Teacher rewords pupil's answer to make it more scientific
	Teacher exploits unforeseen occurrences in lesson (18)	a) Teacher exploits unforeseen occurrence in lesson
	Teacher overrides pupil response (E)	*i) Teacher overrides pupil's answer*
	Teacher leads pupils to answer, but not necessarily understanding (F)	i) Teacher uses village idiot voice ii) Teacher indicates answer by gesture iii) Teacher tells pupils the answer and then poses the question iv) Teacher sounds out answer to the class v) Teacher asks a question, but immediately gives a clue vi) Teacher implies an answer without reason vii) Teacher suggests silly answer
	*Teacher reveals doubt negatively (G)**	i) *Teacher reveals doubt negatively*
	Teacher anticipates future learning (25)*	a) Teacher sets up next learning step b) Teacher suspends discussion until a more appropriate time
	Teacher and pupils chant/sing and do actions (30)**	a) Teacher and pupils chant/sing and do actions
	Teacher tells pupil his answer is incorrect (31)**	a) Teacher tells pupils his answer is incorrect

The Teacher Asks Questions	**Aspects**	**Incidents**
Factual	Teacher reviews pupils' prior learning (2)	a) Teacher links today's learning to yesterday's. b) Teacher relates learning to pupils' everyday experiences.
	Teacher encourages the pupils to observe (11)	a) Teacher asks pupils to compare items/outcomes b) Teacher asks what happened
	Teacher asks questions that demands factual recall (12)	a) Teacher asks questions that demand factual recall
	Teacher asks 'how many?'(19)	a) Teacher asks 'how many?'
Reasoning	Teacher encourages the pupils to think (10)	a) Teacher asks what do you think? b) Teacher tells pupils to discuss their ideas c) Teacher facilitates discussion d) Teacher questions the pupil's answer e) Teacher tells pupil to check work/answer f) Teacher questions pupil's response by gesture and non-committal statement g) Teacher questions pupil by gesture
	Teacher asks questions that demand an explanation (13)	a) Teacher asks why? b) Teacher asks pupils to tell how c) Teacher asks why did that happen? d) Teachers asks 'how do/will you know? e) Teacher asks pupil to clarify answer to make it more scientific
	Teacher asks questions that demand application of science (14)	a) Teacher asks questions that demand application of science
	Teacher asks 'what happens if?' (21)	a) Teacher asks 'what happens if?'
	Teacher asks questions that demand interpretation (22)*	a) Teacher asks questions that demand interpretation
	Teacher asks pupils to report a judgment (29)**	a) Teacher asks pupils to report a judgement
Open	Teacher asks pupils to describe what they will do (17)	a) Teacher asks pupils to report what they have done
	Teacher asks questions that demand comparison (20)	a) Teacher asks questions that demand comparison (20)
The Teacher Explains	Teacher uses representations of the real thing (4)	a) Teacher uses drawings, diagrams, photographs to represent real thing b) Teacher uses a model to represent the real thing c) Teacher mimes/acts the real thing d) Teacher uses pupils as representations of the real thing e) Teacher mimes a science concept
	Teacher uses pupil's answer as a basis for explanation to the class (9)	a) Teacher uses the pupil's answer, but rewords it make it more scientific b) Teacher uses the pupil's answer, but expands it
	Teacher explains (27)*	a) Teacher explains
Not Teaching	*Teacher gives wrong information (A)*	i) Teacher gives wrong information ii) Teacher affirms incorrect response
	Teacher misleads the pupils (B)	i) *Teacher misleads the pupils*
	Teacher ignores pupil's question (C)	*i) Teacher ignores pupil's question*
	Teacher ignores pupil response (D)	*i) Teacher asks a question but does not respond to pupil's answer* *ii) Teacher doesn't pay attention to pupil's response* *iii) Teacher acknowledges pupil's suggestion, but doesn't act on it.* *Iv) Teacher dismisses pupil's response*
	*Guess what I am thinking (H)***	i) *Guess what I am thinking*
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*	a) Teacher tells pupils to pose questions for research.
	Teacher reveals doubt positively (28)*	a) Teacher reveals doubt positively

6.11 Using the Engagement Schedule

The six categories, two with sub-sections identified were used to form the Engagement Schedule that would be used to analyse the participants' lesson transcript for evidence of engagement with science. Figure 6.5 shows all of ways in which the participants engaged with science that were identified during the development of the Engagement Schedule. During the analysis of the lesson transcripts if any new Incidents or Aspects were identified, these would be classified using the existing nine Categories, or if necessary a new Category would have to be formed. In the event, no further Aspects or Categories were formed. Thus the Engagement Schedule, was a shown in Figure 6.4.

I read each lesson transcript and using the schedule noted and plotted the Aspects of engagement with science for each participant. My colleague, a science education tutor, carried out the same process independently of me, and we then compared our findings. There were few differences, but most were Incidents that one or both of us had overlooked. He did spot an Aspect that I had missed. I found the first evidence of a participant directing pupils to a secondary source in SE2. My colleague identified this Incident in Esther's SE1 lesson. The pupils were discussing digestion, several pupils had already asked questions

E "Liver produces a liquid called bile and the gall bladder is the storage of it".
ch1 "Can you take out the gall bladder?"
E "I don't want to hear about all these medical complaints now, but you can use all the books and find out to tell us all later."

Thus the Category **The Teacher directs pupil to secondary sources** should have been formed during the analysis of the SE1 transcripts and not during SE2.

A further Incident of 4(a) 'Use of drawings, diagrams, photographs of represent the real thing', was identified in Luke's lesson, in which he used a video to show the pupils different weather conditions, to support his explanations of the water cycle.

6.11 The validity and reliability of the engagement schedule

The validity and reliability of the engagement schedule was sought in several ways. In order to be valid, the researcher must ensure that the data is corroborated. This was achieved by ensuring the participants read their transcripts, to confirm their accuracy. Other people read extracts of the transcripts to check that my identification of Incidents with engagement was valid. Also, the development of the engagement schedule over the three years of the main study has been shared with others, who have commented on it.

In order to be reliable, the researcher must demonstrate consistency in procedures and findings, that is the degree to which they are replicable, (Golby, 1993). Reliability has been demonstrated, by the careful and explicit explanation of how the engagement schedule was developed. Readers, with access to the data, should be able to track the development of the engagement schedule from the initial analysis of the SE1 transcripts to the analysis of the SE6 transcripts.

6.12 Summary

The engagement schedule was developed over three years of the main study. After each set of lesson observations, the transcripts were analysed for evidence of Incidents of positive and negative engagement with science. Each new Incident of engagement was described, with examples taken from the lesson transcripts. These Incidents were sorted into Aspects of engagement. These Aspects were sorted into the six Categories that made up the successive versions of the engagement schedule.

The final version of the Schedule was achieved after the analysis of the lesson transcripts of the fourth set of observations. It was made up of the following six Categories:-

1. **The Teacher Instructs**
2. **The Teacher Gives Information**
3. **The Teacher Asks Questions**
4. **The Teacher Explains**

5. **Not Teaching**

6. **The Teacher Directs Pupils to a Secondary Sources**

Categories 2 and 3 were further divided into sub- sections. Category (2) was divided in to sub-sections, **The Teacher Gives** direct **Information** and **The Teacher Gives** indirect **Information**. Category (3) was divided into three sub-sections, **The Teacher Asks** factual **Question**, **The Teacher Asks** reasoning **Questions** and **The Teacher Asks** open **Questions**. Each Category was made up of several Aspects of engagement with science. Two Categories that is, **The Teacher Gives Information** and **Not Teaching** contained negative Aspects of engagement with science.

The Final version of the Engagement Schedule was used to chart the participants' patterns of engagement with science for the periods that they were involved with the main study. The patterns of engagement identified by the researcher were checked independently by a science education tutor.

Chapter 7 introduces the ten participants and is the account of their patterns of engagement with science, described as ten individual case studies. Each participant's pattern of engagement is shown using Figure 6.4. Information from the post observation interviews is used to offer an explanation for each participant's pattern of engagement and each participants' practice, that is, engagement with science, is discussed in terms of the teacher types discussed in Chapter 3.

Chapter 7 Analysis of data- the changing patterns of engagement over time and the factors affecting engagement

7.1 Introduction-the case studies of the ten participants

This chapter describes the case studies of the ten participants. The case studies track each participant from the initial questionnaire used to select them for the main study to the post SE6 interview. The Engagement Schedule was used to chart each participant's pattern of engagement with science over time. The patterns show the number of Incidents for each Aspect of engagement for the participants. Where the number of Incidents does not fit a trend for that participant, the number is highlighted in bold and commented on. I have used evidence from the post observation interviews to try to explain these patterns of engagement. I have also attempted to identify what teacher type each participant best fitted. These types were *Linear Transmission* and *Social Constructivist*, two models of effective practice identified by Murphy et al. (2001) and the three teacher types by Askew et al. (1997), namely the *transmission*, *connectionist*, *discovery*, as well as the *co-learner*, as identified by Appleton (1995), see section 3.7. All participants best fitted more than one teacher type.

7.2 Individual case studies

The case studies vary in length as not all of the participants remained in the main study for the six SEs. Each describes the participant's pattern of engagement with science over time and the factors that may have contributed to these patterns. The case studies start with the information gathered via the initial questionnaire used to select them for the main study, for example, their pre course science qualifications, their feelings about teaching science before SE1 and what they think the purpose of primary science is. The participants' responses to some of the questions asked after each lesson observation are used to help explain their patterns of engagement with science.

An overview of the participants' School Experiences is shown in figure 7.1, italics indicate that the participant was not observed teaching or interviewed in person. Examples from the lesson transcripts and comments made by the participants in the post observation interviews and informal conversations are used to illustrate engagement with science and the participants' feelings about science and teaching science. The examples used to illustrate engagement have been selected to what teacher type the participant fits. The Engagement Schedule is used to show each participant's pattern of engagement with science, over the period of the main study.

Figure 7.1 An overview of the participants' School Experiences

Participant	SE1 Spring 1996	SE2 Summer 1996	SE3 Spring 1997	SE4 Summer 1997	SE5 Spring 1998	SE6 Summer 1998	The end of the main study Summer 1998
Veronica	Light 9-10 yrs	Sound 7-8yrs	*Taught in Cyprus*	*Taught in Cyprus*	*Taught in Cyprus*	*Taught in Cyprus*	*Not interviewed*
Ruth	*Not possible to observe.*	Skeleton and Muscles 8-9 yrs	Materials 9-10 yrs	Electricity 9-10yrs	*Travelling abroad*	*Travelling abroad*	*Postal Interview*
Mark	Electricity 9-10 yrs	Electricity 7-8yrs	*Travelling abroad*	*Travelling abroad*	*Human Body. pre SE3 8-9yrs Materials SE3 8-9 yrs*	*Sound SE4 8-9 yrs*	Post lesson interview
James	Forces 7-8yrs	*Not observed Ofsted Inspection*	Earth and Space 10-11yrs	Forces 10-11yrs	Earth and Space 8-9yrs	Forces 8-9yrs	Post lesson interview
Thomas	Magnetism 9-10yrs	Earth and Space 8-9yrs	Forces 5-6yrs	Minibeasts 5-6yrs	Living and Non-living 5-7yrs	Assessing Skills 5-7yrs	Post lesson interview
Peter	Forces 10-11yrs	Electricity 10-11yrs	Smoking 9-10yrs	Materials 9-10yrs	Electricity 9-10yrs	Ecosystems 9-10yrs	Post lesson interview
Luke	The Water Cycle 7-8yrs	*Not observed Ofsted Inspection*	Forces One pupil aged 9yrs	Electricity One pupil aged 9yrs	The Water Cycle 5-6yrs	Materials 5-6yrs	Post lesson interview
Esther	Human Body 10-11yrs	Minibeasts 7-8yrs	Living and Non-living 5-7yrs	Materials 5-7yrs	Materials 5-7yrs	*Not observed, as no longer teaching*	*. Postal Interview*
Mary	Electricity 9-10yrs	Plants 8-10yrs	Plants 10-11yrs	*Not possible to observe.*	Food chains 9-11yrs	Human Skeleton 9-11yrs	Post lesson interview
Rachel	Materials 8-9yrs	Electricity 9-10yrs	Plants 10-11yrs	Materials 10-11yrs	Minibeasts 10-11yrs	Drugs Education 10-11yrs	Post lesson interview

7.2.1 Veronica

Background

Veronica's degree subject was humanities. She had a GCSE in biology. Veronica did not feel at all confident to teach science, because " I've got no idea what to expect and I'm only a few steps ahead of the children". On the positive side Veronica said that the "children like science, so that helps". She also said "I'm quite excited about it, I'm trying to remember what I did at school, how far into science do you go with eleven year olds?" Veronica thought that the place of science as a core subject was justified because

> "science makes children immediately aware of everything around them apart from materials things, this is very important"

Before SE1 Veronica was looking forward to "the children's faces as they discover things about the world around them, fascinated". She was not looking forward to "disaster, experiments that don't match predictions and organisation of the lesson".

Figure 7.2 Veronica's pattern of engagement with science

Category	Aspects	SE1	SE2
The Teacher Instructs	Teacher instructs pupils about the task (3)	14	11
	Teacher acknowledges pupils' suggestions (23) *		
	Teacher invites questions from pupils (26) *		
The Teacher Gives Information			
Direct	Teacher affirms correct response (1)	3	5
	Teacher gives science information (5)	**14**	7
	Teacher gives science labels (6)		
	Teacher highlights health and safety (7)		
	Teacher answers pupil's question (15)		1
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)		
	Teacher rewords pupil's answer to make it more scientific (16)		
	Teacher exploits unforeseen occurrences in lesson (18)	1	
	Teacher overrides pupil response (E)		
	Teacher leads pupils to answer, but not necessarily understanding (F)	*1*	
	*Teacher reveals doubt negatively (G)**		
	Teacher anticipates future learning (25)*		
	Teacher and pupils chant/sing and do actions (30)**		
	Teacher tells pupil his answer is incorrect (31)**		
The Teacher Asks Questions			
Factual	Teacher reviews pupils' prior learning (2)	1	1
	Teacher encourages the pupils to observe (11)	9	7
	Teacher asks questions that demands factual recall (12)	5	2
	Teacher asks 'how many?'(19)		2
Reasoning	Teacher encourages the pupils to think (10)		
	Teacher asks questions that demand an explanation (13)	1	
	Teacher asks questions that demand application of science (14)		
	Teacher asks 'what happens if?' (21)	**9**	
	Teacher asks questions that demand interpretation (22)*		
	Teacher asks pupils to report a judgment (29)**		
Open	Teacher asks pupils to describe what they will do (17)	2	5
	Teacher asks questions that demand comparison (20)	2	4
The Teacher Explains	Teacher uses representations of the real thing (4)		1
	Teacher uses pupil's answer as a basis for explanation to the class (9)		
	Teacher explains (27)*		1
Not Teaching	*Teacher gives wrong information (A)*	*1*	
	Teacher misleads the pupils (B)		
	Teacher ignores pupil's question (C)		*1*
	Teacher ignores pupil response (D)	*3*	*3*
	*Guess what I am thinking (H)****		
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*		
	Teacher reveals doubt positively (28)*		

First School Experience (SE1)

For SE1 Veronica taught a class of 28 pupils, aged 9-10-11years. The science topic was Light and Sound. In the post lesson interview Veronica said her main concern for this lesson was how to evaluate the pupils' learning. The learning outcomes for the lesson were

for the pupils to know "when light hits concave mirrors it distorts the image so it is different from a convex mirror". Veronica said the pupils had met the objective, but she was "going to look at their books to make sure". However, she had drawn diagrams and written an explanation describing what happens when light hits concave and convex mirrors on the board for the pupils to see throughout the lesson. When I pointed this out to her during the interview she said, "I do tend to teach backwards. I start with the answer and then ask them the question". The following example from the start of the lesson shows this;

V "What might it do to the image?" *(holds up a convex mirror)*
ch1 "It will get wider"
V "Any other answers?"
ch2 "Yes it will get wider"
V "Yes it will spread it, it will go wide, it will tend to cast it out and portray it wider. I want you to write your predictions down"

This is an example of incident F (iii) ' *Tells pupils the answer and then poses the question*'. Veronica asks the pupils to predict something, after she has just told them the correct answer. Although the lesson was designed to involve the pupils in an investigation, Veronica told them the outcome before they had an opportunity to investigate.
There were 14 Incidents of 'giving information' and 9 Incidents of asking 'what happens if', as Veronica asked the same questions of each small group.

Veronica ended the lesson by asking the pupils what they had found out and summing up what they should have found out. The following example shows how her summing up would probably have led to misunderstanding.

V "What did you see in the mirror? What you saw depends on how you hold your mirror. *The pupils were using metal spoons as mirrors.* In the concave it makes your face smaller, in the convex mirror it spreads your face out. Basically that's what happens".
ch1 "Mine was the other way round"
V "Yeah, that happens sometimes *laughs*, copy the diagrams from the board and
write a sentence to explain what is going on in each of the two diagrams"
Diagrams and explanation already written on the board.

In this example Veronica and ch1 both used the terms concave and convex, although ch1's use was not explicit. It could be that neither knew what the other understood these terms to mean. The pupil may have made the same observations that Veronica made about the images in the mirrors, but simply mislabelled the types of mirror.

I have called the problem that can occur when pupils use newly introduced terminology, the *concept / label conflict* Khwaja (1996). The teacher cannot be certain whether or not the pupils have failed to make a careful observation / grasp the concept or simply that they have not remembered what new label applied to what concept / item.

However, Veronica's response could show that she did not know what image would be seen in concave and convex mirrors. Even though she had written a full and correct explanation of what happens to light when it hits concave and convex mirrors on the board. Here Veronica was not able to link phenomena with theory. Light spreads out on a convex mirror, but the image is smaller. Light is brought 'closer' in a concave mirror, but the image is larger when the mirror is held close. Veronica was describing the image in terms of what happens to the light and this caused confusion for her and the pupil. Veronica did not challenge ch1 and gave the pupils incorrect information.

Second School Experience (SE2)

For SE2, Veronica taught a class of 25 pupils aged 7-8 years. The science topic was Sound. Veronica said her main concerns about this lesson were the pupils' behaviour (especially the health and safety aspect of pupils using scissors to make holes in the paper cups) and lack of resources. The pupils spent most of the lesson making string telephones and testing them. The learning outcome for the lesson was "that the pupils would experience sound travelling through different materials". Veronica said that the pupils had met this outcome as "we've done it before and this is a bit of reinforcement". However during her limited discussions with the class it was clear that several pupils had not understood the purpose of the activity, even though they were all able to make a successful telephone. Many of the pupils used their telephones to talk to themselves, saying it was clearer than when they weren't using the telephones, or when they were using the telephones in pairs to talk to other pupils. The

lesson lacked a focus. Veronica, as in SE1, told the pupils the answers, without challenging their responses, as the following example shows.

V	"What else happened"
ch1	"We did it round the corner" *the pupils had been instructed to try the telephones with one of the pair standing around a corner*
V	"Could you hear it?"
ch1	"It was louder because it was round the corner"
V	"When you heard it round the corner could you hear it just a little bit?"
ch1	"Louder"
V	"Was it louder?" *disbelieving voice*
ch1	"Yes, it was a little bit"
ch2	"I could hear it a little bit"
V	"When? when it wasn't straight?"
ch2	"When it wasn't straight"
V	"Yes, that's right"

Here Veronica interpreted ch1 saying a "little bit" as *quiet*, rather than as *a little bit louder*; they were therefore talking at cross-purposes.

All of the pupils made a successful string telephone and tested them, but there was very little discussion about how they worked. Veronica told the pupils when the telephones worked best and then asked the pupils to test them.

In interview Veronica said that she did not feel confident to teach science because "I'm not very good in science, sometimes I handle it alright. I need a good science base, I just faff about, I haven't got time to research, I just have to knock things up". Even though she had taught the topic Sound on SE1, Veronica said "I've done this on SE1, I don't know any more, that's my fault, I didn't research anything. I am defunct when I get home".

