Reflections on the contribution of Paulo Freire’s work to teacher education: the Thematic Investigation of primary teachers’ thinking and practice with regard to the teaching of science

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Abstract

This work analyses strategic knowledge, within the domain of science content knowledge in teaching. It concerns the ways non-specialist teachers talk about science education and report their activities in this realm. However, it also attempts to look at general issues such as the distance between theory and practice in teaching (as well as in educational research); and differences and similarities between the discourse of practising teachers and that of science educators. In addition, it discusses the problems concerning the elicitation and development of professional knowledge in teaching.

The specific strategic knowledge studied in the thesis is that of primary teachers in England and Wales post-National Curriculum. The empirical study consists in a Thematic Investigation, in the manner proposed by Paulo Freire, of teachers’ discourse. Research in Science Education and in Teacher Thinking has approached thinking from a cognitive and therefore individual point of view. In this thesis, however, thinking is considered socially bound, historically situated and also subject to the emotional states of individuals. Moreover, thinking is considered inseparable from action. Reflection thus becomes a collaborative enterprise. The individual teacher thinks about idiosyncratic propositions and exemplary cases, while the collaborative researcher acts as an ‘other’; someone who is knowledgeable of formalized propositions and established patterns of action, who challenges individuals, problematizing their ideas and interpretation of actions.

The goal of reaching understanding in this dialogue leads its interlocutors to think explicitly about taken-for-granted elements of discourse. This offers the researcher the possibility of a further level of analysis about the discourse (not just of structures within the discourse). The outcome is eight Generative Themes concerning propositions and strategies for teaching science in primary school. These themes serve as an example of how teachers’ strategic knowledge may be seen in relation to formalized pedagogical content knowledge structures and the mechanisms of professional development of teachers.
To Marialice, 'minha flor'
and Pedro, my son

In memory of
Yara Emboava Dias and Alexandrina Moura
We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time

T.S.Eliot
Little Gidding in *Four Quartets*, 1943
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Note on Vocabulary

Throughout the study all references made to Paulo Freire strictly follow his texts available in English - even at the expense of losing some of the nuances the text in Portuguese brings, such as when he uses ‘educador-educando’ instead of ‘professor’ (‘educationist-learner’ as opposed to ‘teacher’) and ‘educando-educador’ instead of ‘aluno’ (‘learner-educator’ as opposed to ‘student’). Where the available translations seem to misrepresent the original text I have assumed the responsibility for the text presented. Two terms, however, deserve a special note: conscientização and problematização/problematizador(a). The former is used here without being translated for two reasons. First, this is how it appears in the books in English. Second, as a concept popularized by Freire, if not coined by him, it seems more appropriate than conscientization or consciousness raising. In the editions of Freire’s books in English, the latter (double) term has been translated as ‘problem-posing’, for that reason it appears this way in this study. However, because sometimes ‘problem-posing’ seems to distort the idea Freire imparts, I have used instead ‘problematization’ or ‘problematizing’. ‘Problematiza-tion’ has been used in the same way as problematização: the noun that refers to the act, or the effect, of problematizar (to problematize). Therefore, ‘problematizing’ is used as problematizador(a): an adjective to qualify anything or anyone which ‘problematizes’, as opposed to simply pose a problem.
INTRODUCTION

In this study I deal with questions which have long been of concern to educationists and which, more recently, have become a matter of empirical and philosophical enquiry. These questions are mainly concerned with:

* teacher professional development;
* the problems of elicitation of teachers' professional knowledge.

To talk about the professional development of practising teachers is to deal with a complex issue. One of the general goals of this thesis is to discuss such issue in an attempt to provide a rational description of its complexity. In this thesis, I constrain the discussion to certain aspects of this issue and develop an empirical investigation based on the insights gained through such discussion. In addition, taking into account the results of my study and my empirical investigation, I propose a programme for the professional development of teachers. The philosophical, epistemological and educational framework for this thesis is the work of Paulo Freire.

I limit my discussion to the sphere of science. In chapter 1, I show that over the last forty years or so science education has established itself as an area of research. My argument is that science educators - as we call the researcher in this area - have distanced themselves from practising teachers as the corpus of that research has grown in size and complexity. Although the concepts, formalized propositions and methods of enquiry of science education relate to matters of concern to practising teachers, they involve the employment of a logic and a language that are strange to the non-initiate. This fact creates some difficulty to science teacher educators - those teachers of teachers working within the area of science teaching. With the recognition of this difficulty comes a central problem as regards teacher professional development: science teacher educators risk equally distancing themselves from practising teachers of science. This risk is not, of course, one which is only run by science teacher educators. The training and subsequent
professional development of teachers, which we generally call teacher education, is the stage set for many tensions - tensions between academics and prospective or practising teachers; between formalized propositions and wisdom of practice; or between theory and practice. As Alexander says:

Training and teaching have become two separate worlds. The ivory tower/chalk face, theory/practice rhetoric symbolises not merely an institutional gulf but a linguistic and intellectual one. Educationists agree on the need for dialogue, but dialogue presumes a common language of discourse. Dialogue also depends upon mutual acceptance of the need for self-critique. The character of the training process and of teaching must both be regarded as problematic (Alexander, 1984, p. 4).

There is an important cohort of scholars working to close this gulf between teachers and teachers of teachers. They conduct research on teachers' thinking and action. In chapter 1, I look at the outcome of their work and consider the scope and limitations of their approach to the subject in question. I analyse, in particular, the work of those authors who adopt collaborative forms of research.

One of the positive aspects of the effort of 'Collaborative Researchers' is the determination to reflect on what practising teachers have to say about teaching and learning. However, there are also negative aspects to that effort, particularly when one listens unreservedly to teachers. If teachers are allowed to express their ideas without interruption or challenge from the person conducting the investigation, they are bound to maintain their discourse within the scope of their present thinking. It is usually argued that this freedom would enable the researcher to understand teachers' 'implicit theories' or to know their beliefs and assumptions. The argument is that once that knowledge and understanding is gained, then this can be shared with teachers and teachers will make good use of it. The problem with this argument is that, although - like any one else - teachers have customary practices and ways of thinking that may not seem logical, they are likely either to dislike having their deficiencies pointed out to them by another person, or simply hear the arguments but maintain their habits. In the last analysis, where the goal of a research programme is to change teachers' attitude, and consequently to improve their practice, it must arguably involve the striking of a balance between listening unreservedly to what teachers have to say about their strategic knowledge, and trying to describe such knowledge by means other than simply listening to teachers.

My argument, therefore, is that the formalized debate of science educators, on the one hand, and teachers' personal wisdom of practice, on the other, develop each in
its own way. They thus turn into what can be described as independent ideologies - adopting here Marx’s critical concept of ideology in which ‘ideology’, or ‘ideological’, refers to explanations, or actions and symbols based on such explanations (Allman, 1994, p. 148). The premise in this study is that any ideology is partial and fragmented and thereby distorted. This means that a view about science teaching of science educators is just as likely to be distorted as that of practising teachers. From this premise follows the assumption that one way for the body of knowledge accumulated by science educators to be passed on to teachers, is through a form of ‘dialogical teacher professional development programme’ similar to the ‘Metodo Paulo Freire’ - method which was originally developed for work with adult literacy programmes. Such programmes necessarily involve a ‘problematizing collaborative research agenda’. Hence, in chapter 2, I argue that the most fundamental feature of Freire’s work is an analysis of how to be with the people so that they can develop a critical (dialectical) way of thinking. In addition, I explain Freire’s philosophy and epistemology, together with a description of aspects of Freire’s work that are germane to the present study.

I then return to the main subject of the thesis: the problems of elicitation and development of professional knowledge in teaching. In chapter 3, empirical research is devised to give substance to the argument concerning the relevance of Freire’s ideas in teacher education. Freire’s methodological strategy for the study of cultural aspects of groups of learners, called ‘Thematic Investigation’, is adapted to study teachers’ professional knowledge. To accomplish this, I use Shulman’s theoretical framework with regard the professional knowledge base for teaching and apply Kelly’s Repertory Grid Technique. As I discuss in chapter 3, the case of primary teachers of science is illustrative of tensions between theory and practice at the various levels just mentioned. The same applies to other situations, such as the legal requirement for teachers to introduce topics for which they lack subject-related content knowledge, or worse, subjects they actively dislike. In the design of the empirical investigation reported here these factors were considered in the choice of sample and focus of interest.