When asked how she would recognise a good science teacher Veronica said, "I don't know really, how about how they talk to the children? Yeah, they would explain things to them, they wouldn't just tell them". For both SE1 and SE2, Veronica, *told* rather than *explained* concepts to her pupils.

Veronica leaves the main study

Veronica was very despondent. She was thinking about applying for a teaching post in Cyprus. Veronica did apply for and get a teaching post in Cyprus. I did not have contact with Veronica after the end of her PGCE year.

Veronica's pattern of engagement with science and teacher type

Veronica was only observed during her PGCE year, so it is difficult to draw any firm conclusions about her teaching style, see figure 7.2. Veronica's lack of confidence in her subject knowledge was because; she had not done any reading in preparation for SE2.

In both of Veronica's lessons she reviewed the pupils' previous learning. The pupils did investigations that built on prior learning. In SE1 the pupils looked at images in concave and convex mirrors and in SE2 the pupils made string telephones to find out if sound travelled better through a solid, string or through the air.

But in both lessons, Veronica did not seem certain about what she wanted the pupils to gain from the investigations. It may be that Veronica was unsure of the science herself, or that she was not sufficiently engaged with the pupils to be bothered to ensure that the learning was appropriately summarised. It is likely to be the former, as Veronica did not rate her own subject knowledge and understanding very highly and she said that she had not done any reading in order to prepare for the lessons.

Veronica planned appropriate activities to illustrate practically the concepts she wanted the pupils to grasp, but because she was insufficiently prepared, she was unable to engage adequately with the pupils' observations that questioned her understanding. Veronica best fitted the *transmission* teacher type. She was clear about what she wanted the pupils to know and allowed them to carry out investigations that would support the learning of the lessons' concepts. However, Veronica did not question or challenge the pupils' responses and she told rather than explained the correct answers. She was unable to link the practical experience to the correct science explanation.

7.2.2 Ruth

Background

Ruth's degree subject was computer science. She had GCE 'O' levels in biology, chemistry and physics. Ruth felt very confident to teach science, because "science is one of my favourite subjects". She said "science has changed a lot since I did it at school" but "I hope my confidence in the subject will encourage the children". Ruth thought that the place of science as a core subject was justified because

> "science is the basis of all things therefore the subject area covered is vast, it's a subject that can encourage inquisitiveness in children"

Before the start of SE1, Ruth was most looking forward to the "children's enthusiasm", and least looking forward to the "lack of resources and/or support from the school".

Figure 7.3 Ruth's pattern of engagement with science

Category	Aspects	SE1	SE2	SE3	SE4
The Teacher Instructs	Teacher instructs pupils about the task (3)		12	14	10
	Teacher acknowledges pupils' suggestions (23) *			2	
	Teacher invites questions from pupils (26) *				
The Teacher Gives Information					
Direct	Teacher affirms correct response (1)		10	12	8
	Teacher gives science information (5)		2	3	**8**
	Teacher gives science labels (6)				3
	Teacher highlights health and safety (7)			**5**	
	Teacher answers pupil's question (15)				
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)				
	Teacher rewords pupil's answer to make it more scientific (16)				
	Teacher exploits unforeseen occurrences in lesson (18)				
	Teacher overrides pupil response (E)				
	Teacher leads pupils to answer, but not necessarily understanding (F)				
	*Teacher reveals doubt negatively (G)**				
	Teacher anticipates future learning (25)*				
	Teacher and pupils chant/sing and do actions (30)**				
	Teacher tells pupil his answer is incorrect (31)**				1
The Teacher Asks Questions					
Factual	Teacher reviews pupils' prior learning (2)				
	Teacher encourages the pupils to observe (11)		12	11	9
	Teacher asks questions that demands factual recall (12)		2	3	10
	Teacher asks 'how many?'(19)		6	**10**	2
Reasoning	Teacher encourages the pupils to think (10)			2	
	Teacher asks questions that demand an explanation (13)			8	
	Teacher asks questions that demand application of science (14)			2	
	Teacher asks 'what happens if?' (21)			**8**	
	Teacher asks questions that demand interpretation (22)*		**8**	**9**	**8**
	Teacher asks pupils to report a judgment (29)**				
Open	Teacher asks pupils to describe what they will do (17)		**7**	**8**	2
	Teacher asks questions that demand comparison (20)		**9**	**8**	
The Teacher Explains	Teacher uses representations of the real thing (4)				1
	Teacher uses pupil's answer as a basis for explanation to the class (9)				
	Teacher explains (27)*				
Not Teaching	*Teacher gives wrong information (A)*				
	Teacher misleads the pupils (B)				
	Teacher ignores pupil's question (C)			*1*	*1*
	Teacher ignores pupil response (D)				
	*Guess what I am thinking (H)****				
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*				
	Teacher reveals doubt positively (28)*				

First School Experience (SE1)

I was unable to observe Ruth teaching on SE1 as her class was out on a visit when I had arranged to observe her.

Second School Experience (SE2)

For SE2, Ruth taught a class of 33 pupils aged 8-9 years. The science topic was The Skeleton and Muscles. Ruth said her main concern for this lesson was that the pupils had not had much experience of doing science investigations. The learning outcome (on Ruth's written plan) was for the pupils to "make investigations into muscle strength and to work in groups". Ruth worked with groups of six pupils at a time, whilst the rest of the class got on with other non-science based tasks. During the interview, Ruth said that the learning outcome was for the pupils to "understand fair testing and designing (*sic*) a results table", she said that the pupils had met the outcomes. After an initial introduction with the pupils, there was little discussion once the pupils got on with the task. Ruth did not discuss with the pupils why they should find out which of their legs was stronger. These initial discussions about the task got briefer for each group that Ruth worked with. There was only a very brief lesson conclusion. At about two thirds of the way through the lesson Ruth said to me "I'm not doing any more groups, I've had enough".

Ruth said that a confident science teacher was one who "kept the children on task, the children would be interested in the task, and the children and I could see the reason for the task", but she did not tell the pupils why they were doing the investigation. This was also the case in her SE3 lesson.

Ruth asked 8 questions that demanded interpretation and 9 that demanded comparison, but as for Veronica, these were similar questions asked to small groups.

Third School Experience (SE3)

For SE3 Ruth taught a class of 33 pupils aged 10-11years. The pupils worked in small groups devising and carrying out a test to find out which carrier bag was strongest. Ruth interacted with each group separately and guided them towards using bibles as weights to find out how many the different carrier bags could hold, hence 10 'how many' questions. As in SE2, there was little discussion of what the purpose of the test was, that is, why were the pupils trying to find which bags were stronger and how might any difference be explained. Ruth spent most of the lesson in brief discussions with each group, thus there was little opportunity to engage with science at any depth. The pupils *concluded* that *Marks and Spencers* carrier bags were the strongest. Very little attempt was made to identify features of a strong carrier bag, in terms of material or structure. In fact most of the bags were identical

apart from their logos. In both SE2 and SE3 Ruth concentrated on helping pupils to identify the feature of a fair test, that is, that all variables except one should be the same. In neither SE did Ruth relate the findings of the fair test to any subject knowledge or understanding. Being able to draw a conclusion based on the fair test seemed to be sufficient. At the end of Ruth's two lessons, the pupils might have understood what a fair test is and how to construct one, but it is unlikely that they had gained any further knowledge and understanding. Like Veronica, Ruth answered the questions that she posed to the pupils, as the following example shows;

R	"How are you keeping it safe?" *the carrier bag full of books*
ch1	"We're going to be careful"
R	"How? You're not going to dangle it over you feet?"
W/C	"No!" *laughing*
R	"Good".

Ruth did not question the pupils to check their understanding.

Fourth School Experience (SE4)

For SE4, I observed Ruth teaching Electricity to her class (the same class as for SE3, pupils aged 10-11years). The pupils had been given two wires, a battery and a bulb; their task was to make a circuit and record how they did this, using the conventional electricity symbols. Ruth went to groups who sought help, but she did not initiate many discussions with them. All of the pupils were able to make a circuit; most had done this activity before in year 2. Ruth said the lesson was "so boring", there is so "little equipment, I hardly do any science, I struggle to find equipment". Ruth asked 10 questions that demanded factual recall, that is, the name of the circuit components and 8 questions asking pupils to interpret electricity symbols.

Ruth leaves the main study

Ruth was very disenchanted with the school and left, saying "all of my confidence has gone, I feel like I'm useless, I can't wait to leave". Ruth left the school at the end of the year to teach in New Zealand. I did not observe Ruth teaching again.

Sixth School Experience

When she returned from abroad, Ruth did supply teaching. She completed a questionnaire that I sent (which was similar to the one that I used to interview the participants after SE6). Ruth said that her main concerns when teaching science were "Am I motivating the class? Is the concept clear? Have I met my objectives?" Ruth thought that her own scientific knowledge was good.

At the end of the main study

She thought that the main benefit of teaching science to primary pupils was that

> "It gives them an investigative approach to life. They will rely less on taking information as gospel and hopefully be more curious about things"

Ruth's view of the importance of science had not changed significantly over three years. She still thought that science helped pupils to be inquisitive. However, none of the lessons I observed Ruth teaching allowed the pupils to be inquisitive.

Ruth did not continue to teach the following year, she took up a post as an accountant.

Ruth's pattern of engagement and teacher type

Ruth was observed three times for the main study, see figure 7.3. Ruth's attitude, like Veronica's was very much influenced by her well being in school.

All three lessons were very teacher led, so it is not surprising that the number of Incidents of teacher instruction was high. In all three lessons, Ruth organised the class so that the pupils worked in small groups. This meant that during the main activity part of the lesson, Ruth taught a series of mini lessons. In SE2 and SE3, Ruth asked lots of reasoning questions, but it was several repetitions of the same question, as she went from group to group, for example, for SE3, all groups were asked

"what will happen if you put too many bibles in the bag?"

For SE3, all groups were asked to interpret possible results posed by Ruth, when she asked

"what if one bag broke with ten bibles and another with twelve?"

For SE4, Ruth's interaction comprised mostly giving instructions, asking factual recall questions and affirming a correct response, as the lesson was mostly revision. Ruth's SE4 lesson provided lots of examples of IRF, that is, initiation - response- follow-up, (Wellington and Osborne 2001). Here the teacher asks a question, to which there is usually just one answer, and then indicates if the answer is acceptable. Ruth asked questions that 'demanded factual recall', she 'affirmed the correct responses'. She reminded pupils of facts, by giving them information. For SE1 and SE3, Ruth best fitted the *discovery* teacher type, in that she provided experiences where the pupils to 'discover' things for themselves through fair testing. However, because Ruth did not identify what she wanted the pupils to learn, there was little discovery of science knowledge and understanding. I would characterise Ruth as a *fair tester without a purpose*. For SE4, Ruth adopted a more *transmission* mode. She gave the pupils a task, making a circuit, which they could already do. Ruth told the pupils what the conventional electricity symbols were, and they copied them from the board. Ruth said that she had taught in this way, as she "struggled to find equipment" and so the activity was limited. There were fewer Incidents of engagement with science in SE4 compared to SE2 and SE3, as once Ruth completed the brief question and answer sessions, she left the pupils to get on with the tasks. There was no evidence that Ruth attempted to make *connections* between areas of knowledge and there was no evidence of her working with the pupils to construct knowledge, indeed there was little knowledge development for SE2 and SE3.

7.2.3 Case study of Mark

Background

Mark's degree subject was economics. He had GCE 'O' and 'A' levels in physics and GCE 'O' levels in chemistry, human biology and general science. Mark felt confident to teach science, but said "I'll need to do a lot of reading before teaching it" and "I'll be OK with a lot of practice". However, he thought that "Science has changed a lot since I did it at school" and that "Science is a vital step in understanding the world in which we live and a very varied, interesting and exciting subject". Mark thought that the place of science as a core subject was justified, because

> "I believe it is vital in the steps towards a greater understanding of the world in which we live. The breakdown in (*into*) three broad headings of chemistry, biology and physics, are all very important in their own right"

Before SE1, Mark was looking forward to "exciting investigations", but concerned about "resources at school and I'm not exactly sure of the children's previous knowledge, I need to find out in more detail".

Figure 7.4 Mark's pattern of engagement with science

Category	Aspects	SE1	SE2	PreSE 3	SE3	SE4
The Teacher Instructs	Teacher instructs pupils about the task (3)	5	6	**14**	6	**13**
	Teacher acknowledges pupils' suggestions (23) *			1		
	Teacher invites questions from pupils (26) *			3		1
The Teacher Gives Information						
Direct	Teacher affirms correct response (1)	8	10	6	8	6
	Teacher gives science information (5)	5	7	6	4	5
	Teacher gives science labels (6)	1	4			
	Teacher highlights health and safety (7)			1		
	Teacher answers pupil's question (15)		1	3		
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)		1	1		
	Teacher rewords pupil's answer to make it more scientific (16)		2	1		
	Teacher exploits unforeseen occurrences in lesson (18)					
	Teacher overrides pupil response (E)					
	Teacher leads pupils to answer, but not necessarily understanding (F)					
	*Teacher reveals doubt negatively (G)**					
	Teacher anticipates future learning (25)*					
	Teacher and pupils chant/sing and do actions (30)**					
	Teacher tells pupil his answer is incorrect (31)**					
The Teacher Asks Questions						
Factual	Teacher reviews pupils' prior learning (2)			1		
	Teacher encourages the pupils to observe (11)	6	4	8	**18**	**21**
	Teacher asks questions that demands factual recall (12)	2	4	4	1	
	Teacher asks 'how many?'(19)					1
Reasoning	Teacher encourages the pupils to think (10)	1	1	3	3	
	Teacher asks questions that demand an explanation (13)	1	3	2	1	
	Teacher asks questions that demand application of science (14)		3	1	1	
	Teacher asks 'what happens if?' (21)	5	2	8	**15**	1
	Teacher asks questions that demand interpretation (22)*			3		1
	Teacher asks pupils to report a judgment (29)**					
Open	Teacher asks pupils to describe what they will do (17)	6	3	2	5	1
	Teacher asks questions that demand comparison (20)					5
The Teacher Explains	Teacher uses representations of the real thing (4)					
	Teacher uses pupil's answer as a basis for explanation to the class (9)					
	Teacher explains (27)*					
Not Teaching	*Teacher gives wrong information (A)*					
	Teacher misleads the pupils (B)					
	Teacher ignores pupil's question (C)					
	Teacher ignores pupil response (D)	*2*	*3*			
	*Guess what I am thinking (H)***					*1*
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*			1		
	Teacher reveals doubt positively (28)*					

First School Experience (SE1)

For SE1, Mark was teaching class of 30 pupils, aged 9-10years. The topic was Electricity and Magnetism. I observed a "finishing off lesson". The pupils were making a simple circuit, designing on/off switches, drawing circuits using the conventional symbols and writing up what they did. As with Ruth and Veronica, Mark was keen that the pupils should know the correct answers, as this example shows;

M	"Who can tell what the source of power was in the circuit? Where does the power come from?" *taps the battery*
ch1	"Battery"
M	"Well done, which part of the circuit carries the electricity around?" *taps the wires*
ch2	"Wires"
M	"Yes"

Mark was unaware that he had done this and realised that he couldn't be sure what the pupils actually knew. In interview he said "You want them to know it, I panic if I think they haven't got it".

Second School Experience (SE2)

For SE2, Mark taught a class of 28 pupils aged 7- 8 years. The science topic was again Electricity. The aim of the lesson was for the pupil to "complete their quiz cards and to use appropriate scientific language to describe and explain what is happening". Mark said, "I'm happy that they realise that aluminium strips mustn't touch, I'm not sure what they know about insulators, we only really touched on it".

The activity was straightforward, and the pupils had little difficulty with it. Throughout the main activity, most of Mark's interactions were to do with the task, they were not to do with the science. However, Mark did include a plenary, in which he questioned the pupils on how the quiz card worked, using the terms conductor, insulator and circuit.

Asked about how he felt teaching science Mark said "I know what I've got to get across, I enjoy science, they enjoy it, but I don't feel as comfortable with it, I'm not sure where it's going". Mark did not attempt to make any connections with other areas of science, not did he anticipate future learning. The pupils were clear about what they had to do, but there was no discussion as to why they were doing it.

Mark leaves the main study

At the end of the PGCE year Mark travelled abroad for a year. I observed him teaching science in the third year of the main study, which was Mark's first year of teaching post qualification that is, his SE3 and SE4. I also made an additional observation of Mark in his first term of teaching post qualification, that is, pre SE3; this was to 'welcome' him back into the main study after being abroad for a year.

Third School Experiences (pre SE3 and SE3)

Mark taught the same class of 32 pupils aged 8-9 years, for the pre SE3, SE3 and SE4 observations. The science topic for the pre SE3 observation was The Human Body. Mark was not "worried about the interest, but of carrying out the practical in the confines of the classroom". The class was doing an investigation to find out the effect of exercise on pulse rate. The pupils had planned the investigation in the previous lesson. In interview Mark said that the majority understood that pulse rate increases due to exercise, but was unsure how well they were able to plan an investigation. During the lesson, there were 14 Incidents where Mark instructed the pupils about the task. This was because the class carried out the main activity in pairs or small groups, so Mark gave the instructions to each pair/small group, hence many of his instructions were repeated.

Mark would have liked to be able to observe experienced teachers teaching. He also felt isolated because there was no parallel class teacher to plan with.

Mark taught the topic Materials for SE3. Mark said his main concern was "how to make it interesting, the planning part of it, they'll be more interested tomorrow when they look at the results". The topic was changing states, the pupils were planning an investigation to find out what would happen to materials when they are cooled. The main focus was for the pupils to understand the importance of predicting when planning. In interview Mark said he thought that the majority of pupils were able to predict. However, Mark was unsure about the difference between i) predicting the outcome of something and ii) understanding the importance of predicting when planning an investigation. Mark thought that he was focussing on (ii), but he was actually doing (i). Hence there were 15 "What will happen if" questions. Again the class was organised into small groups for the main activity, so Mark

asked 18 questions where the pupils were required to observe, that is, what did the materials look/feel like at room temperature. Mark asked the same questions to several of the groups.

Fourth School Experience

Mark taught the topic Sound for SE4. The objectives were for the pupils to "understand that sounds get fainter as they travel from the source, to understand that sounds can be made in many ways and to generate a table with help". As with SE3, there were a lot (13) Incidents of giving instructions and 21 Incidents of asking observation questions, as Mark interacted with small groups.

The end of the main study

Mark had just completed his first year post qualification. His view on the value of teaching primary science was;

> "Enjoyment, the fascination of finding out about things and inquisitiveness, for them to find out more, to question why things are as they are, and not to just accept them"

After two years Mark's view of why primary pupils should learn science, moved away from an acquisition of knowledge and understanding, to promoting inquisitiveness and not simply accepting things. His new position was very similar to Ruth's.

Mark's pattern of engagement and Teacher Type

Mark was observed five times during the main study, see figure 7.4. Mark provided lots of opportunities for the pupils to carry out practical work. He was very keen that the pupils should leave the lesson knowing and / or understanding more science, this often led to him *telling* rather than *teaching* science. However, unlike Veronica this was not because he had not prepared the lessons. Mark was very keen that the pupils should find out things for themselves, but he did not always make it clear why the pupils were carrying out the investigations. For SE4, the pupils spent a lot of time describing the sounds that a random collection of items made and recording the sounds in a table. The activity seemed to lack purpose. I would characterise Mark as *find out for yourselves, but if you can't I will tell you.* Mark best fitted both the *discovery* and *transmission* teacher types. I think that Mark was more a discovery teacher, but his concern that pupils must 'learn', meant that he adopted a more transmission mode.