Chapter 4 reports the results of the Thematic Investigation of primary teachers’ strategic knowledge of science teaching. It presents eight themes that emerged from the discourse of the teachers as they were challenged to provide the most meaningful anecdotes and allegories they associate with the teaching of science. The description of such situations by teachers were at times accompanied by a number of propositions. I classify all this according to a pre-established framework. Hence, the eight themes are at the same time relevant to the teachers and related
to broader issues which science educators consider pertinent to the improvement of science teaching in schools.

In chapter 5 this correspondence between teachers' wisdom of practice and science educators' formalized propositions is discussed. This final chapter also describes the ways teacher professional development can be conducted so that the complexity of this issue and the problems of elicitation of teachers' professional knowledge are both overcome and teachers can move on to a stage of critical consciousness with regard to science education.
CHAPTER 1

THE STATE OF ART ON SCIENCE EDUCATION AND TEACHER THINKING RESEARCH

A. RESEARCH IN SCIENCE EDUCATION
   1. The Science Projects Era
   2. The Main Fields of Research
   3. Teacher's Friend or Foe?
   4. In Search of the Missing Link

B. TEACHERS, TEACHING AND EDUCATIONAL RESEARCH

C. THEORY AND PRACTICE IN RESEARCH ON TEACHERS' THINKING AND ACTION
   1. Parameters for a Review of Literature
   2. A Chart of Teacher Thinking Research

D. OVERVIEW OF TEACHER THINKING RESEARCH
   1. A Critical View of Research in Teacher Thinking and Action
   2. The Scholar-Practitioner Dilemma of Cognitive Research
   3. Collaborative Agendas for Research
   4. Collaborative Biographies
   5. Collaborative Research on Student-Teachers' Knowledge
   6. Action Research as a Collaborative Research Agenda

E. FOR A PROBLEMATIZING COLLABORATIVE RESEARCH AGENDA

F. DILEMMAS AND PROPOSITIONS
One condition necessary for dialogue to take place is a common language of discourse. In science education, there has been a history of increasing separation between theory and practice, between science education academics and science school teachers. This chapter starts with a brief historic account of science education research, coupled with an outline of the social and historic context on which this research took place. The obvious rationale for this review of literature is self-criticism. Dialogue also depends upon our acceptance of the need for self-critique, particularly the fact that we were once dismissive of teachers in that curriculum and teaching innovations were proposed by science educators alone.

Nevertheless, the main aim of this review of literature is rather to argue that science education has accrued a substantial cultural capital. The acknowledgement of this accumulation is important for at least two reasons. First, it is necessary to appreciate the value of this asset. This corpus of research and recorded experience contains lessons that can spare present day practitioners of vain efforts to improve pupils' learning of science. Second, it is important to admit that a great deal of such lessons were not trivial to learn. Since they were not trivially learned, it may be difficult, for those who come to learn them now, to fully appreciate their meaning and their implications. In other words, if on the one hand, science education today has a worthy cultural capital, on the other hand, in accruing this asset we have widen the linguistic and intellectual gulf between ourselves and practising teachers. Unless this gulf is bridged, any attempt to establish dialogue seems impractical since the discourses of the parties are not on a common language.

Some people working within the realm of science education have recognized that the character of the training process and of teaching need to be regarded as problematic. These people propose varied forms of collaboration with teachers as means to improve school practice. This attitude is the same of scholars who investigate teachers' professional knowledge and practice. The discussion thus turns to the corpus of research on teachers' thinking and action, focusing on what has been described as its collaborative research cohort.

There is a practical rationale to conduct this literature review of collaborative research on teachers' thinking and action. This rationale is to find a methodological approach that would reduce the distance between science educators and practising teachers; respectively, the ivory tower and the chalk face of science education. The strategy of this enquiry, laid out only in the next two
chapters, is to describe, first, the cultural gap between teachers and teachers of teachers; second, the gap between teachers' own rhetoric and their actions. The critique of current research I make, signals that my strategy of enquiry moves away from the interpretive paradigm towards that of the critical social sciences. In this mode, I analyse Elliott's and Calderhead's strategies of enquiry to point out what these strategies leave out without answer.

The chapter ends with a summary of dilemmas within 'collaborative teacher thinking research'. Finally, I put forward my criticisms of current responses to such dilemmas and propose directions research could take.

A. Research in Science Education

A recent article about the contribution of *Studies in Science Education* to research in science education analyses the broad directions taken in this area (Gilbert, 1995). *Studies in Science Education* is an international journal, which has reached its 25th volume, a fact that inspired the article in question. The author contends that there is no consensus about what constitutes research in science education; consequently, he offers the following picture:

Science education research might be thought of as consisting of a general region of enquiry broken up into a series of fields of research (Gilbert, 1995, p. 173).

What Gilbert suggests is that fields of science education research can be identified through an analysis of what has been published in *Studies in Science Education*. He justifies this by arguing that this journal publishes only review papers. Indeed, as stated in its editorial policy, the commitment of its editors is 'to publish comprehensive reviews of research on specific aspects of science education'. Figure 1 shows the end result of Gilbert's (1995, p. 180) analysis; in brackets are the number of articles in each field and, where relevant, also in the corresponding sub-fields.

In this respect, figure 1 provides us with an interesting summary of research in science education in recent years. This summary is useful for it helps form an account of the historical evolution of this area. Such an account could not start, however, without mention of events dating back forty years, at least, or a word about the demands of society which have made such research desirable or necessary.
Figure 1

1. The Science Projects Era

World War II showed Western political leaders what an important part science, mathematics and technology played in the successful conduct of military affairs. In the United States, for example, scientists were employed by government and industry, in the post-war years (DeBoer, 1991, p. 130). In consequence, those years saw a shortage of quality scientists in higher education as well as of chemistry and physics teachers in schools. There were, naturally, efforts to redress those shortages. However, the big push to increase the level of instruction for pupils opting for science courses, as well as to provide science education for all students in secondary schools, was the threat felt by the U.S. to their national security. American leaders reckoned at the time that the great emphasis which the Russians placed on science favoured the Soviet Union in the race for international influence and military supremacy (Luehamn, 1955). As a result, in the late fifties there was a great burst of activity in the development of science curricula, not only in the USA, but also in Britain and elsewhere (See Bybee, 1977; Jenkins, 1979). It spread in a chain reaction; springing up in an unprecedented fashion, for at least fifteen years, from one area of science to another. At the core of this explosion was the PSSC (1960), a physics teaching project that resulted from the work of a group of
physicists at the Massachusetts Institute of Technology; this group first met in 1956 to revise the content of a high school physics course.

The launch of the Soviet satellite Sputnik in 1957, as is well known, was the precipitating factor that led the American National Science Foundation to give financial support to the efforts to revise science courses. What is worth noting, however, is the fact that Sputnik also represented a coup de grace for American progressive education. Its supporters had been at pains to defend themselves from charges that progressive education had turned its back on intellectual values, while advancing educational programmes that emphasized the everyday activities and interests of the youth. One important example in that respect is the Illinois Secondary School Curriculum Program, organised according to a belief in the importance of the 'life adjustment' function of education (Sanford, 1950); in the UK, an initiative that aimed at the 60% of the school population which was receiving neither vocational training nor college preparatory work is Teaching Science to the Ordinary Pupil (Laybourn et al, 1957). The critics of the progressive philosophy in the USA claimed that, to face the shortages of technical personnel and the perceived threats to national security, education should move away from the theme of social relevance towards a mastery of the traditional disciplines. The launch of Sputnik gave these traditionalists an opportunity to discard science programmes that aimed to make science meaningful and relevant to ordinary students:

A half-century [1900s-1950s] of noble efforts to make science meaningful and relevant to all students had produced a science program that was satisfying to neither traditionalists nor progressives. Energized by the excesses of the life adjustment educators, traditionalists would grab hold of the science education in the decade ahead (DeBoer, 1991, p. 146).

Science courses were now to be organized around the central concepts of the established disciplines, practical and technological applications of science being almost totally absent from these projects. This fact changed the direction of science education and, more importantly, had crucial effects on educational matters at a global level. As Fensham argues, a form of 'educational imperialism' occurred in the 1960s:

Materials for the school populations of Britain, the USA or France were exported, with or without minor adaptation, to the school systems of other countries where quite different socio-political and socio-educational needs and demands prevailed. Countries like Australia and Canada made extensive use of
materials from the National Science Foundation's projects in the USA. It can now be seen that this period of direct importation of science curricula distorted the educational scene and inhibited more appropriate local developments (Fensham, 1988, pp. 2-3).

2. The Main Fields of Research

Returning to the recent history of research in science education: informed about these events of the curriculum projects era described above, it is possible to understand some of the current trends in this area. For example, curriculum analysis, that was once a field of research in the area of science education (Tawney, 1976; Brown, 1977), has seen a decline in the preference of scholars. This decline, noted elsewhere (Gilbert, 1995, p. 182), has been accompanied by the fall in prestige of science projects, and rise in the vogue for prescribed curricula. The same fact can be seen as a cause for the rise in policy studies (King, 1989b; Lewin, 1990; Raizen, 1991; Donnelly, 1994) - studies with sociological (Delamont, 1989) and socio-cultural tones (Knamiiller, 1984; George et al, 1988; King, 1989a; Swift, 1992) - as well as the publication of geographical overviews of research (Maddock, 1984; King, 1986; Sjoberg, 1991; Yager, 1993).

Regarding the events of the intermediate years since the boom of teaching projects, it is possible to argue that a paradigm shift has taken place in the field of science education. The improvement of learning in school science was once thought to be a function of the ability to convey knowledge derived from the scientific community in suitable forms. It was a time when behaviourism had a great influence in education, a time when educational psychologists preferred to think of 'learning theory' in terms of rats, stimuli and reinforcement schedules (Skinner, 1963). The climate then, particularly with regard to the shortage of teachers, seemed appropriate for the dissemination of science projects that could do without teachers altogether. The maxim of the PSSC project, for instance, was "to make physics teacher-proof" (Matthews, 1994, p. 17). The expectation that curriculum would have great impact on students' learning in and attitude towards science has since decreased considerably (Welch, 1979, p. 301). Learning has moved from being the piecemeal accretion of new information, to being seen in terms of conceptual development or change (Scott et al, 1992).

In this shift of perspective, science educators became critical of rote memorization of the mere facts and minutiae of science and looked to fresh approaches. For some time many supported the teaching of the scientific method, critical thinking, the scientific attitude, the problem-solving approach, the discovery method, and
the enquiry method (Rutherford, 1964, p. 80). It is interesting to note some of the proponents of the ‘enquiry’ or ‘discovery’ method. Among them were the prominent theorists Joseph J Schwab (1960), University of Chicago educationist who worked on the Biological Sciences Curriculum Committee (BSCS) project, and Jerome S Bruner (1961), Harvard cognitive psychologist. Also Lee S Shulman was someone who wrote on the theory and practice of discovery learning (Shulman et al, 1966); as discussed in Chapter 3, his later works have influenced this present study. However, the inductive form of teaching, characteristic of this approach, has acquired many critics over the years. These critics can be divided into those who argue that the problem of discovery learning lies in large part with the teachers, and those who locate the problem in the epistemology of science assumed in this approach. Here is an example of the latter criticism, given by Matthews (1994, p. 16):

A basic flaw in the process is the apparent assumption that science is a sort of commonsensical activity, and that the appropriate ‘skills’ are the primary ingredients in doing productive work. There seems to be no explicit recognition of the powerful role of the conceptual frames of reference within which scientists and children operate and to which they are firmly bound. These general views of the physical world demand careful nurture... (Myron Atkin, in Glass, 1970).

This kind of argument can also be found articulated by scholars studying children’s conceptions in science. This latter field of research is undoubtedly the most fertile in the area of science education research. Review papers and commented bibliographies are available which provide an overview of it (Gilbert et al, 1983; Driver et al, 1985; Carmichael et al, 1990; Driver et al, 1994; Pfundt et al, 1994; Duit, 1995). Teaching which acknowledges children’s alternative conceptions has also been researched, developed and tested (Scott et al, 1992). Indeed, as has been acknowledged elsewhere (Driver, 1988; 1994), after the boom in research on children’s alternative ideas of scientific concepts in the 1980s, three strands of research seem to have caught the interest of science educators, the study of children’s learning in classroom being one of them. Nevertheless, the first of these strands to establish itself was, perhaps, research into the public understanding of science (Lucas, 1983; Layton et al, 1986; Furnham, 1992). Within this strand, there has lately been some interest, for instance, in studying common-sense science (Mariani et al, 1991; Ferracioli-da-Silva, 1994).

These latter fields of research have gained a life of their own. It is my view that, in some respects, they are for school education what theoretical physics is for
manufacturing: the one studies the reality the other lives in practice, but they do not always successfully communicate with each other their knowledge or wisdom of practice. This view is shared by many in the area of science education. An example is the way curriculum development is currently understood and approached in a number of countries. Here is an illustration drawn from the latest great American effort to chart new directions in science, mathematics, and technology education, Project 2061:

Project staff considered who would be best equipped to take on such a demanding assignment. Scientists and engineers know their subjects but are at a distance from the classroom. Learning and education researchers understand the difficulties children have, but only in a rather narrow range of topics. Classroom teachers, despite their keen sense of what interests children and what they learn under current conditions, often lack a full kindergarten-through-graduation perspective on education as well as needed resources, training, and time to envision radical departures from current curriculum (American Association for the Advancement of Science, 1993, p. 303).

What we note there is not unlike what can be noticed in projects such as CLIS (Children’s Learning in Science at Leeds University) and SPACE (Science Processes and Concept Exploration at Liverpool University). First, an acknowledgement of the value of research on children’s alternative conceptions and public understanding of science in showing that current teaching of science in schools is not promoting the conceptual changes one would expect after so much curriculum planning and development of pedagogical resources. Second, an understanding that, although those conceptual changes need to take place, the complexity of the problem is such that only through some form of collaboration between the parts involved might it be possible to reverse the situation. Finally, the rise in interest in - if not a concern about (Driver, 1988, p. 139) - "teachers’ conceptions about knowledge and learning", as well as the interest in teachers’ practical expertise. With respect to this point, for instance, the CLIS project has, according to its director, two parallel agendas: alongside the development of teaching schemes which promote conceptual change, "the implementation of a way of working as a project which promotes the conceptual development of participating science educators" (Driver, 1988, p. 139). This same concern can be inferred from Project 2061’s statement about their own way of working as a project:

We decided that if traditional constraints were removed and adequate time and resources were provided, school teachers and administrators, advised by education specialists and backed by scientists, would be most likely to develop...
intellectually sound curriculum models and other curriculum-design tools that would prove credible to other teachers (American Association for the Advancement of Science, 1993, p. 303).

As these examples show, school teachers, it is now being recognized, have a fundamental role in the scientific education of pupils (see Brandwein et al, 1991 for a development of this argument). This fact contrasts with the developments of the 1960s and 1970s in which curriculum-related materials and teacher training courses were mostly developed by teams of professionals from outside the schools. These examples also stress the importance of research in areas to which science educators have not traditionally paid close and detailed attention: teaching and teacher education, as noted by Gilbert (1995, p. 183, 189), or even teachers' thinking.

3. Teacher's Friend or Foe?

Returning to the criticisms of 'discovery' and 'enquiry' approaches in science teaching, in the past, some people claimed that the problem with these approaches lay largely with teachers (Welch et al, 1981). According to this view, the lack of attention to teachers' perceptions of science and learning, or the lack of attention to their teaching practice, was a flaw in the curriculum projects sponsored by the USA National Science Fund. Quoting Arons (1983, p. 117), Matthews writes:

Respected physics teacher, textbook writer and curriculum planner, Arnold Arons, has drawn attention to the fact that "curricular material, however skilful and imaginative, cannot 'teach themselves'". [Arons] attributes the failures [of NSF-sponsored curricula] to two causes: first, inadequate logistic support for school teachers; second, and more importantly, the inadequate training of teachers (Matthews, 1994, p. 19).