7.2.4 James

Background

James's degree subject was English literature. He had a GCE 'O' level in physics. James did not feel confident to teach science. He felt that he was "only one step ahead of the children" so "I'll need to do a lot of reading before teaching it" but "I'll be okay with a lot of practice". James thought that the place of science as a core subject was "partially justified". This he said was because

> "science is more of a hands on subject than the other two (*English and Mathematics),* this allows kids with deficiencies in these areas to try something less abstract and also to see how maths and English can be applied to real situations. However, the sort of science taught in primary schools is not especially likely to lead to a massive change in the take-up rate for science in secondary schools"

Figure 7.5 James's pattern of engagement with science

Category	Aspects	SE1	SE2	SE3	SE4	SE5	SE6
The Teacher Instructs	Teacher instructs pupils about the task (3)	10		6	8	6	2
	Teacher acknowledges pupils' suggestions (23) *						
	Teacher invites questions from pupils (26) *			1			
The Teacher Gives Information							
Direct	Teacher affirms correct response (1)	4		5	6	6	4
	Teacher gives science information (5)	4		8	4	6	8
	Teacher gives science labels (6)			2		3	
	Teacher highlights health and safety (7)			1			
	Teacher answers pupil's question (15)						
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)						
	Teacher rewords pupil's answer to make it more scientific (16)			1		1	1
	Teacher exploits unforeseen occurrences in lesson (18)						
	Teacher overrides pupil response (E)						
	Teacher leads pupils to answer, but not necessarily understanding (F)						
	*Teacher reveals doubt negatively (G)**						
	Teacher anticipates future learning (25)*						
	Teacher and pupils chant/sing and do actions (30)**						
	Teacher tells pupil his answer is incorrect (31)**			2			1
The Teacher Asks Questions							
Factual	Teacher reviews pupils' prior learning (2)	2		1			
	Teacher encourages the pupils to observe (11)	9		9	8	3	15
	Teacher asks questions that demands factual recall (12)			7	8	**20**	12
	Teacher asks 'how many?'(19)				8		10
Reasoning	Teacher encourages the pupils to think (10)	1					
	Teacher asks questions that demand an explanation (13)	1					2
	Teacher asks questions that demand application of science (14)	1			1		
	Teacher asks 'what happens if?' (21)	2		9	7		6
	Teacher asks questions that demand interpretation (22)*				4		1
	Teacher asks pupils to report a judgment (29)**						
Open	Teacher asks pupils to describe what they will do (17)	4			5		5
	Teacher asks questions that demand comparison (20)						
The Teacher Explains	Teacher uses representations of the real thing (4)						
	Teacher uses pupil's answer as a basis for explanation to the class (9)						
	Teacher explains (27)*			2			1
Not Teaching	*Teacher gives wrong information (A)*						
	Teacher misleads the pupils (B)						
	Teacher ignores pupil's question (C)	*1*		*1*			
	Teacher ignores pupil response (D)	*3*		*5*	*3*	*1*	*3*
	*Guess what I am thinking (H)***						
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*						
	Teacher reveals doubt positively (28)*						

First School Experience (SE1)

For SE1, James taught a class of 29 pupils, aged 7-8 years. The topic was Bridges (Forces). James was apprehensive about teaching this topic saying, " I have no prior knowledge. I am still unsure of the children's abilities. I am not at all excited by bridges". The lesson objectives were for the pupils to "1. learn what a beam bridge is, 2.that a bridge can sag under its own weight and 3. that folding a light material like paper makes it stronger / more rigid". In interview James said that 30% met the first objective, none the second and 60% the third. He said that the "evidence I would trust is what they write up". His main concern was "What I'm going to do and how I'm going to talk to them, how to tone down the concepts, rephrasing them", he thought that the science required at this level was "pretty basic".

It was a practical lesson, which allowed for a wider range of engagement with science processes. However, there was little discussion about the reasons why some shapes were stronger than others. As with the previous participants, James was keen that the pupils should know the correct answers. He seemed at the end of his tether, when he used, what I have called a *village idiot voice*, to *appeal* to the pupils to share his view of what shape made a strong bridge. This is where James chanted the answer in a funny voice, and the pupils repeated what he had said. There was no explanation, so it was unlikely that there was much understanding. The following example illustrates this;

J	"Which ones are strongest?" *points to squares and triangles drawn on board*
ch1	"Squares"
J	"Are you sure? can you remember what you did with Ms X? *class teacher*
ch1	"It was a triangle"
J	" Yes a triangle is the strongest" *village idiot voice* "So which ones are the strongest?" *points to squares and triangles on the board*
W/C	"Triangles!"
J	"Yes, these ones, we know that these three" *points to triangles* " because they are triangles"

Second School Experience (SE2)

I did not observe James on SE2, as Ofsted was inspecting his school.

Third School Experience (SE3)

James got a post in a primary school where I observed him teaching for SE3 - SE6. For SE3 and SE4 James taught the same class of 30 pupils, aged 10-11years. The SE3 topic was Earth and Space, the main focus was for the pupils to know that "the Earth moves and the Sun stays still", which he thought that most of the pupils understood. The main concern for James was that "the subject is very dry, the overall thing to do with night and day is difficult. I have a problem trying to break it down to manageable chunks, without boring them stupid". He invited pupil interventions, but did not always welcome them. In the following example he *baffled the pupil with science* that is, he gave an inaccessible explanation;

J	"So the Earth is moving and the Sun stays still"
ch1	"Yes sir, the Sun is moving because the universe is expanding"
J	"Yes, do you know the word pedantic?"
ch1	"No"
J	"Well that's a new word for you *sarcastic tone,* you're right the Sun is moving as the Universe expands, but everything is moving in relation to each together, so we still see things in the same way, okay?" *usual tone, but very fast*
ch1	"okay" *shrugs*

James asked a lot of questions, but many of them had little to do with the lesson objective, as this question at the beginning of the lesson shows;

J	"Can anyone give me a brief idea of how the Sun came about?"

Fourth School Experience (SE4)

For SE4 the topic was structures. The lesson content was almost identical to that on James's SE1. At the end of the lesson James said to me "That was terrible, you've come in twice and it was awful! I can do this job really!" Most of the lesson was spent on whole class discussion, however, when the pupils did not get the correct answer or if they did not understand the concept James simply told them or abandoned the discussion, as the following example shows;

J	"Okay, why is the triangle the strongest?"
ch1	"It has three sides and three angles"
J	"Okay"
ch2	"If you put something at the top the weight is equally spread out to support it"

J "Good, any other principles? Why fold it? *the paper* Why not just put it there?"
ch3 "It's kind of, well you know"
ch4 "You can bend it"
J "You can bend it? What are you getting at?"
ch4 "Because it's easier to use"
ch1 "What was the question?"
J "Well it doesn't matter, no one remembers anyway. Any basic principles we can skip, because you've got it already"

A change in James's teaching role

James stayed in the same school for SE5 and SE6, where he taught science to a class of 28 pupils aged 8-9years. The school's curriculum had altered, so that James taught English and philosophy throughout the school, but he taught some science to his own class. He was the school's English coordinator.

Fifth School Experience (SE5)

The SE5 science topic was again Earth and Space, as it had been for SE3. James wanted the pupils to know "how the Earth and Sun originated, the difference between astrology and astronomy and that the Earth orbits the Sun once a year". Following a question/ answer session, where James asked 20 factual recall questions, the pupils did a role-play of the *Big Bang*. They played the part of matter, before, during and after the Big Bang. James was the first of the participants to use drama to model a science concept. In interview James said that he was worried that "It felt a bit unfocussed, a bit self indulgent". He said, however, that the pupils had met and some exceeded the learning outcomes.

I would agree with James that the lesson was unfocussed. A lot of time was spent talking about the Big Bang, a discussion, that only involved a few pupils. The role-play consisted of the pupils racing and dancing around the hall. There was very little on the movement of the Earth around the Sun.

James was interested in reading popular accounts of the Big Bang and quantum physics and so he spent time discussing these with the class, rather than getting to grips with the essential science curriculum, as the opening of his lesson shows;

J " We're going to be looking at some cosmic things. What did we look at in creative arts week?"
ch1 "The Big Bang"
J "Who invented the Big Bang?"
ch1 "Stephen Hawking"
ch2 "And Einstein"

James was concerned that he had not taught much science and so felt "de skilled". Likewise, James was concerned that his science subject knowledge had not developed, because "I don't really teach science so I don't read up, I've got too much to do with English".

Sixth School Experience (SE6)

For SE6, James taught a lesson for the topic Forces. He said that the focus was the "idea of displacement linked with water pushed out of the way with upthrust". Just before the lesson James said to me that "I was going to do an experiment, but they're all a bit mental today! So I've changed it". The whole lesson was a discussion of what would happen when an object was placed in a jar of water and then discussing what actually happened when the object was placed in the jar of water. James asked 15 observation questions and 10 'how many' questions as he asked the pupils to read the scale on the measuring cylinder. There was no mention of upthrust.

At the end of the main study

James said that a daily science lesson was more beneficial than a daily mathematics lesson because "the skills in science are important for life". He thought that the main benefits of science for primary pupils were

> "for them (*pupils*) to be interested in what is going on around them. Getting a buzz about something they know. Thinking about things in a theoretical way"

After three years James's position had changed completely. Before SE1 he thought that science was beneficial because it was less abstract than English and mathematics; by SE6, he thought that science was abstract. This may have been because of the topics he taught that is, Forces, and Earth and Space.

James felt that compared to his PGCE "Structuring questions is easier. I can manage whole class discussions. I can pull the class back *when the discussion goes off at a tangent* this was a big fear when I was a student".

James's pattern of engagement and teacher type

James was observed for all SEs apart from SE2, see figure 7.5. James's main subject was English and he was particularly interested in literature. James continued to teach at this school when the main study ended. At Key Stage 2 (pupils aged 7-11) the pupils at James's school followed a secondary school style timetable, that is, teachers taught their specialised subject to all classes. Thus James spent most of his time teaching English and philosophy across Key Stage 2. I am not sure if James was keen to engage the pupils with literature, or if he was keen to impress me with his knowledge, but all of his lessons from SE3 to SE5 contained literary references. For SE3 a lesson about the Earth orbiting the Sun, James read a poem about the Catholic Church and propaganda. For SE4, a lesson about the forces acting on bridges, James said that the plastic bricks were a metaphor for a bridge and that it was impossible to have a fair test because of the uncertainty principle. James did not explain what he meant by the uncertainty principle. For SE5, a lesson about the Earth orbiting the Sun, James read the Ted Hughes poem 'Cat and Mouse'. James also engaged the pupils in discussion, often wandering away from the lesson focus. Often the class discussions involved James and just a few pupils, with the others listening or switching off. James also included the use of drama in his lessons, for SE3 the pupils acted out the Earth orbiting the Sun, for SE5 the pupils used drama to show the Big Bang theory. I would characterise James as *encouraging the more able pupils to explore their ideas through discussion,* but how much this discussion contributed to the class's understanding of the science concepts was not clear. I am not sure if James sidestepped the science because he had difficulty explaining it, or if he simply was not interested in it. James's passion for English was evident in all of his lessons. James best fitted the *discovery* teacher type, but like Mark, he also adopted a *transmission* mode, when the pupils did not grasp the ideas through discussion. Thus Mark would best fit the *Linear Transmission* model. As he said in interview for SE6, his main concern was "Am I articulating clearly enough for the kids, is it a clear and logical sequence? Getting ideas into their long term memory".

7.2.5 Thomas

Background

Thomas's degree subject was history. He had no pre course qualifications in science. Thomas felt confident to teach science, despite saying that "I'll need to do a lot of reading before teaching it" and "I'll be OK with a lot of practice". However he also said that "Children like science so that helps" and "Science can be fascinating, it is never or should never be boring. Thomas thought that the place of science as a core subject was justified because

> "It's a subject never alone, but very much part of many other subjects, and very necessary for the development of a questioning, thinking mind"

Before SE1, Thomas was looking forward to "investigations" but not "Having to know my subject perfectly".

Figure 7.5 Thomas's pattern of engagement with science

Category	Aspects	SE1	SE2	SE3	SE4	SE5	SE6
The Teacher Instructs	Teacher instructs pupils about the task (3)	7	**14**	6	5	4	3
	Teacher acknowledges pupils' suggestions (23) *						1
	Teacher invites questions from pupils (26) *						1
The Teacher Gives Information							
Direct	Teacher affirms correct response (1)	5	6	10	13	11	10
	Teacher gives science information (5)	**13**	**17**	2	10	3	8
	Teacher gives science labels (6)		1	2	2		
	Teacher highlights health and safety (7)	1		1	4	2	1
	Teacher answers pupil's question (15)		3	1	2	8	
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)						
	Teacher rewords pupil's answer to make it more scientific (16)	1					2
	Teacher exploits unforeseen occurrences in lesson (18)						
	Teacher overrides pupil response (E)						
	Teacher leads pupils to answer, but not necessarily understanding (F)		*1*				
	*Teacher reveals doubt negatively (G)**		*1*				
	Teacher anticipates future learning (25)*		1				
	Teacher and pupils chant/sing and do actions (30)**						
	Teacher tells pupil his answer is incorrect (31)**						2
The Teacher Asks Questions							
Factual	Teacher reviews pupils' prior learning (2)						
	Teacher encourages the pupils to observe (11)	5	4	**18**	**23**	**25**	**10**
	Teacher asks questions that demands factual recall (12)	**18**	**20**	1	2	3	4
	Teacher asks 'how many?'(19)		**11**		5	2	
Reasoning	Teacher encourages the pupils to think (10)			1			
	Teacher asks questions that demand an explanation (13)						
	Teacher asks questions that demand application of science (14)						
	Teacher asks 'what happens if?' (21)			2	1	3	
	Teacher asks questions that demand interpretation (22)*			3	1		5
	Teacher asks pupils to report a judgment (29)**						
Open	Teacher asks pupils to describe what they will do (17)	5		8	5	7	
	Teacher asks questions that demand comparison (20)			3	1	**9**	2
The Teacher Explains	Teacher uses representations of the real thing (4)		4	1		1	2
	Teacher uses pupil's answer as a basis for explanation to the class (9)						
	Teacher explains (27)*		1				
Not Teaching	*Teacher gives wrong information (A)*						
	Teacher misleads the pupils (B)	*1*					
	Teacher ignores pupil's question (C)						
	Teacher ignores pupil response (D)		*3*	*2*			
	*Guess what I am thinking (H)****						
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*		1				
	Teacher reveals doubt positively (28)*						

First School Experience (SE1)

For SE1, Thomas taught a class of 30 pupils, aged 9-10 years. The topic was Electricity and Magnetism. In interview Thomas said that the pupils met the learning outcomes (the earth is a magnet and magnets point north), because they "had returned the facts to me correctly". Thomas asked 18 questions that demanded factual recall and gave a lot of information, most of which was read to the class from a book.

Second School Experience (SE2)

For SE2, Thomas taught the topic Earth and Space to a class of 24 pupils aged 8-9 years. He said that his main concern was the "language in the video, Penny (class teacher) and I have a policy of using the real word with a simple word, and then getting rid of the simple word". The lesson was a review of the *facts* already learned and to make sundials. As with SE1 Thomas asked 20 factual recall questions and gave 17 lots of information. Indeed, Thomas started the lesson by asking the class

T	"How many facts did we learn yesterday?"
ch1	"Twelve"
T	"Twelve, you must have had another teacher"
ch2	"four"
T	"four?"
ch3	"six"
T	"Yes, six, what were they about?"
ch3	"Aztecs"
T	"No, that was geography. What did we learn about in science?"
ch4	"The sun and earth"
T	"Can anyone remember the six facts?"

The class had learned eight facts about the Aztecs, but at the start of the science lesson, Thomas did nothing to indicate that it was a science lesson. The focus seemed to be on how many facts the pupils had learned, rather then what those facts were.

Several of the pupils had difficulty doing the mathematics needed to make the sundials, so many of the 14 Incidents of giving instructions was Thomas showing individual pupils how to divide by two. No pupil completed a sundial. Thomas said, "I should have considered differentiation in maths, they surprised me, I expected more".

For both SE1 and SE2 Thomas's interactions involved a lot of question - answer- feedback, as he checked that the pupils *knew* the *facts*.

Third School Experience (SE3)

I observed Thomas teaching the same class of 24 pupils aged 5-6 years, for SE3 and SE4. Thomas taught the topic Forces on SE3. The focus was that the pupil should know that "you could move things by pushing or pulling them". Thomas used songs with actions to illustrate push and pull, "the popcorn song and Mr. Bendy", Thomas made up these songs. The pupils were able to do the correct actions for the song, but several had problems applying the terms push and pull correctly to everyday activities, so Thomas was unsure how much they understood. There were 18 observation questions, as the pupils did practical activities involving pushes and pulls.

Fourth School Experience (SE4)

Thomas taught the topic Minibeasts for SE4. The class discussed the characteristics of living things and then collected minibeasts from the school grounds. In interview Thomas said that he was "not completely happy with the lesson, I feel they need more time". Thomas welcomed the pupils' questions, and encouraged them to think for themselves. This exchange shows that Thomas answered ch3's question with a question to enable ch3 to answer it himself.

T	"Pretend that this is a real spider" *toy*. "Would you do this?" *grabs the toy and shoves it into a petri dish*
ch1	"No!"
T	"Why?"
ch1	"It would die"
ch2	"And get squashed up"
T	"Yes, it is delicate, you must pick it up with a spoon or paper towel carefully and then put it in the petri dish"
ch3	"And then you put in another one"
T	"No, only put in one"
ch3	"Why?"
T	"Because they might not like each other"
ch3	"Why?"
T	"What if you put a spider and a fly in together?"
ch3	"The spider would eat the fly"
T	"Yes"

There were very few questions that demanded factual recall for SE3 and SE4. Here the focus was on the pupils finding out for themselves, albeit in a teacher controlled environment. Thomas still gave a lot of information for SE4, but this was a lesson on minibeasts, which were new to the pupils. Several pupils had not encountered minibeasts before this lesson.

Fifth School Experience (SE5)

Thomas moved schools at the end of the year. For SE5 and SE6, I observed Thomas teaching science to a class of 25 pupils aged 5-7 years. For SE5 the topic was Living and Non- Living Things. The pupils discussed the difference between living and non-living things. The examples used were the pupils and a plastic plant. The pupils were keen to share their ideas and Thomas said that most understood the differences. There was no practical work in this lesson.

Again, as with SE3 and SE4, there were a lot of observation questions, 25 for SE5. There were 9 comparison questions as Thomas asked the pupils how they were different to the plastic plant.

Sixth School Experience (SE6)

Thomas carried out an end of term assessment for SE6. In retrospect, this was not a good lesson to observe as Thomas was attempting to assess the whole class on aspects of Sc1 (science skills). The pupils were required to do the tasks without help, but Thomas prompted them by asking observation questions.

At the end of the main study

Thomas did not like the idea of a daily science lesson saying that "Science permeates everything, but we would end up teaching it in a way that will switch children off". He thought that the main benefits of teaching science to primary pupils was that it

> "disciplines the mind, it focusses them. It is good for boys, it grabs them. I notice that boys self select science information books, the girls choose literature. It gives discipline, we haven't got Latin anymore, science gives the discipline. It encourages those skills"

Thomas's view of the benefits for primary pupils learning science changed. At first he said that science was necessary for a "questioning, thinking mind", after three years, he said that it provided the discipline that Latin used to provide. Thomas's approach to science was very much about pupils learning scientific facts, especially at Key Stage Two.

Thomas said "There is no one on my back about science. If I eat away at any subject it's science less *science.* I don't have anything to stimulate me to teach science, it's not pushed like literacy, numeracy and ICT. It's not a strength in this school".

Thomas's pattern of engagement and teacher type

Thomas was observed for all six SEs, see figure 7.6. Like Esther, Thomas taught at Key Stage 1 once he completed his PGCE year. Thomas wavered in his enthusiasm for science. However, by SE3 his attitude was positive and he was planning to become a science coordinator. This changed by SE5, when Thomas decided that he wanted to become an ICT or language coordinator. There was no discernible pattern to Thomas's engagement with science. He gave more information in the earlier SEs and asked more factual recall questions, but this could have been because he was teaching Key Stage 2 pupils for SE1 and SE2. On both occasions he was keen that the pupils should record and *know* the facts. For SE2 the lesson started with Thomas asking, "how many facts did we learn?" These facts were then reviewed. For SE1, Thomas read from an encyclopaedia about magnetism. The pupils were told to "listen carefully to the rest of this, because you have to make notes about all of this". As a Key Stage 2 teacher, Thomas could be characterised as *know the facts.* Here Thomas best fitted the *transmission* teacher type. He had a body of facts that he inputted into the pupils. Thomas thrived in the Key Stage 1 environment; indeed, he had always wanted to teach at Key Stage 1. He enjoyed using songs, chants, stories and drama to illustrate ideas and concepts to the pupils. Thomas was aware that for SE5 and SE6 there was insufficient focus on science, but said this was because the pupils needed support with English. Thomas was keen that the pupils should not simply be told the science, but they should be given opportunities for discussion. Although, there was more investigative work in the Key Stage 1 lessons, Thomas did little to make connections with other areas of science. The pupils did not *construct* knowledge, they acquired it. Indeed Thomas said "In science I can only give the children what I have prepared to cover the PoS (programme of study), I rarely go further".