This type of criticism was, however, not the most convincing of the time. More science educators persuaded by other critics, those who suggested that what was not being recognised was the role of the conceptual frames of reference within which children operate and to which they are firmly bound (Myron Atkin, in Glass, 1970). It is understandable that scholars have chosen to study children's conceptions and learning in science, rather than studying teachers' thinking or ways to improve science teacher education. The comments about the lack of recognition for children's conceptual frames of reference were valid. Besides, educational researchers would have to learn about this issue in order for teachers' training courses to cover it accordingly.
However, if in the 1960s and 1970s science teachers were not seen as professionals likely to contribute to curriculum development, what can one say of the role primary teachers have been expected to play in this respect since then; particularly with regard to the teaching of science? An interest in primary teachers would be far from fortuitous. For obvious reasons, scientists and science educators will want to be involved with science teaching at the primary school level; there lies the basis of the edifice for which they care so much. As Cunningham (1988) points out, in the UK a rise in interest in this issue coincided with the other movements mentioned above:

Science in the primary school was the focus of growing interest in the later 1950s as a vehicle for working from the child’s own experiences and for learning by discovery, reflected in a number of publications from the National Froebel Foundation (1958) Scientific Interests in the Primary School, the Educational Supply Association (1960) Approaches to Science in the Primary School, and the British Association for the Advancement of Science (1962) The Place of Science in Primary School (Cunningham, 1988, p. 28).

Apart from the desire to become involved with primary science because it is part of the whole science education edifice, my interest in primary teachers has other motivations. I go into further details on these motivations when discussing the design of the present investigation (chapter 3, part II, section A); however, it is important to outline them beforehand. To that end, it seems opportune to quote a further passage from Matthews’s reference to Arons criticisms to the NSF-sponsored curricula:

[The inadequate training of teachers] covers such things as [1] lack of knowledge of subject matter, [2] failure to appreciate the psychological requirements for science learning, particularly the need for experience and familiarity with reality to precede theory and concepts, [3] poor in-service courses where teachers were "given more of the same rapidly paced, irrelevant, and unintelligible college courses that had had no visible intellectual effect in the past" (Arons, 1983, p. 120), and [4] the failure of science teachers to appreciate and convey the rich intellectual and cultural import of their subject (Matthews, 1994, p. 19).

Assuming that the four points made there cover the issue adequately, we can appreciate the complexity of the matter. The huge research effort of the last two or three decades in the fields of science learning and alternative conceptions barely addresses point 2, about the psychological requirements for science learning.
Initiatives like the CLIS and SPACE projects are testimony that the criticism of in-service courses in point 3 above has been addressed. This leaves just those points which state that the problem lies in large part with teachers. Concerning point 1, there is empirical evidence that science teaching is impoverished when the teacher lacks content knowledge. This applies to primary teachers in particular (Smith et al, 1989; Kruger et al, 1990; Russell, 1992), and science teachers in general (Villani, 1991). As evidence that science educators recognize the relevance of point 4 above, there is growing interest in teachers' views of the nature of science (Lederman et al, 1987; Kouladis et al, 1989; Brickhouse, 1989, 1990; Lederman, 1992; Lakin et al, 1994; Nott et al, 1995). In this respect, there have also been studies of exemplary science teachers' practice (Fraser et al, 1988; Tobin et al, 1989), as well as of (student-) teachers' conceptions of science teaching (Aguirre et al, 1990; Boyle, 1990; Aubusson et al, 1992; Haggerty, 1992).

4. In Search of the Missing Link

The fact that research is being conducted from these various perspectives is inspiring for it suggests the existence of an orchestrated effort to cover every area of concern about the matter. Certainly, there is no conductor or strategist leading this war-like effort. Each one of us tries to undertake a critical analysis of the educational and epistemological reality we are all dedicated to scrutinize. Thus, the responsibility for defining new directions of research is shared by every scholar in this area of study. Personally, I believe that we have been a little uncritical about the nature of our task when it comes to our sharing, with school teachers, our practical, empirical and philosophical heritage. Compared with the beginning of the science projects era, late in the 1950s, we now have a considerably greater cultural gap to bridge when we engage in any relationship with teachers. The brief retrospect I present above gives just a partial idea of the cultural capital any science education scholar carries with him/her. In my view, this situation implies another, rather delicate. The bridging of that gap is a problem which transgresses issues of cognition to take us to socio-cultural questions. At the heart of this matter, more significant than our capacity to convey our knowledge to teachers or their capacity to assimilate what we have got to offer, is the very possibility of our interaction. Driver, for example, has put the question this way:

However effective and empirically well-established certain teaching approaches may be, unless the research findings are implemented they are of little value to the educational world. This raises questions not only about how well researchers communicate their findings to practitioners but also who ‘owns’ and is committed to the enquiry in the first place (Driver, 1988, p. 147).
The response of the CLIS project to these questions about communication and ownership of research findings has been ‘action research’:

Since teachers are involved in such a fundamental way in the successful implementation of a curriculum, it was decided by this project that the research and development of constructivist approaches to science teaching should be a collaborative exercise between teachers and researchers (Driver, 1988, p. 139).

Notwithstanding the reservations I have about action research, discussed later in this chapter, I consider this course of action viable and worthwhile. However, in cases like that of the CLIS Project, where knowledge of the subject content matter is shared by both parties, the cultural gap between science educators and teachers might not be perceived. Besides, in such situations, the consequences of ignoring such a gap may only show with time. To provide some sort of empirical evidence that a gap exists and is unfavourable to the effective improvement of conditions to promoting children’s learning in science, I decided to conduct an investigation of primary teachers’ interaction with the cultural capital of science educators.

Primary teachers lack knowledge of subject matter and may also fail to appreciate and convey the rich intellectual and cultural import of science. But do science educators appreciate what it takes to communicate these to them? I suggest that we leave aside, for the moment, the prospect of imparting scientific knowledge and imagine that, paraphrasing Matthews, quoted above (1994, p. 19), we only have to convey the rich intellectual and cultural import of the area of research in science education. With regard to primary teachers, we can appreciate the prospect of many friction points emerging in the process; science education experts and primary teachers certainly possess different levels of knowledge and experience. However, I contend we are dealing with more than various degrees of either knowledge or experience. I suggest the prospective divergences would show varied types of knowledge and experience. The differences between science education experts and primary teachers are such that they can be considered members of two different cultures. I will return to this point later, but first, I would like to concentrate on the subject of how teachers’ knowledge and experience can be studied. In the next part of this chapter I analyse areas of educational research which can inform such a study of teachers’ thinking and practice.

B. TEACHERS, TEACHING AND EDUCATIONAL RESEARCH

To define it in very simple terms, teaching is what teachers do - usually within the classroom, although not necessarily so. Simple as this might seem to the lay person,
such an assertion is open to somewhat controversial interpretations, especially outside the classroom. In this other sphere, 'what teachers do' becomes a matter of social, political, economic and cultural interest, not only for teachers, or even for educationists, but for society as a whole. It is, therefore, reasonable that the debate about teaching should change with the times.

Educational research is one place where classroom activity is debated. The history of research on teaching, in particular, illustrates the extent to which different fashions have superseded one another. Although, as Brown and McIntyre contend, it can be argued that instead of changing fashions,

the kinds of questions which informed the earliest research on teaching continue to be asked and investigated, but both the significance attributed to these questions by researchers and also the ways in which these questions are formulated have changed in recognition of the importance of other perspectives (Brown et al, 1993, p. 2).

Therefore, the history of this branch of educational research to some extent illustrates the susceptibility of its researchers to the changing political and philosophical thoughts permeating society in general, and the academic community in particular.

Hence, in order to understand what is currently studied by research on teaching, one should better appreciate its historical evolution. The American Educational Research Association handbooks of research on teaching (Gage, 1963; Travers, 1973; Wittrock, 1986) give a thorough and extensive account of the field; a more succinct review, however, is given by Brown and McIntyre; they assert that:

One kind of question which dominated research on teaching from its nineteenth-century beginnings until the middle of this century was about how best to teach in relation to different topics, subjects or general approaches to teaching. The question was typically formulated in terms of 'What methods are best?' and the orthodox approach to their investigation was the methods experiment, comparing one or more idealized 'method' with one another, or with what was seen as normal practice (Brown et al, 1993, p. 2).

The questions asked and hypotheses raised at that time seem characteristic of what is usually identified as the positivist paradigm. The adoption of experimental and manipulative methodology is typical of this view of research. Within the positivist approach to qualitative research "questions and/or hypotheses are stated in propositional form and subjected to empirical test to verify them" (Guba et al, 1994,
This basic belief system guiding the investigators at that time was also influential in studies of teachers. It was thought that good teachers could be characterized in terms of scores on intelligence and attainment tests, attitude scales and personality inventories (Brown et al, 1993, p. 2).

In the 1950s and 1960s, the questions and approaches in this field of educational research changed.

Research on teaching was transformed by the simple recognition that teaching could not be tidily described in terms of the use of different standard methods and that the most significant characteristics of teachers were likely to be those they manifest in the ways they act in classrooms. As a result, research on teaching in the third quarter of this century was dominated by attempts to investigate what teachers and their pupils observably did in classrooms (Brown et al, 1993, p. 3).

During this period, again, research on teaching seems to have been influenced by the prevailing paradigm in social sciences. This new perspective, centred on classroom observation, seems to comply with the postpositivist paradigm emerging at the time. The methodologies adopted then were still experimental and manipulative, although no longer intended to verify hypotheses. These methodologies were meant, instead, to falsify hypotheses "by doing inquiry in more natural settings, collecting more situational information, and reintroducing discovery as an element in inquiry" (Guba et al, 1994, p. 110). Rosenshine and Furst (1973) provide an overview of the use of observation to study teaching. Their paper, being a description made over a decade after the postpositivist shift, gives a general idea of the thought that then accompanied this sort of research.

The widespread recognition of the need not only for systematic observation of classroom teaching but also for systematic study of teachers' thinking came only in the 1970s (Brown et al, 1993, p. 3). This move coincided with a recognition by sociologists of education of the persistent failure of functionalism to question the positivist assumptions on which much of the sociological research in education was based at the time. These sociologists of education took the 'new direction', which endorsed a preference for an 'interpretive' approach derived from the social phenomenology of Schutz (1967) and the sociology of knowledge developed by Berger and Luckman (1967). Among these sociologists, Keddie (1971) was one of the pioneers in the study of teachers' thinking. Her research examines what teachers 'know' about their pupils and how this 'knowledge' is related to the organization of curriculum knowledge in the classroom. On the premise that
'knowledge' and 'ability' are socially constructed organizing concepts, Keddie sought to show how these concepts are employed both in the interpretation of pupils' behaviour and in the organization of the knowledge made available to them.

C. THEORY AND PRACTICE IN RESEARCH ON TEACHERS' THINKING AND ACTION

Apart from its reflection on school teaching, this recent development in research on teaching has clear implications for the professional development of teachers. The overarching idea guiding research on teachers' thinking is that education - as well as social reality as a whole - is not an 'objective reality' to which teachers, pupils, school administrators etc are somehow subject. According to this point of view, classroom activity is not amenable to law-like rules or explanations. The consequence of this for teacher education is clear. The provision of training in teaching skills and exposition of the foundations of education (sociology, philosophy and history of education plus learning psychology) should no longer be regarded as appropriate if they do not take into consideration the subjective meanings teachers attribute to these theories and practices.

Research on teachers' thinking, however, is not always clear about the distinction between the benefits its enquiries might have for teaching practice and those it might have for teacher education. This seems to be a distinction worth making. For example, I consider myself to be engaged in the effort to improve school practice, especially the effort of most researchers in science education. Nevertheless, as stated above, I am particularly committed to promoting the professional development of teachers in that realm of teaching. These aims, though complementary, are different. This distinction provides me with a rationale for moving into an area where research on science education overlaps research on teachers' thinking. Besides, such a distinction is also intended here as a parameter to analyse the literature in the latter field of research.

The community of researchers on teacher thinking yields quite a diverse and complex corpus of research papers, books and doctoral theses. Therefore, as its leading figures recognize (Shavelson et al, 1981; Clark et al, 1986; Elbaz, 1990; Calderhead, 1993; Pope, 1993), any attempt to offer an exhaustive summary and review of it is impractical. To offer some form of guide to this literature, I have given priority here to those major themes, propositions and perspectives that form the basis of my own arguments. In so doing, I introduce a degree of simplification in my overview, while at the same time introducing a degree of complexity to it.
The simplification is that, to frame research on teachers' thinking, I adopt the same parameters used by Carr and Kemmis (1986) to analyse curriculum research. The complexity, on the other hand, is the distinction I make between studies which seek primarily to intervene in teaching practice and those whose main aim is to reassess teacher education. Many scholars in the field of teacher thinking research are concerned with changing teacher education, as I am with changing *science* teacher education. However, I find in Carr and Kemmis's analysis of curriculum research, arguments for change in teaching practice akin to propositions expressed by many other scholars in the field of teacher thinking research. Thus, I am led to adopt the parameters used by these two authors in my own study. Besides, as Calderhead has recognized, the work of these authors "has stimulated considerable thought about the importance of increasing teachers' awareness of the causes and consequences of their action" (Calderhead et al, 1993, p. 1).

In their drive to offer a theoretical rationale for the 'teacher-as-researcher' movement, Carr and Kemmis outline different images of the teaching profession. They do so through a critical examination of some of the dominant views of educational theory, research and practice. While these authors develop their analysis with particular reference to *curriculum* research, this analysis is of interest to the present study for yet two more reasons. First, it offers a philosophical frame of reference which helps to discern the range of assumptions about the kind of professional knowledge that teachers require and about the role of the researcher in making this knowledge available (Carr et al, 1986, p. 29). Second, it explores the potential of 'critical social science' to redress the balance between the two main streams of research in education: the positivist and the interpretive. The principles on which I draw in undertaking the present research are compatible with arguments stemming from Critical Social Science. These principles are expounded in chapter 2; in this present section I simply look at the frame of reference these authors adopted to discern the range of assumptions found within curriculum research.

The bare bones of these authors' analysis is the relationship between theory and practice:

To most researchers and teachers, the concepts of 'theory' and 'practice' have more or less settled meanings. 'Practice' is particular and urgent; it is what teachers do in meeting the tasks and demands confronting them in their everyday work. 'Theory', in sharp contrast, is timeless and universal; it is something produced by researchers through the careful process of inquiry. This tendency to regard educational theory as something different from educational
practice is, of course, just a particular manifestation of the widespread disposition to draw a sharp distinction between 'theoretical' matters concerning what is the case and 'practical' matters concerning what ought to be done (Carr et al, 1986, p. 2).

Carr and Kemmis contend that to understand these concepts it is important to know their history. They also assert that to understand the meaning of them is, in part, to understand the intellectual traditions in which they have been, and still are, embodied (Carr et al, 1986, p. 3). Hence they discuss in some detail these traditions within education and trace some aspects of the history of those two concepts.

However, the reassessment of the relationship between theory and practice has been one of the central aims of Habermas (1974) and of the critical theorists of the 'Frankfurt School' (see Jay, 1973; Bottomore, 1984). While Habermas's work is challenging, the simple attempt to give an account of it would constitute a separate study, so extraordinary is its breadth of scholarship. My purpose at this point is only to provide a reasoned frame of reference to analyse the corpus of teacher thinking research. To that end, I trace here only a sketch of the complex question, namely, the relationship between theory and practice. This sketch is based on *Becoming Critical* of Carr and Kemmis, which in turn has its base in Habermas's work. The purpose of Carr and Kemmis's interpretation of Habermas is to analyse *curriculum* research and then propose *critical action research* as a particular way in which curriculum studies should relate to the professional *role* of the teacher. This is a similar purpose to my own: I want to analyse *teacher thinking* research in order to propose one way in which it could relate to the professional *development* of teachers. Nevertheless, I acknowledge that it is possible to have different interpretations of Habermas in particular, or critical theory in general. Gibson (1986), for example, assesses the contribution of Habermas and of critical theory to the study and practice of education. In his own way, Gibson is also concerned with the professional development of teachers - his book is admittedly tailor-made for teacher education - but, being "very sceptical of many aspects of critical theory" as he is, his purposes are different from those mentioned above.