Thomas could best be described as a *discovery* teacher when teaching in Key Stage one. The pupils carried out the practical activities and discussions to provide them with evidence of scientific phenomena, for example, in SE3, *push* and *pull*, in SE5, *living* and *non -living*. This is characteristic of the *Linear Transmission* teacher.

7.2.6 Peter

Background

Peter's degree subject was English literature. He had GCE 'O' and 'A' levels in physics, chemistry and biology. Peter felt confident to teach science saying "Children like science so that helps". However he also said "I've no idea what to expect" but "I will try to give science lessons a sense of adventure". He enjoyed science at school. Peter thought that the place of science as a core subject was justified because

> "science is such a huge subject that influences every aspect of our daily life"

Before SE1, Peter was looking forward to "experimenting and making predictions with the children, organising enjoyable activities". He would have liked a further session on "Planning a topic for example, Forces (his SE1 topic) and organising a scheme of work".

Figure 7.7 Peter's pattern of engagement with science

Category	Aspects	SE1	SE2	SE3	SE4	SE5	SE6
The Teacher Instructs	Teacher instructs pupils about the task (3)	7	**20**	6	**18**	5	4
	Teacher acknowledges pupils' suggestions (23) *		2		**6**	2	
	Teacher invites questions from pupils (26) *		4				
The Teacher Gives Information							
Direct	Teacher affirms correct response (1)	10	6	6	3	11	10
	Teacher gives science information (5)	4	6	10	4	5	8
	Teacher gives science labels (6)					3	2
	Teacher highlights health and safety (7)	2	**10**		1	1	
	Teacher answers pupil's question (15)			2			
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)						
	Teacher rewords pupil's answer to make it more scientific (16)						
	Teacher exploits unforeseen occurrences in lesson (18)						
	Teacher overrides pupil response (E)						
	Teacher leads pupils to answer, but not necessarily understanding (F)	*2*			*1*		
	*Teacher reveals doubt negatively (G)**						
	Teacher anticipates future learning (25)*						
	Teacher and pupils chant/sing and do actions (30)**						
	Teacher tells pupil his answer is incorrect (31)**			1			2
The Teacher Asks Questions							
Factual	Teacher reviews pupils' prior learning (2)						
	Teacher encourages the pupils to observe (11)	10	6	**2**	**16**	15	12
	Teacher asks questions that demands factual recall (12)	2	1	10	1	9	10
	Teacher asks 'how many?'(19)		2				10
Reasoning	Teacher encourages the pupils to think (10)						
	Teacher asks questions that demand an explanation (13)						
	Teacher asks questions that demand application of science (14)			3	3		
	Teacher asks 'what happens if?' (21)	**10**			4	6	2
	Teacher asks questions that demand interpretation (22)*	6		6		2	6
	Teacher asks pupils to report a judgment (29)**			3			
Open	Teacher asks pupils to describe what they will do (17)				9	5	
	Teacher asks questions that demand comparison (20)	**8**			2	4	4
The Teacher Explains	Teacher uses representations of the real thing (4)		2				2
	Teacher uses pupil's answer as a basis for explanation to the class (9)						
	Teacher explains (27)*						
Not Teaching	*Teacher gives wrong information (A)*			*1*			
	Teacher misleads the pupils (B)						
	Teacher ignores pupil's question (C)						
	Teacher ignores pupil response (D)			*2*			
	*Guess what I am thinking (H)***	*2*		*1*	*1*		
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*						
	Teacher reveals doubt positively (28)*						

First School Experience (SE1)

For SE1, Peter taught Forces to a class of 22 pupils aged 10-11years. Peter was mostly concerned about "how to demonstrate the experiment". In interview when asked what went well in the lesson, Peter replied "No one got injured and some people did the investigation". Peter wanted the pupils to understand that "Friction is a force between two surfaces". They were placing blocks on different surfaces to see how quickly they slipped down.

In his lesson evaluation he wrote, "I still feel that very little learning took place". Even though "The class did not really develop their ideas about friction", Peter thought that "I have done enough friction work with the class, and it's time to move onto air resistance". Peter was concerned about his own subject knowledge for this topic, "Physics isn't my strength", even though he had a GCE 'A' level in physics. It was difficult for Peter to engage with the pupils, because he was fully occupied managing the class. The class worked in small groups, so Peter interacted with each group, giving the same instructions, asking what would happen if the blocks were placed on particular materials and what each group had observed. So although there were lots of questions, there were not very many different ones.

It was a practical session and involved several science processes. Peter, however, did not have the opportunity to pursue them, as his focus was the management of pupil behaviour.

Second School Experience (SE2)

Peter taught Electricity to a class of 26 pupils, aged 10-11years. For SE2, before the SE he was concerned about "How to introduce the subject and how to stop the subject dragging on". Before the lesson Peter said that he was concerned that "There would be log jams on certain bits of equipment and not enough resources". The pupils were making an electric buggy. Peter demonstrated how to make the buggy and then the pupils worked in pairs to make one. Peter spent most of the lesson, supervising pupils who were using a hot-glue gun. Due to his poor organisation there was, as Peter feared, a log- jam, as several pupils needed to use the hot-glue gun at the same time. As a result, Peter had little opportunity to engage the pupils in the science of the lesson. Peter was unsure whether the pupils had met the objectives "To manipulate materials and use tools, and to find out how to power something by electricity", as no pupil completed the task.

This was not really a science lesson as there was almost no discussion about electricity and very little about what made a *good* buggy. In the post lesson interview I discussed the lesson's learning objectives with Peter. He agreed that they were more suitable for a technology lesson. We discussed how the activity could have been extended, that is, by testing the buggies, in order to make it a more science based activity. Most of Peter's engagement was to do with 'giving instructions', (20 Incidents), and reminding pupils about 'health and safety' (4 Incidents).

Third School Experience (SE3)

For SE3 Peter taught a small class of 16 pupils aged 9-10 years. Before the lesson Peter said, "I hope that you are not looking for progression in our (the participants) science teaching, regression seems more appropriate". The focus of Peter's SE3 lesson was that the pupils would "know that smoking is harmful and the effects of smoking". The class discussed the findings of a smoking survey that they had completed for homework. They then designed anti-smoking posters. In interview Peter said that the pupils understood that smoking was harmful but he wasn't sure how well they understood the effects of smoking. Peter had recently taken on the post of science coordinator in the school, although he said that science was not his forte.

In this lesson Peter asked a lot of factual recall questions, as the pupils had been finding out about smoking for homework. Peter also asked questions about the information that he gave during the lesson. There was a limited range in the Aspects of engagement with science covered in this lesson, as the focus was on why people smoked and how to encourage them to give up. The lesson was really more of a PSHE (personal, social and health education) lesson.

Fourth School Experience (SE4)

For SE4, Peter taught the topic Materials to the same class as for SE3, that is, pupils aged 9-10 years. The pupils predicted what would happen when different materials were heated and then tested them, by placing them in foil boats floating on trays of hot water. Peter also wanted them to do "Fair testing, a little bit, group work and planning". Peter asked 16 'observation' questions, as he asked each small group of pupils to describe the materials to be

tested. The lesson was abandoned, as the pupils had difficulty making the boats. This difficulty meant that there were 18 Incidents of giving instructions. Also the focus of the lesson was unclear. The pupils were trying to find out what happens to different materials when they are heated, yet Peter started the lesson by asking

P "Can anyone tell me, I don't suppose you can tell me, I don't know if I know, can you tell me why some things are hotter than something else?" *hesitant voice*

During his SE6 interview, Peter said " occasionally I start a lesson and realise I've forgotten the content".

Peter gave up his science post and took a post coordinating ICT.

Fifth School Experience (SE5)

For SE5 I observed Peter teaching science to a new class of 26 pupils aged 9-10 years. The SE5 topic was Electricity (as it had been for SE2). The focus was that the pupils would know "that different factors (number of batteries and length of wire) can affect the brightness of a bulb. To make a successful circuit and be able to change it". In interview Peter said that he thought about 75% of the pupils met these outcomes. He wanted further support on "doing investigations successfully". The lesson was revision, so there was little need for new information, but Peter did remind the pupils of the symbols for drawing electrical circuits. As with SE4, Peter organised the class into small groups, so his 'observation' questions were not varied, although he asked 15 of them.

Sixth School Experience (SE6)

I observed Peter teaching a topic on Ecosystems for SE6. The focus was to "understand food chains and observe a small artificial ecosystem". Peter's class was making a soil ecosystem in a large fish tank in the playground. In interview Peter said that he thought that most of the pupils met the learning outcomes as they had studied food chains before. The class spent most of the lesson looking at the minibeasts, so it is not surprising that most of Peter's questions were 'observation' and 'how many'. However, Peter might have expected to ask more 'comparison' questions, as the pupils were already familiar with the minibeasts. Overall when teaching science, Peter said that his main concerns were "Getting resources and thinking up good investigations".

At the end of the main study

Peter thought that a daily science lesson was a good idea saying, "That would be good, I'd like it, it would force more teachers to teach science. It might make them (DfEE) organise science better for teachers". He thought that the main benefits of primary pupils learning science were

> "It satisfies their curiosity and it makes them more curious themselves, they question more"

Like Ruth and Mark, Peter thought that science developed the pupils' curiosity.

Peter was planning to stay in the same school next year.

Peter's pattern of engagement and teacher type

Peter was observed for all six SEs, see figure 7.7. Of the ten participants, Peter had the highest qualifications in science. Peter's confidence in his own science subject knowledge and understanding remained high throughout the main study, as did his confidence to teach science. This confidence may have caused Peter not to think through some of the activities that the pupils did. For SE2 and SE4, Peter did not think through how the activities could be managed in a class of 30 pupils, so for SE2 only one pair of pupils made an electric buggy, the rest did not complete them. For SE4, none of the pupils managed to make the foil boats and complete the task. Also, for SE2, Peter thought that making the buggies was an end in itself, he was unable to draw much science from the activities. He was keen that the pupils should enjoy science. I would characterise Peter as *science is fun,* but he was *not always sure of the science content of the lessons*. For SE2 Peter adopted the *transmission* mode, to demonstrate how to make an electric buggy. For SE4 Peter was a *co-learner,* working alongside his pupils, trying to find out how to make the foil boats and test the materials. However, Peter, had to be a co- learner, because of his lack of preparation. The activities for SE1 and SE4 were designed to illustrate science concepts that Peter wanted the pupils to grasp. This is a feature of the *Linear Transmission* teacher. For SE5 and SE6, the lessons were revision, so Peter asked questions to check the pupils' knowledge and to direct their observations.

7.2.7 Luke

Background

Luke's degree subject was political history. He had a GCE 'O' level in integrated science. Luke felt confident to teach science, but said that "I'll need to do a lot of reading before teaching it" and "I'll be OK with a lot of practice". He also said "Children like science, so that helps" and that "interesting experiments are useful". Luke enjoyed science at school. Luke thought that the place of science as a core subject was justified because

> "It covers so many areas relevant to everyday life. The children enjoy science and are excited by experiments (an extension to play). It answers so many questions about what things do, what are they for etc"

Before SE1 Luke was looking forward to "explaining ideas" but not "doing experiments".

Figure 7.8 Luke's pattern of engagement with science

Category	Aspects	SE1	SE2	SE3	SE4	SE5	SE6
The Teacher Instructs	Teacher instructs pupils about the task (3)	3		12	12	8	4
	Teacher acknowledges pupils' suggestions (23) *			2	3		
	Teacher invites questions from pupils (26) *						
The Teacher Gives Information							
Direct	Teacher affirms correct response (1)	2		6	7	9	3
	Teacher gives science information (5)	**11**		3	1	**20**	2
	Teacher gives science labels (6)	4		3	1	3	1
	Teacher highlights health and safety (7)	3				3	
	Teacher answers pupil's question (15)	1					
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)						
	Teacher rewords pupil's answer to make it more scientific (16)	1					
	Teacher exploits unforeseen occurrences in lesson (18)						
	Teacher overrides pupil response (E)						
	Teacher leads pupils to answer, but not necessarily understanding (F)	*1*					*1*
	*Teacher reveals doubt negatively (G)**						
	Teacher anticipates future learning (25)*						
	Teacher and pupils chant/sing and do actions (30)**						
	Teacher tells pupil his answer is incorrect (31)**						
The Teacher Asks Questions							
Factual	Teacher reviews pupils' prior learning (2)	2					
	Teacher encourages the pupils to observe (11)	7		1	4	10	**30**
	Teacher asks questions that demands factual recall (12)	5		2	6	1	2
	Teacher asks 'how many?'(19)			2			
Reasoning	Teacher encourages the pupils to think (10)						
	Teacher asks questions that demand an explanation (13)						
	Teacher asks questions that demand application of science (14)						
	Teacher asks 'what happens if?' (21)	3		3	1	2	**20**
	Teacher asks questions that demand interpretation (22)*						**19**
	Teacher asks pupils to report a judgment (29)**						
Open	Teacher asks pupils to describe what they will do (17)						
	Teacher asks questions that demand comparison (20)						1
The Teacher Explains	Teacher uses representations of the real thing (4)						
	Teacher uses pupil's answer as a basis for explanation to the class (9)						
	Teacher explains (27)*	1					
Not Teaching	*Teacher gives wrong information (A)*						
	Teacher misleads the pupils (B)						
	Teacher ignores pupil's question (C)						
	Teacher ignores pupil response (D)						
	*Guess what I am thinking (H)****						
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*						
	Teacher reveals doubt positively (28)*						

First School Experience (SE1)

Luke taught a class of 22 pupils aged 7-8 years for SE1. The topic was Heating and Cooling. Luke's main concern was "the boiling water, it could be dangerous". The class watched a video about the water cycle and Luke demonstrated evaporation and condensation, involving the use of a kettle of boiling water. In interview Luke said that some of the pupils understood that heating and cooling altered the state of water, but he would be sure "When I've looked at their worksheets". The lesson involved at lot of 'information giving' (11 Incidents).

In this example Luke was focussed on *teaching* the pupils new science words that is, "Teacher gives science labels". Few pupils participated in the discussion. Several pupils who were not paying attention distracted Luke, and so he was not listening to the ch1's first response.

L	"The ice melted and turned into water. What would happen to the water if you put it in the freezer?"
ch1	"It would turn back to ice"
L	"What if you put it in the room?"
ch1	"It would melt again"
L	"You could carry on doing that, what do we call that? Remember that long word? It's a bit like a car going backwards"
ch2	"Reverse"
L	"Yes, it's reversible. The car reverses back to where it started from and the water reverses back to what it was, ice"

Here ch1 has understood that the action is reversible, as he says "it would turn back again" and that "it would melt again". Luke does not use ch1's responses, but refers to a word, which had been mentioned in a previous lesson. Luke seemed to be preoccupied with the pupils knowing the term reversible. He talked about the car reversing, because the word *reverse* is similar to the word *reversible*. This falls short of what Shulman (1987) would call a "powerful analogy". By introducing the car analogy, Luke confused rather than helped the pupils. He could have used ch1's responses "turn back" and "melt again" to explain the concept to the rest of the class, that is, using the pupils' language for a teacher explanation or rephrased ch1's responses, (Aspect 16). Later Luke could have introduced the term

reversible simply as a shorthand label for the grasped concept (Khwaja 1996). The analogy that Luke used is inappropriate, and is in fact a language clue, rather than a science clue. Towards the end of the lesson, Luke checked the pupils' understanding,

L "We cooled the steam down and it turned back to water. What do you think that change is called?
ch4 "Reverse"
L "It is reversible"

Again Luke focussed on the new word, reversible, rather than question the pupils' understanding of the concept.

Luke had said that he was looking forward to "explaining ideas", but there was little evidence of explanation here.

Second School Experience (SE2)

I did not observe Luke teaching on SE2, as Ofsted was inspecting his school.

Third School Experience (SE3)

Luke did not start his first teaching post until the second term of the NQT year. He was a special needs teacher, working with pupils individually. The focus of Luke's work was to help pupils with their language work. Luke taught science to the pupils for SE3 and SE4, because he wanted to participate in the main study.

For SE3, I observed Luke teaching a 9 year-old pupil, Adam. Luke was focussing on Adam's fine motor skills, that is, cutting and folding. Adam's class was doing the science topic Forces. Luke showed Adam how to make a windmill, they discussed what to do and Adam wrote an account. In interview Luke said that Adam grasped that a force was a push, but that "I was really concentrating on getting him to talk and do the cutting and folding". However, as this example shows, Adam did not understand force as a science term, his understanding was the everyday understanding.

L "Today we are going to talk about wind"

Later he said

L "When we played football it went....? it made the coats.....? Do you know what that is ffffffff?"
A "fffffffffff"
L "Like that" *gently pushes p's cheek* "For"
A "For"
L "Force"
A "Force"
L "Yes, force right"

Luke and Adam then spend most of the lesson making a windmill, towards the end of the lesson, Luke told Adam what the point of the lesson was.

L "All I want you to learn from this is one word"
A "Force"
L "What does it mean?"
A "When they are making you do it"
L "Yes, the wind is pushing you"

Luke had focussed on Adam learning a new word 'force', but he was unable to explain it in scientific terms.

Fourth School Experience (SE4)

Since SE3, Luke had not taught any science, so SE4, was the second science lesson of his NQT year. I observed Luke working with Adam to make an electrical quiz card. Again the focus was Adam's fine motor skills, but it was also "Following written instructions and knowing how a circuit works". Adam was delighted to have made a successful quiz card, which had questions about the six times table. There was no discussion about how the quiz card worked.

Fifth School Experience (SE5)

For SE5 Luke taught a class of 16 pupils aged 5-6 years. For SE5, Luke taught the Water cycle. This was a very similar lesson to the one that he taught on SE1, to a class of 7-8 year olds. Again his main concern about the lesson was "boiling water". In the post lesson interview Luke said that most of the pupils understood the water cycle, but agreed with me that "I tend to over-estimate their ability". There was a lot of information giving (20 Incidents), more so than for SE1, but there were fewer interruptions in the SE5 lesson, so Luke was able to get through more information.

In previous examples (see Mark and Veronica SE1), the participants asked a leading question, that is, they gave the pupil the answer. In Luke's case he was rather more explicit;

L "What happens to water when it gets very hot? It turns into .....?"
ch1 "erm"
L "Steam" *whispers*
ch1 "Steam!"
L "Good girl!" *laughs*

However, Luke recognised that he had over-estimated ch1's ability saying, "At this age you sometimes just have to tell them you've got to move on".

The 'water cycle' features in the Key Stage 2 programme of study (Pos), "pupils should be taught the part played by evaporation and condensation in the water cycle". Although Luke's year 1 class was able, the topic was beyond most of them. Luke had taught this topic on SE1 to a class of 7-8years olds, who found it difficult. In view of this, I had expected that Luke would have simplified his input for a younger age group.

Sixth School Experience (SE6)

Luke's SE6 topic was Materials; the class was testing a variety of materials to see if they were waterproof. As with Luke's previous whole class lessons (SE1 and SE5), the practical activity was demonstration by the teacher, but in this lesson pupils assisted. The following extract is an example of how Luke tested items to see if they were waterproof;

L "What will happen if I pour water over ch1's hand? Will it get wet?"
ch1 covers hand with plastic bag
W/C "No!" *Luke pours water over ch1's hand*
L "Is your hand wet?"
ch1 "No" *W/C cheer*
L "Right put a tick here" *Luke ticks the no column in a table on the board which the pupils copy*

This sequence was repeated 20 times for 20 different items, different pupils were used each time to test the materials. The learning was limited, because all the pupils did was to predict (but not to give reason for their predictions), observe and copy the table of results that Luke

wrote on the board. The pupils' predictions about which items were waterproof were all correct, but Luke did not change his questions. At no time were the pupils asked what made a particular item waterproof. There was no discussion about the features of waterproof materials and what such materials might be used for.