1. Parameters for a Review of Literature

One way to analyse contemporary understandings of education, educational research and teaching is to look for the underlying motives and attitudes that inform the thoughts pervading them. This should result from a reassessment of the relationship between theory and practice in each style of thought present in
different understandings (Carr et al, 1986, p. 34). For example: education can be seen as essentially technical. From this point of view questions of educational purpose and goals are separated from questions about the best means to achieve them - a division which relates to the parallel distinction between values and facts (Carr et al, 1986, p. 68). Educational research, in this case, concentrates on facts because an attitude of neutrality towards values must be adopted. This is a positivist view of research. There is within it a belief that science provides the methods of enquiry that educational research should seek to emulate. The attraction of placing educational research on scientific foundations lies in the idea that, in the same way that science grants us control over the natural world, it will allow us to control education and make it more congruent with the needs of society (Carr et al, 1986, p. 52).

On the other hand, education can also be seen as practical - as a process or an activity. In this case, research initiatives are critical of the assumptions of the positivist approach. One example is the 'interpretive' approach mentioned above as derived from social phenomenology and the socio-constructivist sociology of knowledge. In seeking to replace the scientific notions of explanation, prediction and control, the 'interpretive' approach introduced those of understanding, meaning and action (Carr et al, 1986, p. 83). Thus it sees educational reality as fluid, as having an open, undetermined character. According to this view, to regard social order as a given feature of society fails to explain how such order is produced. Research should therefore reveal the network of meanings out of which this order is constituted. Hence, in the words of Carr and Kemmis, in 'interpretive' research,

within the field of education, enquiry should focus on understanding the social process through which a given educational reality is produced and becomes 'taken for granted'. In particular, there should be a move towards treating 'what counts as knowledge' as 'problematic', so as to facilitate research into the ways in which knowledge is socially organized, transmitted and assessed in schools (Carr et al, 1986, p. 85).

Within this approach, the argument is that social life is the product of everyday understandings people have of their own actions. These understandings consequently stop being the simple starting point in the search for testable hypotheses, a characteristic of the 'positivist' approach, within which it is considered that social science should aim at scientific explanation. In contrast, the 'interpretive' approach proposes that social science should aim at 'interpretation' of these understandings.
There is yet a third outlook. This involves a view of education which is essentially strategic. Those who hold this view contend that education is taking place against socio-historical backgrounds and therefore projects the kind of future one hopes to build. They also maintain that education is a social activity with social consequences, not simply a matter of personal development. The cornerstone of this view, in sum, is the opinion that education is intrinsically political (Carr et al, 1986, p. 39). In itself, the strategic view of education results from a 'critical’ approach to theory and practice. Moreover, it rejects the idea that knowledge has a purely instrumental value in solving educational problems. According to this view, therefore, it is more important to grasp the meanings that educational practices have for those who perform them; in other words, the interpretive categories of teachers need to be considered (Carr et al, 1986, p. 129). However, unlike the 'interpretive’ approach, the 'critical’ approach does not consider such interpretation to be sufficient in itself: reality might distort consciousness, besides being defined by it.

The objections to the interpretive view of social science which are positivist-inspired include claims that it does not produce wide-ranging generalizations, nor provide ‘objective’ standards for verifying or refuting theoretical accounts. Criticisms of interpretive social science inspired by critical social science are of a different nature; this is basically because both consider social reality itself to be a construction, both consider that social reality cannot be taken as an objective entity. As Carr and Kemmis have said, "social activities must be understood in terms of their meanings and such meanings derive from rules embodied in a social context" (Carr et al, 1986, p. 94). One important criticism made by critical social science concerns the way in which the interpretive approach insists on considering inadmissible any explanation of social action which is incompatible with its actors' own accounts. The ways people characterize their actions do not necessarily correspond to what they are actually doing. In this sense, their understandings and explanations may be rationalizations which obscure the very nature of their situation, masking reality. These rationalizations might be conditioned by certain social mechanisms which bind people to irrational and distorted ideas about their social reality.

The interpretive model neglects questions about the origins, causes and results of actors adopting certain interpretations of their actions and social life, and neglects the crucial problems of social conflict and social change (Carr et al, 1986, p. 95).

In other words, the interpretive approach neglects questions about the relationship
between individuals' interpretations, as well as their actions, and external factors or circumstances. As will be discussed later (chapter 2, section D), Freire suggests that, although discerning, people may show a 'naive consciousness', being disengaged from reality and somewhat passive:

an initial, predominantly naive, stage of transitive consciousness is characterized by an over-simplification of problems; by a lack of interest in investigation, accompanied by an accentuated taste for fanciful explanations; by fragility of argument; by a strongly emotional style... (Freire, 1974, p. 18).

The understandings of individuals may be conditioned by 'naive consciousness'. This can be demonstrated revealing, at the social-structural level, the ideological character of group life. According to the critical approach (Carr et al, 1986, p. 96), for instance, social processes, such as language and the processes of cultural production and reproduction, shape our experience of the social world in specific ways and for specific purposes. As Carr and Kemmis have argued (Carr et al, 1986, p. 129), ideologically distorted interpretations of reality need, therefore, to be distinguished from those interpretations that are not distorted. Besides, educational practitioners also need to learn how to overcome their own 'naivety'.

Interpretive theories claim that by clarifying the meanings that individuals give to their actions, they overcome problems of communication between different social groups and thereby help people to change the way they think about what they or other social groups are doing. This suggests that simply to present an interpretive account, revealing the possibility of alternative definitions and conceptions, is sufficient grounds for expecting individuals to reinterpret their situation and change their actions. But this is to ignore the fact that conceptual changes do not occur simply because one interpretation is more rational or correct than any other. An individual's ideas and beliefs are not merely a set of true or false statements that have been adopted on the basis of purely rational considerations. Rather, they are intimately related to the individual's way of life, and, as such, they provide the sort of ideas and beliefs about oneself and others that are appropriate to the way one lives. It is precisely because an individual's identity is so closely related to the values, beliefs and attitudes inherent in the style of thought of the social group to which he or she belongs that any alternative interpretation of what he or she is doing will invariably be resisted.

To summarize, when education is seen as essentially technical, questions of educational purpose are separated from questions about the best means to achieve that purpose. Educational research is, then, approached from a 'positivist' position
where the actors' understandings of their reality and practice are starting points in
the search for testable hypotheses. When education is seen as practical, these
understandings are interpreted, not explained. On the other hand, those who see
education as essentially strategic argue that this latter, 'interpretive', approach
fails to explain the relationship between people's understandings of reality and the
social conditions under which these understandings occur. These critics propose an
approach to research whereby, apart from considering an interpretation of people's
understandings, some explanations for the conflicts and anxieties people
experience are also attempted. For example, instead of suggesting that such
conflicts and anxieties arise from people's misunderstandings about their own or
other people's practice, the 'distorted' understandings that give rise to the conflicts
in the first place are considered to be a reflection of real conflicts and tensions
endemic to the practice itself. In other words, according to the 'critical' approach
to research, it may be the social reality itself that is irrational and incoherent,
rather than individual's conception of that same reality. In that sense, when
conflicts emerge, the 'critical' approach suggests ways in which people should
change what they are doing, rather than encouraging them to change the ways that
they think about what they are doing (Carr et al, 1986, p. 98).

2. A Chart of Teacher Thinking Research

These views of education, educational research and teaching (the
technical/positivist, the practical/interpretive and the strategic/critical) constitute
a helpful frame of reference for an understanding of research on teachers' thinking
- as Calderhead (1993) and Pope (1993), for instance, also acknowledge. If not "to
recognise some of the straw man arguments that are being presented" (Calderhead, 1993, p. 14), this classification raises the possibility of looking beyond
stereotypes and fixed standpoints. Clearly, the division of research approaches into
the positivist, the interpretive and the critical does not reflect so much a set of
three discrete categories as the parameters within which researchers work.

Whilst one might well find some examples of research which typify each
stereotype, the vast majority of research actually combines elements of two or
even all three. The diverse range of research on teachers' thinking, therefore,
does not fall within any one tradition but could be represented in terms of
points within a triangle (Calderhead, 1993, p. 14).

McCutcheon (1981) has suggested that each of those approaches could be
imagined as being on an apex of a triangle. However, this gives the impression of
clear-cut distinctions between those three research traditions. I would favour,
rather, a representation which enables one easily to visualize the degree of symbiosis between distinct views on particular research agendas. Imagining those approaches as placed on the sides of a triangle, rather than on its apexes, would allow for that. It would also stress the idea that pure or stereotypical examples of any case are difficult to identify; as difficult as pointing the middle of any one side squarely - possible though it might be in theory.

I present in figure 2 a diagram based on this idea of triangle. I will be referring to it in the next pages, where I undertake an overview of teacher thinking research and other studies of relevance. I present this diagram, though, with the caveat that I do not intend it to lead one to see the comparisons I make in a robust way.

The positivist-interpretive-critical plan just described is shown on two different levels in this diagram, notwithstanding the fact that to talk about 'levels' can be misleading. Indeed, I see no reason why they could not be reversed. In one plan are the different strands of curriculum research, in the other, are the different traditions within research on teachers' thinking. In superimposing these two areas of research I run the risk of losing sight of the individualities of each field, and portraying them with little clarity. But once this superimposition is aided by the positivist-interpretive-critical triangle, it allows me to make distinctions that are not necessarily obvious. As I have mentioned before, it seems worthwhile to distinguish between research which aims primarily at improving school practice -
where curriculum research seems to fall - and research which aims primarily to inform teacher education - the category in which teacher thinking research seems to fit. I hope it is obvious that, once order of priority is disregarded, in principle both criteria are met by each of these fields. One advantage of this distinction is the insight into the action research movement. Such movement has been gathering momentum within educational research although not necessarily as a cohesive school of enquiry or even a co-ordinated initiative (Carr, 1994). It happens that action research is an approach adopted by scholars whose concerns regarding the contribution of educational research to the professional development of teachers are very similar to mine; my use of Carr and Kemmis's work and previous reference to the CLIS project (Driver, 1988, p. 139), are only some evidence of this. In sketching a chart of research on teaching, I locate myself in the field. Referring to this chart, I can argue how the methodological approach I have adopted, although distinct from others, is in accord with current trends amongst researchers on teacher thinking.

D. OVERVIEW OF TEACHER THINKING RESEARCH

Clark and Peterson (1986, pp. 255-6) claim that Jackson’s (1968) *Life in Classrooms* was one of the first studies to call the attention of the educational research community to the importance of describing the thinking of teachers. However, the big incentive for research in this area came from the report of a conference panel chaired by Lee S Shulman (whose later work is discussed in chapter 3) consisting of a group of experts on the psychology of human information processing, the anthropology of education, classroom interaction research, and the practical realities of teaching (National Institute of Education, 1975). This panel had been set up to create an agenda for future research on "Teaching as Clinical Information Processing". It proposed what was in essence a rationale for, as well as a definition of the assumptions and the area of research on teachers’ thinking (Clark et al, 1986, p. 256). It can be argued that in part this was a response from the research community to the failure of the NSF-sponsored teaching projects initiatives to promote pupils’ learning; as discussed earlier in this chapter (section A).

Research on teachers’ thinking was proposed at a point in time when the social sciences, as well as education, were turning away from the so-called positivist paradigm of research. However, that early paradigm was not entirely rejected in favour of the 'interpretive' one, which was new at the time. As is stated in this passage taken from Clark and Peterson's comprehensive literature review of the field, both paradigms are found within teacher thinking research.
Practitioners of [teacher thinking] research seek first to describe fully the mental lives of teachers. Second they hope to understand and explain how and why the observable activities of teachers' professional lives take on the forms and functions that they do. They ask when and why teaching is difficult, and how human beings manage the complexity of classroom teaching. The ultimate goal of research on teachers' thinking is to construct a portrayal of the cognitive psychology of teaching for use by educational theorists, researchers, policy makers, curriculum designers, teacher educators, school administrators, and by teachers themselves (Clark et al, 1986, p. 255).

To judge from this passage, the ultimate aim of such studies is the discovery of what could be regarded as 'laws' governing practice. This is evidenced by the emphasis on the pursuit of a 'cognitive psychology of teaching'. It is possible to infer that in seeking to understand and/or to explain 'the observable activities of teachers' professional lives' researchers can be told apart by their different attitudes towards the subjectivity of teachers' thoughts and knowledge; in other words, by their attention to teachers' implicit beliefs, assumptions and values. The more positivist a stance one adopts, the more reluctant one is to move away from what is observable or can be compared by standards or benchmarks. On the other hand, the more interpretive a stance one adopts, the more reluctant one is to move beyond the idiosyncratic, the person as an individual, and to consider generalizations. Those who adopt a more subjective and interpretive approach to teachers' thinking usually do so with caveats regarding the likely influences of social and historical constraints experienced by the individual. They tend to resist separating teachers as a category into one or multiple cultural groups.

The idea that teaching can be adequately understood in terms of a person's cognitive content and capacities, as Olson (1988, p. 167) notes, is common amongst these two streams of teacher thinking research. In figure 2, the studies in which this cognitive perspective is more evident are placed on the apex opposite to the critical edge of the positivist-interpretive-critical triangle. In these studies, as Olson (1988) says, some pay particular attention to how teachers process information (indicating, therefore, a psychological approach); others ask what teachers know and how they know it (reflecting, in turn, an epistemological approach). Adding a time axis to this description and drawing on words of Clark (1986), Pope notes that:

Much of the earlier work on teacher thinking drew upon cognitive psychology, particularly information processing theory, giving rise to metaphors such as 'teacher-as-decision-maker'. However the teacher of 1985 is a constructivist.
We have begun to move away from the mechanical metaphors that guided that earlier work. A current core assumption is that teacher thinking researchers are trying to understand and interpret ways in which teachers make sense of and adjust to and create the educational environment within their schools and classrooms (Pope, 1993, pp. 21-2).

Studies adopting a psychological approach seem to focus either on subject matter content knowledge (Kruger et al., 1990) and pedagogic content knowledge (Wilson et al., 1987); or, instead, on pedagogical knowledge. The latter type has been summarized and organized (Clark et al., 1986) in two categories that have since been widely adopted; a fact which reinforces Clark and Peterson’s caveat that these categories "reflect the researchers’ conceptualization of the domain of teachers’ thought processes more than an empirically derived categorisation of the domain" (Clark et al., 1986, pp. 257-8). Hence, studies which adopt a psychological approach and focus on pedagogical knowledge can be divided into teacher planning (preactive and postactive thoughts) (Clark et al., 1987; Berliner, 1987; Peterson et al., 1992) and teacher’s interactive thoughts and decisions (Calderhead, 1981; Shavelson et al., 1981).

Studies adopting an epistemological approach seem to concentrate on what has been described as propositional knowledge (Clark et al., 1986, p. 281); namely, teachers’ theories or beliefs (Pope et al., 1986). Sometimes, this is also termed practical knowledge; "the term ‘practical’ used to distinguish the knowledge that derives action from theoretical, or scientific knowledge" (Olson, 1988, p. 168). Clandinin and Connelly (1987), in particular, consider that the "intent of such studies is to get inside teachers’ heads to describe their knowledge, attitudes, beliefs and values in contrast to studies focused on group action and others focused on generalized patterns of behaviour in populations" (Clandinin et al., 1987, p. 487). The study of ‘the personal’ - that is, "the what, why and wherefore of individual pedagogical action" (Idem) - as Olson (1988) also notes, shows a clear resistance to construe teachers’ thinking as interpersonal; as public not private. Later I discuss this point further.