At the beginning of the lesson Luke elicited what the pupils already knew and understood about the concept 'waterproof'.

L	"Who can tell me what waterproof means?"
ch1	"wet"
ch2	"It can't get wet"
ch3	"It can't get in"
ch4	"It like it floats and water can't get in"
L	"Yes, something that doesn't let water in. Can you tell me something that is waterproof?"
ch4	"A bucket"
ch1	" A boat and a ship"
L	"Good"

However, the lesson did not build on the pupils' prior knowledge and understanding. Luke recognised that this was a weak lesson saying "I'm not sure if they learned anything today".

At the end of the main study

Luke thought that the main benefits of primary science were that it

> "Gives them the pupils a wider knowledge of things around them, the environment. It focuses in on specific things. Instead of thinking the tree is nice it has green leaves, you learn why it has green leaves".

After three years Luke's view of science was the same. He thought that science answered pupils' questions about why things were the way there are.

At the end of the year Luke was planning to be a part -time special needs teacher and set up a music company.

Luke's pattern of engagement and teacher type

Luke was observed five times for the main study, see figure 7.8. His confidence to teach science remained fairly high throughout the main study, although he did not teach science (apart from the two lessons that I observed) during his NQT year, (see SE3 and SE4). Luke's limited confidence in his own subject knowledge and understanding remained constant throughout the main study, but he did not do anything to rectify this.

Again there are few patterns to identify. In all five lessons there was a practical element, which involved Luke demonstrating a science phenomenon to the class for example, evaporation, condensation, waterproofing, electrical circuits and forces. For SE1, SE5 and SE6, Luke taught the class as whole. There was limited practical activity for the pupils, as the lessons consisted of teacher led demonstrations. Before SE1, Luke had said that he was not looking forward to "doing experiments". By doing demonstrations, Luke was able to control the practical activity. For the two lessons where Luke taught one pupil, the lessons involved Luke showing Adam how to make an artefact for example, a windmill and an electrical quiz card. Luke did not pitch the learning at an appropriate level for his SE5 and SE6 classes. Luke seemed to engage with science, but not with the pupils. For example in SE6, Luke demonstrated and defined the concept *waterproof.* It was clear that the pupils grasped the concept early in the lesson, but Luke continued to test the waterproofing property of a large number of objects. Luke briefly referred to what made the material waterproof at the end of the lesson, when there was little opportunity for discussion. In the same lesson, several pupils were unable to complete the three-column results table, even though Luke had explained how to do it. However he did not offer further explanation, but simply told the pupils to copy the table from the board, or to fill it out as they wished to.

Thus Luke like Veronica could be described as *telling rather than teaching,* but for Luke *telling* always involved *demonstrating.* Once he had given a demonstration and initial explanation, Luke seemed *unwilling* to offer further explanation. It appeared that he expected the pupils to grasp the concept at once. Of the ten participants, Luke most consistently fitted the *transmission* teacher type. When teaching just one pupil, as Luke did for SE3 and SE4, Luke adopted a more *discovery* mode. However, when his pupil did not grasp an idea, Luke reverted to a transmission mode, where necessary giving a language clue.

7.2.8 Esther

Background

Esther's degree subject was photography. She had GCE 'O' levels in biology, chemistry and physics. Esther did not feel very confident to teach science, because "science has changed a lot since I was at school, I've got no idea what to expect, but I'll be okay with a lot of practice". Esther also said that "science inspires respect, it encourages children to think and it is a practical subject". Esther thought that the place of science as a core subject was justified because

> "it makes children learn in a practical way about the world around them, science is REAL to them"

Before SE1 Esther was looking forward to "Becoming more confident and learning with the children" but not "Things going wrong, being asked questions I might not know how to answer".

Figure 7.9 Esther's pattern of engagement with science

Category	Aspects	SE1	SE2	SE3	SE4	SE5
The Teacher Instructs	Teacher instructs pupils about the task (3)	**3**	8	7	9	**12**
	Teacher acknowledges pupils' suggestions (23) *					
	Teacher invites questions from pupils (26) *					
The Teacher Gives Information						
Direct	Teacher affirms correct response (1)	6	8	**15**	**12**	**11**
	Teacher gives science information (5)	**16**	**10**	**11**	5	6
	Teacher gives science labels (6)				4	
	Teacher highlights health and safety (7)		3			
	Teacher answers pupil's question (15)	7	5	4	8	6
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)					
	Teacher rewords pupil's answer to make it more scientific (16)					
	Teacher exploits unforeseen occurrences in lesson (18)					
	Teacher overrides pupil response (E)					
	Teacher leads pupils to answer, but not necessarily understanding (F)					
	*Teacher reveals doubt negatively (G)**					
	Teacher anticipates future learning (25)*					
	Teacher and pupils chant/sing and do actions (30)**					
	Teacher tells pupil his answer is incorrect (31)**					
The Teacher Asks Questions						
Factual	Teacher reviews pupils' prior learning (2)		2			
	Teacher encourages the pupils to observe (11)	2	**20**	**22**	**16**	10
	Teacher asks questions that demands factual recall (12)	15		1		2
	Teacher asks 'how many?'(19)		**10**			
Reasoning	Teacher encourages the pupils to think (10)	1				
	Teacher asks questions that demand an explanation (13)	1				1
	Teacher asks questions that demand application of science (14)	2	5			1
	Teacher asks 'what happens if?' (21)		1			4
	Teacher asks questions that demand interpretation (22)*					1
	Teacher asks pupils to report a judgment (29)**					
Open	Teacher asks pupils to describe what they will do (17)					
	Teacher asks questions that demand comparison (20)				**6**	3
The Teacher Explains	Teacher uses representations of the real thing (4)	2	1			
	Teacher uses pupil's answer as a basis for explanation to the class (9)					
	Teacher explains (27)*					
Not Teaching	*Teacher gives wrong information (A)*					
	Teacher misleads the pupils (B)					
	Teacher ignores pupil's question (C)					
	Teacher ignores pupil response (D)					
	*Guess what I am thinking (H)***					
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*	**1**	**3**			
	Teacher reveals doubt positively (28)*		1			

First School Experience (SE1)

Esther's SE1 topic was The Human Body, which she taught to a class of 30 pupils aged 10-11 years. The focus was that "Food is vital for life, but it has to go through processes before it can be used by the body". The lesson consisted mostly of giving the pupils new information (16 Incidents) and asking factual recall questions (15 Incidents). Esther used a poster to show the structure of the digestive system and used a marble and piece of rubber tubing to demonstrate peristalsis. In interview Esther said that the pupils had met the outcomes, but was not sure as "I wanted a ten minute chat at the end, time goes quickly. I will look at their books".

Second School Experience (SE2)

For SE2 Esther taught the topic Minibeasts to a class of 28 pupils aged 7-8 years. The lesson focussed on using a key to identify minibeasts, collecting and drawing them. Her main concern about this topic was "Having to handle creepy crawlies, it's getting better, but I won't put a worm in my hand and I am worried about being presented with creatures I can't identify". In interview she said that the pupils were all able to use a key and they knew that "creatures are adapted to their environment". The lesson lasted for nearly two hours (the class spent one morning a week doing science). The lesson therefore involved many features of investigative work, individual and whole class discussion.

This was the only one of Esther's lesson to include 'how many' questions. Several examples of this type of question would be expected in a lesson about minibeasts, as the pupils counted the minibeasts' legs and body parts.

Third School Experience (SE3)

Esther taught in an international school for SE3, SE4 and SE5. The school was for pupils from all over the world whose parents were working or studying in the UK for periods of up to three years. The school followed the National Curriculum, but the focus was the teaching of English, which was the second or third language for all pupils.

For SE3 Esther taught a class of ten pupils aged 5-7years. The class discussed the characteristics of Living and Non Living Things, Esther wrote their ideas on the board. The pupils then cut out and sorted pictures into the two groups, *living* and *non-living*. Esther gave the pupils plenty of time to explore their ideas orally. In interview she said that some of

the pupils "Were confusing living with real, so I'll have to revisit this subject". She had to deal with misunderstandings of both science and English, as the following example shows. This had been Esther's main concern when planning this lesson.

E	"Is this living?" *holds up a plastic ruler* "will it grow?"
W/C	"No"
E	"Will it eat?"
W/C	"No"
E	"Will it go to the toilet?"
W/C	"No!" *laugh*
E	"Will it have babies?"
W/C	"No!" *laugh*
E	"Will it hurt?"
ch1	"No" *others nod*
ch2	"Yes" *others nod*
E	"How will it hurt?"
ch2	"If you do like this" *mimes hitting ch3 with a ruler*
E	"Can the ruler hurt? Will it cry?"
ch2	"No but he might cry" *points to ch3*
E	"Okay we'll come back to that one"

Esther felt that her subject knowledge and understanding had developed but that "I search inside, I know I have to improve. I thought the Sun rotated round the earth, Jane *(her daughter)* told me it didn't". I asked the year 6 teacher "do bugs hibernate? he couldn't tell me and he's the science coordinator. I have to keep reading".

Fourth School Experience (SE4)

For SE4, Esther had taken on the post of deputy headteacher and was enjoying the responsibility. There had been some changes to her class, so that there were now nine pupils all boys aged 5-7 years. Her SE4 topic was Materials. The pupils were sorting a collection of everyday objects into sets according to their properties; again language development was the main focus. As with the SE3 lesson there was a lot of discussion where the pupils were told the names of items and encouraged to use them.

As with SE3, the pupils were encouraged to observe and ask questions.

Esther said that her main concern this year was that "I have to adapt everything I learned at *Key Stage 2*, for KS1, it can be difficult".

Fifth School Experience (SE5)

For SE5 Esther also taught the topic Materials to a class of twelve pupils aged 5-7years. The pupils did an investigation to find out how strong different types of paper were. Esther had not prepared the lesson in advance and so not surprisingly in the post lesson interview she said it was "an unmitigated disaster". However, she said that some of the pupils might "Have started to understand a bit about fair testing". This lesson gave Esther the opportunity to ask comparison questions, for example, "which paper is strongest?", "which paper is softer?"

Esther felt that her science knowledge and understanding had not improved much since her training year, saying, "I just don't have any time to do any reading".

Sixth School Experience (SE6)

I did not observe Esther teaching on SE6. She had become very unhappy with the lack of support in the school and so left at very short notice. However, she completed a postal questionnaire, like Ruth. Overall Esther's main concerns when teaching science were "Being unsure of own knowledge, experiments giving unexpected results, running out of time and being sidetracked". She said that "The more I know the lesson, the better I teach it, if I've done it before it's better and vice versa".

At the end of the main study

Esther thought that primary pupils benefit from being taught science because

> "They have open minds, like painting on a blank canvas"

However, the question asked was "What do think the main benefits of teaching science to primary pupils are?" (Appendix 4.5). I meant the benefits to pupils. I did not interview Esther for SE6, she responded to the interview questions in written form, so she may have misinterpreted the question, and thought that the benefits applied to the teacher. Her

response indicates that pupils do not have any ideas about science before teaching, but during her lessons, she received and welcomed lots of questions and ideas from the pupils.

She said that there should be a daily science lesson because "Science is as important as maths and English".

Esther had no plans to return to teaching and took up a post as a translator for a London based South American Company.

Esther's pattern of engagement and teacher type

Esther was observed five times for the main study, see figure 7.9. Like Thomas, Esther taught at Key Stage 2 for her PGCE year and at Key Stage 1 for her first two years in teaching. Esther's enthusiasm for science remained very high throughout the main study and she was always very keen to receive feedback from me. Esther welcomed the pupils' contributions and their questions. The changes in Esther's pattern of engagement with science can be linked to her change in Key Stage. Esther taught in Key Stage 2 for SE1 and SE2, and in Key Stage 1 for SE3 to SE5. At Key Stage 1 Esther's main focus was helping her pupils to develop their English literacy skills, so involving the pupils in discussion was very important, even though much of it was not science related. At Key Stage 2, Esther directed pupils to secondary sources to find answers, which she did not do at Key Stage 1, as it was not appropriate for those lessons and pupils. Esther's SE1 lesson did not involve the pupils doing practical work, so the giving of instructions was limited. Esther's lessons were very carefully planned and the resources prepared in advance. However by SE5 (the last time she was observed) Esther had become very unhappy in her school. The lesson had not been thought through, so the activity did not *work*. Thus Esther had to give a lot of instructions. I would characterise Esther as *enthusiastic and readily engaging with pupils,* she welcomed their questions and conveyed a lot of enthusiasm for science.

Esther considered herself to be a *co- learner*, that is, learning alongside the pupils. Esther adopted a *transmission* mode for SE1 when she taught the human digestion system, as this lesson involved giving the pupils a lot of information, even though she welcomed and responded to some of their questions. For SE2 to SE5, Esther best fitted the *discovery* teacher type, that is, she used practical activities to allow the pupils to discover concepts.

7.2.9 Mary

Background

Mary's degree subject was history. Mary had no pre course qualifications in science. Mary felt confident to teach science, but said that "science has changed a lot since I did it at school and I'll need to do a lot of reading before teaching it" but "I'll be okay with a lot of practice". Mary thought that the place of science as a core subject was justified because

> "science actually affects every aspect of everyday life. From my own negative experience of science learning, it is important to build self-confidence within the subject. However it can be 'dry' to teach alone, but can be made interesting by incorporating it into cross-curricular themes and topics. It encourages critical analysis, an awareness of our surroundings, environment and promotes problem solving skills"

Before SE1, Mary was looking forward to "trying to pass on my new found enthusiasm for science, planning challenging and exciting activities for the children to do", but not "Those areas which I still don't feel confident about that is, Energy / Forces. Very aware that I don't want to pass on any negativity to children".

Figure 7.10 Mary's pattern of engagement with science

Category	Aspects	SE1	SE2	SE3	SE4	SE5	SE6
The Teacher Instructs	Teacher instructs pupils about the task (3)	10	8	5		**2**	**2**
	Teacher acknowledges pupils' suggestions (23) *						
	Teacher invites questions from pupils (26) *						
The Teacher Gives Information							
Direct	Teacher affirms correct response (1)	8	7	6		7	4
	Teacher gives science information (5)	7	7	**11**		3	7
	Teacher gives science labels (6)	2	2	5		1	4
	Teacher highlights health and safety (7)	1	1				
	Teacher answers pupil's question (15)	3	3				
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)						
	Teacher rewords pupil's answer to make it more scientific (16)	3					2
	Teacher exploits unforeseen occurrences in lesson (18)						
	Teacher overrides pupil response (E)						
	Teacher leads pupils to answer, but not necessarily understanding (F)						
	*Teacher reveals doubt negatively (G)**						
	Teacher anticipates future learning (25)*						
	Teacher and pupils chant/sing and do actions (30)**						
	Teacher tells pupil his answer is incorrect (31)**			1		2	5
The Teacher Asks Questions							
Factual	Teacher reviews pupils' prior learning (2)						
	Teacher encourages the pupils to observe (11)	7	**11**	**10**		1	5
	Teacher asks questions that demands factual recall (12)	8	4	7		**13**	**12**
	Teacher asks 'how many?'(19)	1	**6**	**5**		1	
Reasoning	Teacher encourages the pupils to think (10)	1					
	Teacher asks questions that demand an explanation (13)		1				
	Teacher asks questions that demand application of science (14)	2	1	1			
	Teacher asks 'what happens if?' (21)	2	2				3
	Teacher asks questions that demand interpretation (22)*		**5**			1	2
	Teacher asks pupils to report a judgment (29)**						
Open	Teacher asks pupils to describe what they will do (17)		**6**				
	Teacher asks questions that demand comparison (20)		1				1
The Teacher Explains	Teacher uses representations of the real thing (4)						
	Teacher uses pupil's answer as a basis for explanation to the class (9)						
	Teacher explains (27)*		1	2			
Not Teaching	*Teacher gives wrong information (A)*						
	Teacher misleads the pupils (B)						
	Teacher ignores pupil's question (C)						
	Teacher ignores pupil response (D)			*1*		*1*	
	*Guess what I am thinking (H)****						
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*					2	3
	Teacher reveals doubt positively (28)*						

First School Experience (SE1)

For SE1, Mary taught the topic Electricity to a class of 28 pupils aged 9-10 years. This was the first science lesson that Mary had ever taught. Before the lesson Mary indicated that she was very apprehensive saying, "science is not my strong point". The focus of the lesson was to "Construct a circuit, understanding that a circuit is needed for electricity to flow, know that some Materials conduct and some insulate electrical flow and the role of a switch in a circuit". All of the pupils were able to make a circuit, although a lot of time was wasted as they had to continually replace the faulty equipment. Mary's main concern was "Equipment, there weren't electricity kits, some of the equipment was broken". Later in the post lesson interview she said "I should have checked it by making a circuit myself". Mary said that most of the pupils had met the learning objectives, as they could explain their answers. Mary said that it would have been better to leave conductors and insulators for another lesson, as it was difficult to refocus the class to do this activity after playtime. Mary said "I have done a lot of reading" so she felt able to answer the pupils' questions, although only 3 science questions were asked.

Second School Experience (SE2)

Mary's SE2 topic was Plants. Her class was a group of 24 pupils aged 8-10 years. Mary worked with a group of six pupils. The focus of the lesson was for the pupils to find out the "best soil for growing plants in". In interview Mary said that the activity reinforced fair testing, and that "four of them understood that we were trying to compose an investigation". She was concerned about her weak subject knowledge saying "Science is my weakest subject, if it goes outside the lesson plan, I say I'll find out or you can find it out yourself. I know I don't have the information. I read up, but I am relating knowledge through to the kids, not from me, but from books to the kids through me".

Mary repeated a lot of instructions about the task (10 Incidents) as the group seemed to have difficulty grasping what to do. This was the only lesson I observed Mary teaching where the pupils had involvement in planning the investigation, this included measuring the amounts of soil and water needed, hence the 6 'how many' questions.

Third School Experience (SE3)

For SE3, Mary taught Plants to a class of 26 pupils aged 10-11 years. Mary dismantled a large lily naming the parts and explaining their function. The pupils then dismantled daffodils, drew them and labelled their drawings. Hence the lesson had 11 Incidents of giving information and 10 observation questions. In interview she said that her main concern was "equipment and finding a way of making it interesting". She said that most of the pupils could name the parts and state their functions. Mary was now less concerned about her subject knowledge saying " My knowledge improves for the topics I've taught. I could teach them again with less preparation. I'm like the kids; I'm feeling my way. I'm learning with them".

Fourth School Experience (SE4)

I did not observe Mary teaching on SE4, as there were problems with organising a mutually convenient time.

Fifth School Experience (SE5)

Mary's SE5 topic was Food Chains, which she taught to a class of 28 pupils aged 9-11 years. The focus, was "reinforcement of science language, they need it for SATs (Standard Attainment Tests) and making sure that they understand the directions of the arrows *that represent energy flow* ". In interview Mary said that she did not have any concerns about this lesson because "I've taught it before, last year. All of the kids remembered it all the way to the SATs, so I knew I'd taught it properly last year". Mary was increasingly positive about teaching science saying "I love teaching science. I am shadowing the science coordinator this year, to possibly take over next year". She felt "happier doing demonstrations and researched-based stuff. We did a lot of investigations and fair tasting stuff, I'm happier with this *the book-based lesson on food chains.* But I know that they learn as much from investigations. This comes from my history side, doing research".

Sixth School Experience (SE6)

For SE6 I observed Mary teach a lesson on Human Skeleton to the same class of 9-11 year olds that she taught for SE5. The focus was how the muscles work in pairs to cause movement. This lesson provided a further example of label/concept conflict that was observed in Veronica's SE1 lesson.

Here Mary was discussing with ch1 what happens when the arm is raised.

M "Okay, what have you written?"
ch1 "When you raise your arm the" *hesitant voice*
M "Right, what is this muscle?" *M arm bent at elbow, points to her biceps*
ch1 "Triceps"
M "Again"
ch1 "Biceps" *questioning voice*
M "Yes, the biceps, write that, when you raise your arm it....?"
ch1 "Relaxes"
M "Not quite"
ch1 "The other one, contracts"
M "Yes, when you raise your arm the biceps contracts, good write that down"

In this example the pupil, ch1, did not seem to remember the names of the two muscles, biceps and triceps and what relax and contract mean in the context of muscle action. Mary had used these new words in her introduction to the class and the words were written on the board. It is possible that ch1 simply got the words the wrong way round, not that he failed to understand what happened when the arm is raised.

This was the class's final lesson on this topic and so Mary was keen that the pupils should have the correct information, including the new terminology, in their books, even if they did not understand what the words mean. This was apparent when Mary responded to ch1's incorrect answer

ch1 "Relaxes"
M "Not quite" *hesitant voice*
ch1 "The other one, contracts"
M "Yes....."

Here Mary's response "Not quite" indicated that the pupil is nearly correct, when in fact his answer is the opposite of the correct answer. His answer is only nearly correct, because there are only two answers to choose from, so if it is not "Relaxes" it must be "The other one", contracts.

Using new terms can be problematic for some pupils. Wellington (1983) suggests a taxonomy of words. Those in level one are *naming* words, such as triceps and biceps. These are entities that pupils can easily see. However, as these words are almost always introduced in pairs, it is perhaps not surprising that pupils get the terms the wrong way around. In the second level are *process* words, such as relax and contract. Mary could demonstrate the muscles contracting and relaxing as the pupil bends and straightens his arm, however, the terms contract and relax, are words that the pupil could hear in everyday life, such as 'recording contract' and 'relax by the pool'. The pupil has to use these familiar words in a new science context and remember which word matches which action, it is not surprising that mistakes with terminology are made.

In interview Mary said that most of the pupils understood this, although "Some needed prompting". She had no concerns about this lesson. Mary did not think that her own science knowledge and understanding affected her confidence to teach science saying, "It doesn't really anymore. I make sure that I read up about it beforehand. I still make time for this". As for SE5 this was a revision lesson, preparing the pupils for SATs. There were a lot of factual recall questions and few instructions about the task, as Mary had written the instructions on the board.

At the end of the main study

Mary said that the main benefits for pupils learning science were that

> "It gives them a better understanding of how the world around them works. How to look after themselves. How things work and why they work"

Mary's view of science giving pupils a better understanding of the world around them, was similar to her view three years earlier, that science encourages an awareness of surroundings and environment.

At the end of the year Mary moved out of London. She was planning to travel and then apply for a full time teaching post.

Mary's pattern of engagement with science and teacher type

Mary was observed for all SEs apart from SE4, see figure 7.10. At the start of the main study Mary had little confidence to teach science, citing her lack of science subject knowledge and understanding as the main reason. Mary's pattern of engagement with science did not change significantly. Lessons where the pupils were revising for SATs, that is, SE5 and SE6 involved a lot of factual recall questions. For SE2, when she felt that her subject knowledge and understanding was weak Mary felt that she was *transmitting* knowledge from books to her pupils, saying "I read up, but I am relating knowledge through to the kids, not from me, but from books to the kids through me". By SE3, Mary identified herself as a *co-learner*, saying that " I'm like the kids, I'm feeling my way. I'm learning with them".

Mary's degree subject was history, a subject that she was passionate about. Mary's pupils made a lot of use of secondary sources to find out information, for example for SE5 the pupils used a variety of books to find information to create food chains. For SE6, the pupils used the Internet to find out about bones and muscles. The pupils also used a variety of books to find out *facts* about the human body for a board game. All of the participants had displays of science topic related books in their classrooms, but Mary was the only participant who required pupils to use them. However, the downside to this was that the pupils sometimes collected information about which they had no understanding, for example, two pupils wrote the following question and answer for the board game, it is unlikely that it would have meant much to them;

Q "What is the job of the Golgi apparatus?"
A "To wash out the cell".

When writing a food chain, one pupil included plankton, which she had read about, but because there was no picture in the book, she didn't know what it was. For SE3 Mary taught a year 6 class; for SE5 and SE6, she taught a mixed year 5 and 6 class. Mary was very keen that the pupils should know the facts necessary for success in the Key Stage 2 SATs. As we have seen Mary, when teaching about muscle action when lowering and raising the arm, (for

SE6) was *prepared to sacrifice pupil understanding for having the correct information in* their books. Mary's SE3/SE4 class had been very successful in the Key Stage 2 SATs, so this encouraged her belief that the pupils must *know the facts*. I would characterise Mary as *science is a body of facts that pupils must learn*. Thus Mary best fitted the *transmission* teacher type. Mary continued to read in preparation for the science topics that she taught. She expressed surprise that teachers could consider teaching a topic without adequate preparation.

7.2.10 Rachel

Background

Rachel's degree subject was 3D design. She had GCE 'O' levels in chemistry, physics and biology. Rachel felt confident to teach science, but said that " I'll need to do a lot of reading before teaching it" and "I'm only a few steps ahead of the children" but "children like science, so that helps". Rachel added, "I like the opportunities science gives for children to anticipate think etc, use everyday knowledge. I like the surprises in experiments". Rachel thought that the place of science as a core subject was justified because

> "it's the one core subject where our understanding of the world around us can be explored, without the criteria *(requirement)* of being able to read/ write or do numbers being too important. Also there can be lots of thinking and exploring and no right or wrong!"

Before SE1 Rachel was looking forward to "Investigations".

Figure 7.11 Rachel's pattern of engagement with science

Category	Aspects	SE1	SE2	SE3	SE4	SE5	SE6
The Teacher Instructs	Teacher instructs pupils about the task (3)	6	8	6	7	8	
	Teacher acknowledges pupils' suggestions (23) *						
	Teacher invites questions from pupils (26) *	1	1	1	2	4	
The Teacher Gives Information							
Direct	Teacher affirms correct response (1)	4	6	7	11	4	
	Teacher gives science information (5)	3	4	**14**	4	5	
	Teacher gives science labels (6)	1	5	2			
	Teacher highlights health and safety (7)	1	1			1	
	Teacher answers pupil's question (15)		2	1	1	6	
Indirect	Teacher uses pupil's answer as an exemplar for the rest of the class (8)						
	Teacher rewords pupil's answer to make it more scientific (16)	2		1	1		
	Teacher exploits unforeseen occurrences in lesson (18)						
	Teacher overrides pupil response (E)	*2*					
	Teacher leads pupils to answer, but not necessarily understanding (F)	*3*	*1*				
	*Teacher reveals doubt negatively (G)**						
	Teacher anticipates future learning (25)*						
	Teacher and pupils chant/sing and do actions (30)**						
	Teacher tells pupil his answer is incorrect (31)**			2			
The Teacher Asks Questions							
Factual	Teacher reviews pupils' prior learning (2)	1					
	Teacher encourages the pupils to observe (11)	18	**5**	13	14	20	
	Teacher asks questions that demands factual recall (12)	2		**10**	2	3	
	Teacher asks 'how many?'(19)		4			11	
Reasoning	Teacher encourages the pupils to think (10)	2					
	Teacher asks questions that demand an explanation (13)	3	1				
	Teacher asks questions that demand application of science (14)	1					
	Teacher asks 'what happens if?' (21)	4	6		3		
	Teacher asks questions that demand interpretation (22)*	5	**10**	2	**8**		
	Teacher asks pupils to report a judgment (29)**						
Open	Teacher asks pupils to describe what they will do (17)				**8**	1	
	Teacher asks questions that demand comparison (20)				4		
The Teacher Explains	Teacher uses representations of the real thing (4)						
	Teacher uses pupil's answer as a basis for explanation to the class (9)						
	Teacher explains (27)*						
Not Teaching	*Teacher gives wrong information (A)*						
	Teacher misleads the pupils (B)						
	Teacher ignores pupil's question (C)						
	Teacher ignores pupil response (D)	*2*					
	*Guess what I am thinking (H)***						
The Teacher directs pupil to secondary sources	Teachers tells pupils to pose questions for research (24)*						
	Teacher reveals doubt positively (28)*						

First School Experience (SE1)

Rachel taught the topic Changing Materials to a class of 23 pupils aged 8-9 years. Her main concern was "designing questions to point the children in the right direction". The pupils worked in small groups, to find out what temperature salt dissolves fastest in. Rachel worked with the special needs group, that is, the pupils who had poor reading and writing skills. In the post lesson interview she said her group realised that salt dissolved fastest in hot water, but was not sure if the class understood what a fair test is, but would look at their written work to find out.

Rachel was very keen that the pupils should meet the learning outcomes and so she told them the correct answers, rather than discuss the pupils' observations, as the following extract shows;

R	"Now I'll do the warm water"
	R stirs a teaspoon of salt into a cup of warm water
R	"Does it dissolve?"
ch6	"No"
R	"Well it does a bit, put a question mark in that column *points to w/s*
	What about hot water?"
ch6	"Nearly"
R	"Yes it does, so put a tick in that column" *points to w/s*

At the end of the interview Rachel commented that it "was good to get the chance to really talk about my teaching".

Second School Experience (SE2)

Rachel's SE2 topic was Electricity, which she taught to a class of 24 pupils aged 9-10 years. Rachel was concerned about the lack of resources in the school. The pupils were "Learning the electricity circuit symbols so that they could interpret drawings and make their own circuits", thus Rachel asked 10 questions that required the pupils to interpret, such as, "What does this mean?" as she pointed to various symbols. The opportunities for observation were limited, as the pupils simply had to note whether or not the bulbs in the circuit lit up.

Third School Experience (SE3)

Rachel took up a post in a primary school, where I observed her teach for SE3 - SE6. For SE3 Rachel taught a class of 19 pupils aged 10 -11 years. The school had a high proportion of pupils with EAL (English as an Additional Language) so the one of the foci for all subjects was English language development.

For SE3, Rachel's topic was Flowers Structure and Function. Her lesson was almost identical to Mary's SE3 lesson. The pupils were very excited about the flowers. In interview Rachel said that the most difficult aspect for teaching the class was that "Because they have such a limited life experience, it is difficult to find appropriate examples to link one phenomenon to another". The following example shows the pupils' limited experience;

R	"I'm going to give you a daffodil each"
ch1	"You're generous"
ch2	"Are these actual flowers? You know real ones" *ch3 shrugs*
R	"Thank you, put your daffodils on a piece of white paper like in art"
ch2	"Where do we put the flower?"
ch1	"On the white paper"
ch2	"She said put the daffodil on it"
ch4	"Yeah, that's the flower, a daffodil that's what the flower is called" *laughs*
ch2	"Oh, now you tell me"
ch5	"Can we take them home miss?"
R	"No, we're going to cut them up"
ch5	"Oh no miss, you can't do that you'll kill them" *anxious voice*
R	"Well they're dead already really, they haven't got any roots"

In this lesson Rachel gave a lot of information, which she tested the pupils on by asking a lot of factual recall questions.

Fourth School Experience (SE4)

Rachel taught the same class of pupils aged 10-11 years for SE4. The topic was Decay. The pupils looked at decayed foodstuffs and discussed what they saw. Rachel's focus was to encourage the pupils to observe. In interview Rachel said the pupils had observed the changes to the foodstuffs. She said that she knew this by their oral responses and drawings. Rachel asked 8 questions that demanded interpretation, as the pupils worked out what fraction of the foodstuffs showed signs of decay.

Fifth School Experience (SE5)

For SE5 and SE6 Rachel taught a new class of 20 pupils aged 10 -11 years. Again there were a lot of pupils with EAL in the class. For SE5 the topic was Minibeasts, the pupils were using a key to identify minibeasts and then draw them. Rachel wanted the pupils to be able to observe the minibeasts closely. In this case the minibeasts that the pupils had to identify, a woodlouse and a centipede, were drawn and named on the worksheet, so that the pupils could correctly identify them without being able to use a key. Rachel had given the pupils the answer (as a picture) and then posed the question. This lesson gave Rachel the opportunity to ask 20 observation questions and 11 'how many' questions as the pupils counted the number of legs and body parts of the minibeasts.

Rachel felt that she would like support with helping pupils to plan an investigation, saying "Able children with little experience of planning investigations, tend to make them too broad".

Sixth School Experience (SE6)

For SE6 the science topic was Drugs Education, the lesson focus was "Who influences people to take drugs". In interview Rachel said that she was not sure if "This really is a science lesson, but it's part of the *school's plan*". There was no engagement with science during this lesson, it was a PSHE (personal, social and health education) lesson. Peter's SE3 lesson on smoking differed in that although it covered aspects of PSHE, it also covered the biological effects of smoking.

Rachel said that overall her main concerns when teaching science were "My subject knowledge, when we're studying something, I'm aware the more I know about the subject, the more able I am to change the focus of the lesson to target, support and stretch the children". Rachel's own subject knowledge greatly affected her confidence to teach science, she said, "I have GCSE science, would I be any better with 'A' level? Not necessarily. The best way for me to know, is to teach to be aware of the pitfalls and make sure next time round to be better prepared".

At the end of the main study

Rachel thought that the main benefits to primary pupils learning science were

> "Raising awareness of the world around them. Developing skills in investigating and understanding the world around them. Giving a practical framework to relate other subjects to for example, maths, technology and language. Empowerment, a horrible word, that means everything, self esteem etc"

After three years Rachel still focussed on the role of science to develop practical skills and investigative skills.

Rachel was planning to stay in the same school next year.

Rachel's pattern of engagement with science and teacher type

Rachel was observed for all six SEs, see figure 7.11, but the SE6 lesson was not included as it was not really science. There was little significant change in Rachel's pattern of engagement with science. Any changes, such as a lot of giving of information in SE3 can be accounted for by the topic, 'structure and function of flowering plants'. In both SE1 and SE2 Rachel seemed more anxious that the pupils should *know* something. In both lessons she unconsciously led the "*pupils to the correct answer, but not necessarily to understanding*". In SE1, Rachel did this by pointing to the correct answer. In SE2, she told the pupils the correct answer. In the later SEs, Rachel seemed to want to direct the pupils less. Rachel asked seemingly open-ended questions and encouraged the pupils to respond. For example, in SE4 Rachel asked the pupils to describe mouldy apples. She did not write all of the pupils' answers on the board, but did not explain why some answers were ignored. Rachel taught in the same school for SE3 - SE6. The school had a policy of writing the learning intention on the board, which the pupils wrote in their science books. However, for two of the lessons that I observed there was a mismatch between the learning intention and the activity that Rachel had planned. For SE5, Rachel wanted the pupils to "be able to use a key to identify unknown organisms", and the pupils had to identify a range of minibeasts. However, the minibeasts used were ones that the pupils could identify already for example, earthworm, snail, and spider. The key that the pupils were given had labelled pictures of the minibeasts,

so the pupils simply matched the picture to the minibeast and identified it, that is, they did not have to know how to use a key to successfully complete the activity. For SE6, the learning intention was that the pupils should "understand that some drugs can be harmful". Rachel was uncertain about whether or not the lesson was science, as the pupils spent the session working on their own short plays about how to ignore peer pressure and not to take drugs. Rachel was very aware of the limited experiences that many of her pupils had and was keen to broaden their horizons.

I would characterise Rachel as a teacher who was very keen to *engage with the pupils* and to *introduce* them to new experiences. Her engagement with science was '*hit or miss*' as she did not always think through how the *activity matched the learning intention*. Rachel was keen to get critical feedback about her teaching. Throughout the main study, Rachel always indicated that she would welcome any opportunity to develop her own science knowledge and understanding, and to develop more successful ways of teaching science. Rachel remained a *keen learner* throughout the main study. Rachel regarded herself as a *co-learner*, learning alongside the pupils. Like Mark, Rachel wanted the pupils to *discover* things for themselves, but she adopted a *transmission* mode when her questioning did not result in the pupils' understanding. Rachel best fitted the *linear transmission* model.

7.3 Reviewing the group as a whole

One of the difficulties in making any sensible comparisons between the participants is, as has already been said, that their topics and classes were very different (see figure 7.1). For example, it would not be fair to suggest that the participants rarely mention health and safety issues, as it was not obvious that health and safety issues should have been mentioned in all of the lessons observed.

All of the participants, apart from Veronica actively interacted with their pupils throughout the lessons, that is, the participants were always talking to the pupils, even though it was not always about the science content of the lesson. Despite seeming to be 'switched off ' during the lessons, Veronica's pattern of engagement with science was not significantly different from those of the others.

In all lessons the pupils were given instructions about the task and given science information. There were few Incidents of negative engagement with science.

In most of the lessons there was a definite plenary section, where the participants drew the learning together and attempted to assess pupil learning formatively, by asking questions that demanded factual recall or observation. In few cases was future learning anticipated, that is, the participants did not tell the pupils where 'today's' learning was leading.

The participants were keen to enhance the pupils' scientific vocabulary by introducing new terms. They also encouraged the pupils to use the correct terms and gave clues as necessary, but these clues were not always science based. The participants sounded out words to pupils, by making the initial sound or saying a word that was similar to the word needed.

The participants were also keen that the pupils should leave the lesson having learned something new. This may have led to some of the participants *telling rather than teaching* and by *feeding* the answer, by word or gesture, to the pupils.
The participants did attempt to explain new concepts to the pupils and all engaged the pupils in discussion, by asking questions that required the pupils to apply science or interpret information. The participants also made the pupils think, by challenging the pupils' responses.

Almost all of the lessons involved some practical work. This was either small group work or teacher-led demonstrations. Garrett and Roberts (1982) cited in Harlen (1999) show that teachers used both types of practical work, small group work and demonstrations to maintain a guided *discovery approach*. This is where the practical activity is used to illustrate a concept or phenomenon. The participants used practical activities in this way, for example, Luke used demonstrations to illustrate condensation in the water cycle and waterproofing. Esther demonstrated peristalsis. There was little evidence of the participants allowing pupils to design their own investigations.

7.4 The value of teacher characterisation

The value of these teacher characterisations is that they reveal that the participants teach, using a variety of teaching styles. The three types, transmission, co-learner and discovery were not seen exclusively in any of the participants. None of the participants fitted the connectionist or social constructivist teacher type. The ways in which the participants taught was determined by several factors. Some of these factors were under the participants' control for example, lesson preparation, including reading around the subject. Other factors for example, availability of resources, were not. The pressure of SATs may have lead the participants to adopt a *transmission* mode and teach in a way that they might not have chosen to. Several participants adopted a *discovery* mode, that is, they used practical activities to illustrate the concepts that they were teaching. The transmission and discovery teacher types described above, would fit the Linear Transmission type as identified by Murphy et al. (2001). None of the participants demonstrated a *connectionist* mode, although some of the participants did review prior learning and asked questions that demanded the application of science, that is, the pupils had to draw on prior learning or observations, to answer the question.

An awareness of teacher characterisation, may help teachers to reflect on why they teach in the ways which they do and to think about what style might be more effective for a particular lesson.

7.6 The answers to the research questions

The research set out to answer the following two questions;

1. How does the pattern of engagement of new teachers with the content of primary science develop over their first three years of teaching?
2. What factors contribute to teachers' patterns of engagement with science?

How does the pattern of engagement of new teachers with the content of primary science develop over their first three years of teaching?

In reflecting on the individual case studies, I did not identify any conclusive patterns or trends over time, for the participants. The individual patterns of engagement (figures 7.2-7.11) show that there was little change over the three years of the main study. Significant differences in engagement for each participant can be explained. The participants were consistent in their approaches to teaching, that is, they tended to best fit a type, most were transmission and /or discovery teacher. I had expected that as they gained experience their lessons would include more discussion and opportunities for the pupils to think, apply knowledge to answer questions and to demonstrate their understanding of science. I thought that over time the patterns of engagement would show that teachers asked an increasing number of reasoning questions over time. But this was not the case. Galton, Hargreaves, Comber, Wall and Pell (1999) found that talk in Key Stage 2 classes comprised teachers making statements and asking factual recall questions, as did the participants.

The participants engaged their pupils in limited discussion from SE1 and this continued throughout the three years. The most obvious area of 'weakness' was the Aspect "Teacher explains". The participants offered descriptions of phenomena and concepts, but there was little attempt to go beyond this, although some participants used models to help explain concepts. For example, Esther used a marble and rubber tube to demonstrate peristalsis, James used the pupils to enact the 'big bang', although I am not sure how much science this taught them, as they danced around the hall.

The participants were not explicit in telling pupils their answers were incorrect until SE3, although they implied that pupils were incorrect in earlier SEs. In many instances the participants asked questions, but did not tell the pupils whether or not they were correct.

This was not always problematic, as sometimes it gave other pupils a chance to comment on or disagree with their fellow pupils' responses, as this example from Mark's pre SE3 lesson shows;

M	"What do we expect to happen to the pulse?"
ch1	"The pulse would get faster"
M	"When you exercise?"
ch1	"Yes"
M	"Who else?"
ch2	"I thought it would get less"
M	"Why?"
ch2	"Because you'd be getting tired"
M	"Who else?"
ch3	"When you do all that exercise your heart beats more and sends it all round the body to your pulse"
ch4	"I think fast, when we did dance, I remember"
M	"Ah, what happened?"
ch4	"It went faster"

Mark could have ended the discussion with ch1, who had given the *correct* answer. By throwing the question open Mark drew out an explanation from ch3, a misconception from ch2 and ch3 and allowed ch4 to recall an everyday experience and apply it to the investigation.

My reflections on what factors contributed to the participants' patterns of engagement with science?

The following are the factors that I identified during my reflections on the participants' lessons and their responses in interview, that were likely to affect the participants' patterns of engagement with science;

The learning focus

For some of the lessons observed, even though the context was a science lesson, the participants' focus was not teaching science. For example, Esther's SE3, SE4 and SE5 lessons, the focus was language development, as the pupils with EAL . For SE3 and SE4 Luke only taught one pupil, the focus was the pupil's fine motor skills development and building his confidence. In several lessons, even though the participants' thought that the lesson had a science focus, it did not. For example Peter's SE2 lesson, making electrical

buggies, simply required the pupils to make a buggy, so was really a Design Technology lesson, which did not allow for much beyond giving instructions and health and safety advice. Rachel's SE6 lesson on drug taking included almost nothing about the useful and harmful effects of drugs. The lesson was really a health education lesson.

Participants' attitude to their SE school

The participants' happiness in their schools strongly determined their attitude to teaching. Ruth was unhappy in her SE4 school and said that this had affected her attitude to teaching, and so she was not very enthusiastic. Veronica was unhappy in her SE2 school and said that she had not done any research for the topic that she was teaching. Esther who had been very enthusiastic in SE1 - SE4, became disenchanted with her school and so had not adequately prepared for her SE5 lesson. Ruth and Esther both left teaching citing their unhappiness in their schools.

The topic

The topics taught and the classes taught were not consistent over the six School Experiences, see figure 7.1. When the participant taught the same classes, as they all did for SE3 and SE4, and SE5 and SE6, the lessons were often very different making a comparison unfeasible. For example, Thomas taught a lesson 'identifying differences between living and non-living things' for SE5 and 'assessing science skills' for SE6. Lessons involving the naming of parts and describing their functions, allowed for lots of observation questions and giving of information.

Type of lesson

When the participants were teaching pupils aged 10-11, the focus was often preparing the pupils for SATs. For example, Mary for SE5 focussed on the pupils knowing the facts, rather than understanding. This led to participants giving more information and asking more factual recall questions than they might have done for other lessons. Mary said she was constrained both by the SATs and by time. Thomas's SE6 lesson was to assess science skills, so there were few opportunities to give new information.

A lesson where a new concept or topic was being introduced led to a lot of giving of information.

Type of teacher

Luke and Mary best fitted the *transmission* teacher type. All of the other participants fitted the transmission teacher type, with elements of the *discovery* teacher type, where practical activities were designed to illustrate concepts that the participants wanted the pupils to grasp. The nature of the class or the nature of the lesson often determined the teaching style that the participants demonstrated. For example Esther adopted a *transmission* mode when teaching her SE1 class about human digestion, as the lesson required a lot of information to be given. She adopted a more *discovery* mode for SE2, when her class was investigating where minibeasts live. However, all of the participants asked their pupils questions in an attempt to allow the pupils the opportunity to work things out for themselves. This fits the discovery teacher type. There was little evidence of the *connectionist* teacher type.

Age of pupils

At Key Stage one, the pupils were not directed to secondary sources for information, all of their lessons involved whole class discussions, practical activity. Singing and chanting was only observed in a Key Stage one class.

Planning and organisation

In many of the classes, the pupils were organised into pairs or threes to carry out the practical tasks. In all cases the participants moved around the room interacting with one pair/small group at a time. This often meant that the participant asked the same set of questions to each group. This did not allow for the participants to ask more challenging questions, as there was insufficient time. Often the participants did not allow the pupils time to tackle the tasks before asking them questions. In only a minority of cases, did the participants tell the pupils what the questions would be before they started the task, in some cases this was written on the board.

For example, Ruth's SE3 asked each group how they were carrying out their investigation safely, but she had not asked them to consider safety when planning their investigations. Harlen (1999) cites Australian research that showed that primary teachers had not planned beforehand what the pupils would learn from the activities. "This failure to of the teachers to focus on the development of ideas may have led to the increased incidence of off-task behaviour" (p34). The participants tended to focus on what the pupils would *do* rather than

on what they would *learn* nor on what *the teachers* would do to facilitate this learning (Palmer 1997). Harlen (1999) lists features of better planning, this includes

- What ideas and skills the activity would help to develop
- How to elicit the pupils' ideas
- What classroom organisations are appropriate for different points of the lesson
- What equipment is needed
- What and how instructions should be given

For some of the lessons thought had been given to developing both skills and knowledge. For example, Rachel's SE1 lesson on the effects of temperature on dissolving, where the pupils carried out a fair test. In other lessons, especially where the focus skill was fair testing, the development of knowledge was rather thin, for example Ruth's SE3 lesson on materials, and Mark's SE4 lesson on sound.

Few of the participants attempted to elicit the pupils' ideas at the start of the lesson, most simply tended to ask the pupils what they had remembered from previous lessons. This was done by asking questions that demanded factual recall. In the weakest example, see Thomas's SE2 lesson, the focus was on remembering how many facts the pupils had learned, rather than what those facts were. Luke elicited the pupils' ideas on waterproofing (see Luke's SE6 lesson) but he did not use this information to inform his lesson. The practical demonstration simply illustrated what the pupils already knew.

For practical work, the participants tended to organise the pupils into small groups, as they would have observed experienced teachers doing. This meant that the participants often ended up teaching a series of mini lessons, where they asked the pupils very similar questions, see Ruth's lessons. As the small groups were not based on ability, there were few opportunities for the learning to be taken further. Most of the lessons had a whole class introduction and plenary and small groups for the main activity. This arrangement does not always work best for science, where the pupils all tend to do the same activities each lesson. Small group work should be used selectively, for example, when pupils are required to plan independently. Carlsen (1987) showed that teachers tended to use whole class teaching for topics where they had greater subject knowledge. Harlen et al. (1995) support this finding, as they found that primary teachers, whose confidence to teach science was low, tended to

avoid whole class discussion. My research shows that the participants tended to use whole class teaching to review previous knowledge and to give instructions and information.

The participants had thought about the equipment needed for their lessons, but they had not always carried out the activities themselves to check that the equipment worked, for example, Mary's SE1 lesson on electrical circuits and Peter's SE4 lesson on changing states. The time spent checking equipment could have been spent engaging with science.

All the participants gave instructions for every lesson. In most cases the number of Incidents of giving instructions was high. This may have been because the pupils would have had difficulty reading instructions, especially the Key Stage 1 pupils and those with EAL. Mary had very few Incidents of information giving in her Se5 and SE6 lessons, because she wrote the instructions on the board. Where this can be done, it could perhaps create more time for engagement with science.

The participants' subject knowledge and understanding

Although none of the participants identified their own subject knowledge and understanding as a concern when teaching science, many admitted that they had done little reading around the subject when preparing for their lessons. This may be the reason for their concerns related to the pupils' understanding and how to teach the concepts, (see the participants concerns in the following section). The ability to break down concepts into manageable chunks to teach pupils requires more than simply knowing the subject, it requires the teacher to understand how that knowledge has been constructed. The participants only taught one topic for each of SE1 and SE2. Typically primary teachers teach six different topics during the school year. Where the participants taught the same year group for their first two years of teaching post training, they would normally teach the same six topics. Thus the number of different science topics that the participants would have taught during the three years of the main study could vary between eight and fourteen. For all of the participants, except Thomas, Luke and Esther, this would all be in Key Stage 2. Experience of teaching a topic usually improved the participants' confidence to teach it and would have given them a greater insight into the problems that pupils would have in understanding the concepts. However, few of the participants would have had experience of and an understanding of how that knowledge was constructed at Key Stage 1 and so they might have little to build on.

Changes to the requirements for Initial Teacher Training (DfES 2002), require that trainee teachers must across Key Stages 1 and 2, and that their training courses prepare them to do this.

The participants' reflections on what factors contributed to their patterns of engagement with science?

The participants' concerns when teaching science were, as identified in the post observation interviews;

1. Lack of suitable resources;
2. How to organise pupils for practical work;
3. That the pupils would not understand the concepts taught;
4. How to make a 'dry' subject interesting (the topics were Earth and Space, Magnetism and Forces)
5. Health and safety;
6. How to break the concept into manageable chunks so that the pupils could understand it.
7. Time

Classroom organisation, time and resources

Concerns (1) and (2) above organising pupils for practical work, are what Shulman (1987) identifies as "general pedagogical knowledge- about classroom management and organisation that transcends subject matter". I believe that the participants' concerns about organising the pupils for practical work was related to their concerns about managing pupil behaviour.

In some of the lessons, for example Luke's SE6 lesson on waterproof materials, Mark's SE4 lesson on sounds and Peter's SE4 lesson on changing materials, there seemed to be far too many items for the pupils to test. By the time all of the items had been tested the results recorded, there was no time to develop the concepts further. The pupils were not given the opportunity to identify patterns in the behaviours of the various items. Fewer items, may have allowed more time for the participants to ask more higher order questions, that is, those that demand interpretation, application and explanation.

The participants identified a lack of suitable resources (1) as the most common concern. However, I cannot be certain if the schools lacked suitable resources, or if the participants were not aware of what the schools possessed or if they were not able to make good use of what was available. Some of the participants did not have a routine of trying out the activities beforehand, which often results in resource problems. With experience, it is possible that the participants would become more competent in their use of resources. Shulman (1987) identified the use of material as curriculum knowledge, which includes knowledge of the materials available.

Health and safety

Concerns about health and safety were not unexpected, as this concern was raised when the participants were using boiling water in class (Luke SE1 and SE4 and Peter SE4).

Pupils' understanding and the participants' teaching

The participants concern that the pupils might not understand the concepts taught (3), may have led some of them to tell rather than teach. None of the participants identified their own subject knowledge level as a concern. However, the concerns (3) and (6) indicate that the participants were aware that their pupils' understanding of the concepts taught could be problematic, even if they thought that their own subject knowledge and understanding was not a concern. James identified this problem in his SE1 interview, saying that one of his concerns was "How I'm going to talk to them, how to tone down the concepts, rephrasing them" even though he thought that the science required at this level was "pretty basic. This resonates with Shulman's (1987) reference to the kind of knowledge that relates to how to teach subject matter, that is, 'pedagogical content knowledge'. For science this includes useful illustrations, powerful analogies and examples. Shulman's observation is echoed in the Council for Science and Technology, (CST) report (2000), that states;

> Research indicates that science teachers need to possess good subject knowledge in order to develop the subject-related pedagogical knowledge, skills and competence that is so necessary to present a science topic to pupils, in comprehensible and stimulating ways by drawing on the best possible analogies, examples, illustrations, explanations and demonstrations to build on each pupils' existing level of understanding.
>
> (para 13)

The participants' problem may have been how they understood the science, not how much they knew (see Fiona, Chapter 3, section 3.1). This may be reflected in concern (4). The participants' concern about some subjects being 'dry', may have been because they were not able to relate it to other topics that would have interested the pupils. Some of the participants were not able to relate phenomena to ideas, that is, to present phenomena as evidence (or support) for an idea.

The participants said that experience of teaching a topic increased their confidence to teach it. In interview Mary said "My knowledge improves for the topics I've taught. I could teach them again with less preparation". Rachel also recognised the benefits of experience saying "The best way for me to know is to teach and to be aware of the pitfalls and make sure next time round to be better prepared". During the post lesson interview for SE2 Veronica said that her confidence to teach science had remained unchanged since SE1 because "I haven't taught it (science) much". Carré and Carter (1999) found that in a survey of primary teachers experience led to increased confidence, see section 3.4. This echoes the findings of the survey of BA Primary trainees (section 2.1, Table 2.2) 33% of whom said that experience of having taught a topic gave them confidence to teach it.

The pupils' success also gave participants confidence that their teaching approach was effective. In interview Mary said " I can see the children remember and retain what I taught them, which makes me feel I must be doing something right. The science SATs (results) have gone up and I've been the year 6 teacher, so I must be doing something right".

Mary had a positive attitude to preparing for science lessons. At the start of the main study, Mary identified her subject knowledge as a weakness. By the end of the main study this was no longer the case "It isn't anymore. I make sure I read up about it beforehand. I still make time for this". Veronica recognised that preparation was necessary for improved subject knowledge and understanding. In her SE2 interview she said "I've done this (topic) on SE1. I don't know any more. That's my fault, I didn't research anything". I was surprised, that after their training year, few participants continued to read to improve their subject knowledge and understanding. This could account for why they were not able to make *connections* between areas of knowledge.

The factors that affected the participants' engagement with science

There are many factors that may affect the participants' pattern of engagement with science, some of these, were recognised by the participants themselves. I was not able to identify what the main factor was for each participant. However, the participants' teaching styles remained fairly constant throughout the main study.

7.7 Implications of the research

The participants' patterns of engagement with science remained relatively stable over the three years of the main study. Where there was a higher or lower number of Incidents of particular Aspects of engagement these could be explained, see section 7.2.2 -7.2.11. All of the participants best fitted the *transmission* and *discovery* teacher types, that is the *linear transmission* type. Few were *co-learners* and none were wholly one type. No participant fitted the *connectionist* or *social constructivist* teacher type.

I would offer the following two possible explanations for this stability. Firstly the participants were still relatively new to teaching. It would be interesting to observe the participants after five years to see if their patterns of engagement had altered. The CST report (2000) states that;

> As might be expected, the teachers in the first five of their careers generally had less confidence in teaching science than their more experienced colleagues.
>
> (para 26)

The report does not say that experience made the teachers more competent, but time may have given them experience of teaching more topics to a wider range of year groups. This would have given them a better understanding of how knowledge is constructed and experience of what activities and explanations best support pupil understanding. Experience of teaching a wider range of topics, may enable teachers to make more connections between different areas of science.

Secondly, once they started teaching the participants all had a new set of concerns apart from being responsible for teaching all subjects to their classes full time. These additional

concerns included SATs, staff relationships, Ofsted, pupils with EAL. With the then impending introduction of the NNS (National Numeracy Strategy) and NLS (National Literacy Strategy), the schools and therefore participants were focussing on mathematics and English. Many of the participants had also taken on posts of responsibility, and so their focus was on these subjects. Science was therefore not a main focus/concern for the participants, except in Mary and Rachel's classes. This was not unexpected as these were year 6 classes, having to take SATs in science in the summer term.

This study shows that the participants' teaching styles were established early on in their teaching lives, that is, by the end of their training year. These teaching styles remained fairly constant throughout the participants' first two years of teaching post qualification. Of the 39 Aspects of engagement identified during the three years of the main study, 27 were identified during SE1 and a further eight during SE2. Thus only four further Aspects of engagement were identified once the participants had completed their training year.

Once trainee teachers start teaching after qualification, they may never be observed teaching science. Primary schools are inspected by Ofsted, but not all teachers are observed teaching science. Schools may also be inspected by their own LEA inspectors, but again not all teachers would be observed teaching science. The participants all taught in schools where there was science coordinator. The coordinators were responsible for writing and implementing the school's science policy. None of the participants were observed by their schools' science coordinator. Indeed, in his first year of teaching after qualifying Peter became his school's science coordinator. The opportunities for science INSET for the participants were limited. The participants did attend some INSET courses, but with a focus on implementation of the National Strategies for literacy and numeracy. Although the participants did not identify their own subject knowledge as a concern, this could be misplaced confidence. Kinder and Harland (1991) reporting on the impact of primary science INSET said that

> Many teachers were clearly not aware of their needs in the science area until the advisory teachers and the scheme opened their eyes to the new possibilities. Clearly *needs* is not synonymous with teacher only perceptions of *wants*
>
> (p 45)

Rachel recognised that it was not always possible to identify her training needs. During the SE3 post lesson interview she said "I don't know what I don't know until I teach it".

It is possible that once trainees have completed their training, they do not receive any further training or feedback on how to teach science effectively. As Harlen (1999) reported;

> what holds back teachers' understanding is not ability to grasp ideas but opportunity t to discuss and develop them (ideas)
>
> (p 77)

These teachers would not have the opportunity to discuss their practice and reflect on it with a science specialist and so it is unlikely that their patterns of engagement would change significantly post qualification. Teachers unable to define their deficiencies or reflect on their practice will not be able to improve that practice. The CST (2000) reporting on secondary science teachers states that;

> The key requirement of every science teacher's professional practice and continuous professional development is to maintain and strengthen their subject knowledge and their ability to apply this knowledge to the specific circumstances of a pupils at that moment in time
>
> (para 17)

and that

> This applies particularly to science teachers in the early years of their careers
>
> (para 18)

I believe that this need for continuous professional development is a requirement for primary teachers too. Esther, Luke and Thomas all took up teaching posts in Key Stage 1 classes, even though their PGCE course only trained them to teach at Key Stage 2. None of these three participants received any support for teaching science at Key Stage 1. Thomas seemed to thrive in Key Stage 1, but Esther reported some difficulties, saying ""I have to adapt everything I learned at Key Stage 2, for KS1, it can be difficult". Luke taught the same lesson to his SE1 and SE5 classes, even though they were different Key Stages and had different levels of ability.

The ways that teachers engage with science can perhaps only be changed by direct intervention. The Engagement Schedule and identification of 'critical moments' may be useful instruments for this.

The participants' 'unhappiness' in their schools was a key factor in determining their attitude to teaching and was the reason why two of participants left the teaching profession within two years of qualifying to teach. Thus the support that beginner teachers receive is important to keep them in the teaching profession. Mary and Mark both said that they would like another teacher with whom to plan the curriculum. Esther and Rachel both said that they had enjoyed talking with me about their teaching. Nowadays NQTs have a mentor to support them during their first year of teaching, but this was not a requirement when the participants were NQTs. The mentor, of course, may not necessarily be a good science teacher.

7.8 Summary

The data is presented as case studies. Each case study tells of the participant's pre course qualifications in science, their attitude towards science and teaching science. The case studies show each participants' pattern of engagement with science and describes the lessons they taught. Reasons for the participants' pattern of engagement for the lesson are suggested, using evidence from the post observation interviews and the researcher's own reflections. Some participants were observed only during the first year of the main study, others remained for the three years.

The patterns of engagement remained relatively stable over the three years of the main study. The participants tended to best fit either the *transmission* or *discovery* teacher type, although as they were still rather inexperienced, this is not surprising. It is recognised that these teacher types are best fit, and so there will be some variation..

There were many factors that may have affected the participants' engagement with science. These factors included; the learning focus, was it science or for example, English language development, the participants' attitude to their SE school, type of lesson for example a practical activity to develop a concept, revision or assessment, type of teacher, age of pupils and organisation of the class (pairs/small groups).

Chapter 8 provides an evaluation of the research, an identification of the usefulness of the main study for readers involved in science education and suggestions for further research questions.

Chapter 8 Evaluation

8.1 Introduction

In this chapter I take a critical look at the research methods and explain how I think the research contributes to our knowledge and understanding of what is happening in primary science classrooms. I suggest further questions arising from this research.

8.2 A critique of the data collection methods

There are two possible criticisms, which might be raised about the validity of the data for this research. Both of these relate to how the data was collected. The first relates to the use of verbatim recording for the lessons and the second to the changes identified in the pattern of engagement being a result of changes in the skill of the observer, rather than changes in the pattern per se.

Verbatim recording

The problem of recording by hand, is whether or not the transcripts are a 'true' account of what happened in the lessons or a selective account, albeit at a subconscious level, by the researcher. It is, of course, possible that parts of the lesson were missed. It was therefore important to have a validity check for the transcripts. This was achieved by sending each of the participants a copy of their lesson transcripts within two days of the lesson and asking them if it was an accurate account of the lesson. All of the participants agreed that the transcripts were accurate accounts of the lessons, although Thomas commented that his use of English was not always accurately represented. Several of the participants made comments such as "You must have had a tape recorder hidden in your bag". This gave me considerable confidence.

I had anticipated this problem of recording the lessons by hand at the start of the research and so had tested this method of recording during the pilot phase (see Chapter 4). I found that because the focus of my research was the teacher, what the teacher did and said to engage with science, that I was able to ignore any pupil/pupil interactions and administrative incidents. For example, interruptions for the teacher to read out notices, quizzes/games at the

end of the lessons were ignored, allowing more time for note taking. I found it far easier to record what was happening in a Key Stage Two classroom, as the teaching tended to be more formal, the lessons had distinct parts, the teachers tended to talk at greater length, the plenary was with the whole class and followed a question/answer format. The teachers tended to stay still for the introduction and plenary and only move during the development part of the lesson, so it was fairly easy to follow them. In the Key Stage One classrooms however it was more difficult, because both the teacher and pupils tended to move around the room more.

My concern during the second year of the research was that three of the participants taught in Key Stage One classrooms. However, two of them, Esther and Luke taught classes of ten and fifteen pupils so recording was fairly easy. Thomas taught thirty pupils, but his teaching style was very formal, there was little spontaneous movement and the pupils rarely spoke without invitation. Thus I was confident that I was able to capture the lessons observed, even when they were in Key Stage One.

My confidence in the method was further increased through my research training when I attended a discourse analysis course at IoE. The first set task was to tape record a short conversation and transcribe it. The conversation was to be between no more than four people, one of whom should be the transcriber. Several of the course participants reported that they were unable to interpret what was being said on the tapes, even by themselves. I found this very reassuring, as tape recording did not necessarily result in more talk being captured, compared to use of verbatim recording.

How the skill of the observer may affect the results

The second problem was the possibility that I became, over the three years of the study, a more proficient note taker as the research developed. Thus any change in the pattern of engagement with science over time, could reflect my improved note taking ability rather than any change in the participants' teaching. However, as a teacher and later as a science education tutor, I had spent a considerable amount of time observing trainee teachers and experienced teachers teaching. I was used to making detailed notes whilst I was observing and so was not new to the role when I undertook the main study. The method used for the main study required me to refine a professional skill that I already had.

8.3 A critique of the methods of analysis and interpretation

Another area of concern is that the interpretation of the transcripts is largely one person's view, mine. I have read the transcripts many times and so am very familiar with them. There was therefore a danger that this could lead to me missing Incidents and of making only one possible interpretation. To guard against this other people, my science education colleague, my supervisor, research seminar participants and my own BA Primary Education and Primary PGCE trainees also read the transcripts. This was very useful, as other people offered alternative interpretations.

At the end of SE6 my science education colleague using the Engagement Schedule checked all of the lesson transcripts. When he was unsure which Aspect to classify an Incident under, we discussed it, but there were very few, as he found the Incidents examples so helpful. Following discussion with others, I looked at the transcripts again, and where appropriate identified a new example of an Incident of engagement, which, if necessary, could have formed a new Aspect of engagement. I was also concerned at the start of the research that I had to explain all that I had observed. I soon realised that I could not and did not have to account for all that happened in the lesson. In my own teaching, I am not always able to account for all that I say as it is not always planned or carefully thought through, especially responses to questions that are 'outside' the topic being discussed.

8.4 How useful is this research?

This research has several possible uses to others involved in primary science education. The Engagement Schedule, figure 6.4, is a useful product of the research. It shows the various ways in which teachers engage both positively and negatively with primary science. The Schedule would be helpful to other researchers looking at the ways in which teachers engage pupils in learning science. In developing my own engagement schedule, I believe that I have looked very closely at what is happening in primary science classrooms.

The development of the Engagement Schedule was not an original aim of the research, but it became an essential feature early on. The Engagement Schedule is not static. If further science lessons were observed it is possible that more Incidents would be identified. If these

were not Incidents of existing Aspects, then further Aspects would have to be added. New Aspects might result in new Categories, or sub-sections of Categories.

From this small study, it is useful to see what aspects of engagement feature prominently in the lessons and what aspects do not and what factors contribute to primary teachers' engagement with science. The reader should ask if those aspects of engagement, which are neglected, are those which would result in more effective practice. If this is the case, science education tutors could ensure that trainee teachers are encouraged to incorporate these ways of engaging in their lessons, for example, by preparing higher order questions, that is, those that demand explanation, application, and interpretation.

Another useful product of the research is the identification of 'critical moments' in primary science lessons. Encouraging teachers to identify negative aspects of engagement with science is made more purposeful when they discuss ways that the negative engagement could be made positive. My current trainee teachers have found it useful to read extracts of the lesson transcripts to identify the critical moments and to suggest ways of making the negative Incidents positive. Critical moments, unlike the engagement schedule, was an unexpected product.

How the participants' first posts affect their decision to remain in teaching

The research shows the importance of trainee teachers' first teaching post. The participants whose first posts were in supportive schools have stayed in teaching, usually in the same school. The two participants who left the teaching profession altogether, cited their unhappiness in their first (and only) school as the main reason. Ruth said that her first school had destroyed her confidence and so she left teaching to travel abroad.

8.5 Further questions

One of the starting points for this research was discussing the feedback given to a teacher following a lesson observation, (section 2.1. Martha received very positive feedback for teaching a science lesson *without science*. The subject of the feedback given to trainee teachers following an observation of their science lessons is still of interest to me.

Following each of the observations of the participants' science lessons, I interviewed them and discussed what I had observed. The participants valued the opportunity to discuss their lessons with someone, me, who was not assessing their performance. This has made me question the role of the people involved in supervising trainees on School Experience, perhaps the trainees should have some visits where they are not being assessed for example, a visit by a fellow trainee or another class teacher. The participants also valued the opportunity to read through the transcripts of their own lessons. The participants were able to identify many of the positive and negative aspects of engagement with science for themselves. I believe that this was more effective in highlighting engagement with science and teaching style, than if I simply reported my own impressions of the lessons. I would have liked to have spent time with each participant discussing their lesson transcripts, to get a better picture of how interpreted their own engagement with science.

The model of observing trainee teachers teach and then discussing their performance with them, as soon as the lesson is over, may not be the most helpful model, as it does not always allow time for reflection for the observer and observee.

This research project has prompted the following questions:-

1. How often is the trainee teacher observed teaching science during the School experience?
2. Who observes the trainee teacher teaching science and what is the observer's area of expertise?
3. What is the nature of the feedback from the observer, how does it help the trainee teacher to become a more effective teacher of science?
4. How do trainee teachers interpret the feedback that they receive and do they act on it?
5. What targets are set for the trainees, are these targets related to the teaching of science?
6. How are these targets monitored?

These questions could lead to another thesis. So far I have been prompted to undertake a small survey, relating to points 1 and 2. In June 2001, I asked twenty-five primary PGCE trainees who had just finished their final School Experience to complete a questionnaire about how often they were observed teaching science and by whom, (Appendix 9.1). The preliminary results and my commentary on them are reported in Appendix 9.2.

My current teaching post will provide me with ample opportunity and data to pursue these questions further.

8.6 Concluding remarks

This research is useful in that it describes what is happening in primary science classrooms and gives a valuable insight into the first three years of being a teacher. Few studies of this sort have been done before. The finding, that there was no significant change in the ways teachers engaged with science in their teaching, during those three years, is important. The other two outcomes of the research, the Engagement Schedule and the identification of 'critical moments' are both useful instruments in helping primary teachers examine their engagement with science and thus their potential effectiveness as science teachers. I have already used extracts of the lesson transcripts with my trainee teachers to illustrate critical moments and to identify ways of making the engagement positive.

The research has shown that there is a need for primary teachers to continue to be given opportunities to reflect critically on their teaching of science after qualification. None of the participants received any feedback on their science teaching after qualification. Unless teachers evaluate their teaching it is unlikely that their teaching approaches will develop. Teachers need help for this evaluation, preferably from a science co-ordinator. Although I did not give the participants feedback on their science teaching, they did welcome the opportunity to read the transcripts of their lessons as this gave them insight into how they taught science, which often conflicted with how they believed they taught science.

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Appendix 2.1

Questionnaire A
Research questionnaire on Trainee Teacher Confidence with Primary Science

This questionnaire is part of a research project to explore teacher confidence with primary science. It is hoped that information gained here, will inform future training programmes in primary science. You are asked to complete the questionnaire independently and to avoid any consultation with other colleagues. No individual will be identified. Any publication will take the form of a general survey of results.

1.Main subject(s)
2.Pre BA science qualifications:-
CSE
'O' level
GCSE
'A' level
Other (please specify)
3. Please indicate your confidence to teach these primary science topics

1= no confidence 5 = very confident

Energy	1	2	3	4	5
Air and Flight	1	2	3	4	5
Light	1	2	3	4	5
Electricity	1	2	3	4	5
Magnetism	1	2	3	4	5
Forces	1	2	3	4	5
Sound	1	2	3	4	5
Colour	1	2	3	4	5
Materials	1	2	3	4	5
The Human Body	1	2	3	4	5
Growing Plants	1	2	3	4	5
Animals	1	2	3	4	5
Pond Life	1	2	3	4	5
Minibeasts	1	2	3	4	5
Earth and Space	1	2	3	4	5
Seeds	1	2	3	4	5
The Senses	1	2	3	4	5

Please add to the list if necessary

1	2	3	4	5
1	2	3	4	5
1	2	3	4	5

4. Which topics do you feel most confident to teach? Why?

5. Which topics do you feel least confident to teach? Why?

6. Which age group would you prefer to teach.

Nursery/reception
Years 1&2 (Key Stage 1)
Years 3&4 (lower Key Stage 2)
Years 5&6 (upper Key Stage 2)

7. Has your confidence to teach primary science influenced the age range that you would prefer to teach? Give reasons for your answer.

8. What improvements (if any) to the primary science would you recommend? Are there any topics that have not been covered/not covered in sufficient depth?

Appendix 2.2

Questionnaire B

Research questionnaire on trainee teacher confidence with primary science

This questionnaire is part of a research project about teacher confidence with primary science.

Please complete the questionnaire independently - avoid consultation with others. No individual will be identified. Any publication will take the form of a general survey.

1. What science topic/s did you teach on:-

   SE2
   SE3

2. What age group would you like to teach on SE4?

   Has your confidence with science influenced your choice? YES/NO Why?

3. What science topics would you MOST like to teach on SE4?

   i)
   ii)
   iii)

   Why?

4. What science topics would you least like to teach on SE4?

   i)
   ii)
   iii)

   Why?

5. You have now completed your science input for your BA. What aspects of science do you still feel unsure about?

6. What aspects of science teaching would you like further training on?

7. About you:-

Main subject/s
Previous science qualifications

Subject	CSE	GCSE	'O' level	'A' level	Other, please specify
Biology					
Chemistry					
Physics					
Science					
Other, please Specify					

8. Sum up in few sentences your feelings about teaching primary science.

Appendix 4.1

Initial questionnaire to select research participants

This questionnaire forms part of a research project on "teacher confidence in primary science". Please answer the questions as honestly as you can and AVOID consultation with colleagues.
Results from this questionnaire will be written up as part of a research project, where no individual will be identified.

Each respondent was given a set of cards with the one subject on each card. The subjects were;
English, mathematics, information technology, games/PE, drama, technology, science, art, geography, history, dance, music, RE.

1) Look at the set of cards. Put them in order of preference (that is, your favourite subject first)
   1.
   2.
   3.
   4.
   5.
   6.
   7.
   8.
   9.
   10.
   11.
   12.
   13.

2. What do you remember about science at school?
   Briefly describe incidents that stick in your mind for:-

   a) Primary school

   b) Secondary school

3. Here are some statements that describe trainee teacher feelings about teaching science. Tick 3 that you relate to. Add some of your own.

- I feel very confident, science is my favourite subject
- I'm only a few steps ahead of the children
- Science has changed a lot since I did it at school
- Children like science, so that helps
- I'll need to do a lot of reading before teaching it
- Science is really hard
- I've got no idea what to expect
- I'll be OK with a lot of practice
-
-
-
-

4. Put the cards in order of 'confidence to teach' (that is, put the one you feel most confident to teach first).

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.

5. Here is a list of science topics commonly taught in primary schools.
Tick 3 that you would MOST like to teach.
X 3 that you would LEAST like to teach.

Energy	Air and Flight	Light
Animals	Pondlife	Minibeasts
Electricity	Magnetism	Forces
The Human Body	Plants	Earth and Space
Sound	Colour	Materials
Seeds	The Senses	

6. Science is one of the three core subjects (the others being English and mathematics). Do you think that science's place as a core subject is justified?

Briefly explain your answer.

If you had to replace science as a core subject, what would you put in its place?

Why?

7) All about you

Name:

D.O.B.

Previous science qualifications:

Degree subject/s:

Area you are likely to apply for teaching posts in:

Appendix 4.2

Questionnaire given to participants at the end of the science input for the PGCE programme and before their first School Experience, SE1.

This questionnaire forms part of a research project on "teacher confidence in primary science". Please answer the questions as honestly as you can and AVOID consultation with colleagues.
Results from this questionnaire will be written up as part of a research project, where no individual will be identified.

1. Here are some statements that describe trainee teacher feelings about teaching science. Tick 3 that you relate to. Add some of your own.

- I feel very confident, science is my favourite subject
- I'm only a few steps ahead of the children
- Science has changed a lot since I did it at school
- Children like science, so that helps
- I'll need to do a lot of reading before teaching it
- Science is really hard
- I've got no idea what to expect
- I'll be OK with a lot of practice
-
-
-
-

2. Here is a list of science topics commonly taught in primary schools.
   Tick 3 that you would MOST like to teach.
   X 3 that you would LEAST like to teach.

Energy	Air and Flight	Light
Animals	Pondlife	Minibeasts
Electricity	Magnetism	Forces
The Human Body	Plants	Earth and Space
Sound	Colour	Materials
Seeds	The Senses	

3. What are you most looking forward to about teaching science?

4. What are you least looking forward to about teaching science?

5. What science topics/ aspects of science teaching would you like a further session on?

Appendix 4.3

Letter to Headteachers sent before each of SE1, SE2, pre SE3, SE3, SE5, SE6
(letter sent on University notepaper).

Date

Dear *Headteacher's name*

As part of a research project on teacher confidence with primary science, I will be observing *participant's name* teaching science during this School Experience. The observation period will be followed by a short interview with *participant's name*. I would like to tape record the lessons. Please be assured that no individual or school will be identified in the written report. Participant's name has been asked to inform his/her class teacher of my visit.

Please feel welcome to contact me if you would like any further information about the research project.

Yours sincerely

Christine C Khwaja
Senior Lecturer Primary Science Education

(For pre SE3 to SE6, the letter indicated the terms in which the participants would be observed. Only the SE1 letter indicated that the lessons would be tape recorded, as this method was never used).

Appendix 4.4

Questionnaire given to participants before SE1

Name

Home Tel

School

Classteacher

Science topic

No. children in class

What concerns (if any) do you have about teaching this science topic?

What schemes/books helped you with planning your science topic?

Appendix 4.5

Post interview questions for SE1 - SE6 *(these questions were simply used to start the discussion)*

1. How do you think that lesson went?

2. Tell me two things that you think went well? Can you identify what specifically made it go well?

3. Tell me two things that didn't go well? Can you identify what specifically made it go badly?

4. What were the main concepts that you were trying to get across?

5. Do you think that the children grasped them? How do you know?

6. What was your major concern when planning this lesson/topic? What support did you get?

Participants were also asked questions relating to what had been observed during the lessons.

For SE3- SE6 the participants were also asked

1. Has anyone observed you teaching science
2. What feedback, if any, had you had about your science teaching?
3. What science INSET have you had?
4. What preparation do you do for teaching science?

For SE6 the participants were asked

1. What do you think are the main benefits of teaching science to primary pupils?

(this was also sent to Esther and Ruth, who were not observed for SE6)

Appendix 9.1

Questionnaire to find out about trainee teacher observations on School Experience

Please complete this form for School Experience Two. For the 'observer' use the person's role not name. Indicate what the person's subject that is, for class teachers out the subject they co-ordinate.

Subject	**No. lessons taught**	**No. lessons observed**	**Length of lesson (minutes)**	**Observer's role** *(mentor, tutor, class teacher)*	**Observer's subject**
English					
Mathematics					
Science					
History					
Geography					
RE					
DT					
Art					
Music					
Drama					
ICT *(indicate if taught as a discrete subject)*					
PE/games					

What year did you teach? 3/4/5/6

What science topic/s did you teach?

Appendix 9.2

Preliminary results from further research questions

During a six week School Experience my trainees teachers would expect to be observed teaching a minimum of 18 times and a maximum of 24 times. The trainee teachers would be observed by their class teacher, university tutor or school based mentor, some would also be observed by a university Link Tutor. Trainees expect to receive written feedback on all lessons that are observed. The only exception to this is PE/games, where for safety reasons the class teacher must be present, but s/he will not always formally observe the lesson.

For these 25 trainees the range of lessons observed ranged between 8-26, all trainees taught their classes for 90% of the timetable. The following preliminary results are offered with my commentary shown in italics.

The results focus on science as a core subject (with English and mathematics).

1) The amount of time spent teaching science ranged from 5-12 hours over the 6 week period. The trainee taught all of the science taught to their classes during this period. All of the schools were using the QCA document (1999). *There is no guidance in the National Curriculum on how much science should be taught each week, although the recommendation of 90 minutes for Key Stagel and 120 minutes for Key Stage 2 is generally accepted. These trainees were all teaching Key Stage 2, so some classes were not getting sufficient time for science. Some schools have science-focussed topics at particular times in the year, so the weekly input increases significantly. However, this was not the case for these trainees' classes.*

2) The number of science lessons taught ranged from 5-12, some classes had two science lessons a week, but most had a single lesson of 60-120 minutes a week. One class missed a science lesson, as they were on a history trip. *I would suggest that having two one-hour science lessons a week is the ideal situation. This allows ideas introduced earlier in the week to be followed up later. A 90-minute session may be too long for primary pupils. If the class only has one lesson a week and a pupil is absent, he will have a two-week gap between lessons.*

3) The number of science lessons observed ranged from 0-4. Most of the trainees were observed at least twice and four were observed once. *It is of concern that a trainee teacher is not observed teaching a core subject. It is also of concern of the trainees are only observed teaching science once, as it is difficult to monitor if any science related targets have been met.*

4) All of the trainees were observed teaching mathematics at least three times, most were observed four times and one was observed eight times. The results were the same for English. All trainees taught mathematics and English at least four times a week each. *Thus over the School Experience they taught between 24- 30 mathematics lessons and*

24-30 English lessons, compared to 5-12 science lessons. The trainees not only get more opportunity to teach mathematics and English, they also get more feedback on how well they teach mathematics and English. A survey of trainee teachers identified " teaching experience" as one of the reasons for confidence to teach science see Chapter 2, Table 2.4. In order to gain confidence, trainee teachers need increased opportunities to teach science.

5) In all of the 142 science lessons taught by the group of trainees, 43 were observed. Of these four were observed by a science specialist, one by a science co-ordinator, one by a class teacher who had specialised in science during her BA Primary Education programme. All other science lessons (37) were observed by class teachers, tutors and mentors from other subject specialisms, although most specialised in English. *Of potential concern here, is what is the quality of the feedback that trainee teachers receive. What did the observers think made a 'good' science teacher? What were they looking for, what science related targets (if any) did they set? How confident did the observers feel to comment on the trainees' engagement with science? Were the feedback comments and targets generic or science related?*