1. A Critical View of Research in Teacher Thinking and Action

By and large, those who adopt a cognitive stance in teacher thinking research seem to be pursuing an ideal of teaching, a state of professionalism in which one would be (a) aware of the variables involved in each one situation, (b) cognizant of the various theories and empirical precedents which allow one to frame that particular case, and obviously, (c) capable of choosing the right course of action informed by
all these factors. In this sense, those of more positivist inclinations would probably
tend to propose that item (a) is possible once there is an objective reality to be
apprehended (even if partially so, in view of "human flawed intellectual mechanisms
On the other hand, those who adopt a rather more subjective, interpretive stance
would perhaps pursue this ideal in a constructivist manner. For these,
realities are apprehendable in the form of multiple, intangible mental
constructions, socially and experientially based, local and specific in nature
(although elements are often shared among many individuals and even across
cultures), and dependent for their form and content on the individual persons
or groups holding the constructions (Guba et al, 1994, p. 110).

For each of these views of reality there is a different set of consequences to items
(b) and (c) of the ideal of teaching described above. For the positivist, successful
action follows inevitably from knowledge of the 'way things are'. For the
constructivist, constructions are not more or less 'true', in any absolute sense, but
simply more or less informed and/or sophisticated; therefore, the more informed
and sophisticated one becomes, the more cognizant one is. Consequently, as Guba
and Lincoln (1994, p. 111) contend, for those who adopt an interpretive stance,
there is more than one set of 'right decisions', once constructions are as
changeable as their associated 'realities' are subject to change.

However, it is questionable whether teaching can actually be well understood in
terms of a person's cognitive content and capacities - as the streams of teacher
thinking research described above propose. Clandinin and Connelly - themselves
admittedly in favour of a cognitive research agenda - have pondered over the issue,
considering, for instance, the importance of affect on teaching. They acknowledge
that "a cognitive and affective understanding of the personal practical knowledge of
teachers will help produce more living, viable understandings of what it means to
educate and to be educated" (Clandinin et al, 1987, p. 499). On the other hand, 
critics of the cognitive perspective contend that:

* in focusing on the cognitive, it puts too great an emphasis on the rational
  aspects of the teacher's self;
* it fails to explain the relationship between teachers' understandings of
  reality and the social conditions under which these understandings occur;
  i.e. it ignores the socio-cultural dimension of teaching;
* it focuses solely on teachers' intentions and purposes, failing to account
  for any unexpected ramifications their actions may have and their
unintended consequences.

Olson (1988) is one of those who express such criticisms:

what is crucial in understanding thinking is not personal, but interpersonal; public not private. Teachers' personal accounts can tell us much about the 'game' in which they are players; those accounts point to what is out there in the society to which they belong. This society has ways of doing things: a culture. Making sense of teaching means interpreting what teachers do and say in order that we may reveal the rules of the game in which they participate. Once we get the rules we get the sense of what teachers are doing when they teach. This understanding of the game becomes the ground against which any particular teacher's account has to be placed. We need access to this ground in order to make sense of what teachers tell us about teaching. If we do not understand what kind of game they are playing, the significance of what they say is lost (Olson, 1988, p. 167).

This sort of concern seems to be on the increase amongst those who study teachers' thinking in particular, and among those involved in teachers' professional development in general.

2. The Scholar-Practitioner Dilemma of Cognitive Research

I have already discussed the fact that research on teachers' thinking has always had an applied nature. The mid-seventies push (National Institute of Education, 1975) that virtually established this as an area of research in teaching, was given in face of the failure of curriculum developers to implement innovations simply by providing teachers with appropriate curriculum materials. The ultimate aim of improving classroom practice seemed then to be dependent on improvement in teacher education and training; this, in turn, being dependent on knowing more about teachers' knowledge - both knowledge related to content matter and its teaching, and pedagogic knowledge. Research was undertaken, but as time passed the initial assumption did not seem to prove supportable. The research findings were accumulating but changes in teacher professional development, and indeed initial training as well, were still not enough to produce the expected effects on school teaching. Or at least some educationists began to see it this way. It is worth considering what some of these educationists have said in that respect.

Goodson (1994) uses an interesting metaphor to capture the nature of the situation in which educational researchers find themselves. He suggests that these
scholars face a kind of devil's bargain. In adopting more traditional research methods, educational researchers tend to move away from those who should benefit most from their studies - namely, the teachers; by doing so, however, these researchers are understood and respected by their academic peers and hence are better placed to bid for funds and means to do their research. Clearly, however, if this research does not serve to redress the problems they find, the funding becomes questionable (See also Day, 1993).

Although such a caricature might apply to educationists in general, researchers on teachers' thinking and action do seem to face a dilemma of this nature. For some (Olson, 1988; Day, 1991), the cognitive perspective adopted in studies in this field seems to represent precisely that 'traditional research', referred to above by Goodson (1994) as being well funded but virtually irrelevant outside the academic world. To reinforce the assertion about research usefulness in this field, Day (1991) draws on a presidential address to the American Educational Research Association's (AERA) Annual Conference (Chicago, 1991), which stresses "the worldwide scepticism expressed by teachers about research and researchers which is so unproductive" (Day, 1991, p. 537). On the other hand, a good example of the sort of attitude governments might have towards alternative types of research is that in the UK at the moment 'teacher training' has been accused of "promoting progressive theories that are politically biased in favour of a left-wing egalitarian ideology" and whose overall effect is a failure to raise standards (Elliott, 1993a, p. 1; see also Griffiths et al, 1992; O'Leary, 1994).

The dilemma Goodson's metaphor highlights in essence stresses that the scholars-practitioners opposition needs not only to be overcome but further articulated. Indeed, this dilemma refers directly to the contradiction theory-practice which was responsible for the appearance of positivism in the nineteenth century and for the disillusion with it in this century, by the interpretive as well as by the critical paradigms. Therefore, this is a dilemma whose solution is underpinned by quite intricate philosophical propositions. Concerning teacher education in particular, those who have not ignored it have adopted various attitudes and taken several different courses of action to resolve it. Two of these efforts are worth discussing, even if briefly. They seem to be the prevalent ones on each side of the matter: that which focuses on the practitioner and that which focuses on the scholar. These efforts are represented by the action research movement, to which Day belongs, and by the movement which advocates studying teachers' biographies and life history, which is Goodson's proposition (Goodson, 1992).
3. Collaborative Agendas for Research

As discussed above, some educationists consider the separation theory-practice to be responsible for the inability by educational research to remedy teaching and learning problems in schools. However, as the history of research on teachers' thinking and action shows, this is not the common view. The USA National Institute of Education (1975) drive to push ahead with this programme of research was based on the assumption that better understanding of teachers' practice and ways of thinking should result in sound theory for the implementation of changes in teacher training and professional development. This thrust is still felt within the field. It is necessary to acknowledge, however, that criticism of the traditional model of research is on the increase. Such criticism is based on actual failures of this model and is endorsed by teachers' attitude towards its results.

The point most stressed by these critics is the extent to which research results are generally decontextualised and therefore regarded as irrelevant by teachers. They argue that once teachers are the main beneficiaries of research, this sort of reaction should be averted. In order to achieve this, some kind of collaboration between the academic researchers and school teachers is necessary, as these critics all seem to agree (Carr et al, 1986; Oja et al, 1989; Day, 1991; Elliott, 1991; Brown et al, 1993). Basically, these critics subvert the hierarchy scholar--specialist-teacher--novice so commonly found in many other studies. Despite similarities in their proposals, however, they do not constitute a cohesive group. Consequently, ideas for this collaboration take different forms, since their proposals are underpinned by different philosophical inspirations and practical concerns. Nevertheless, in conveying this trait they have in common of proposing that collaboration is necessary, I have chosen to use the label ‘Collaborative Research’ to refer to these critics.

The subversion of the usual pattern of observer-observed shows a concern among these scholars for the alleged neutrality of research. They contend that 'non-interference' has paradoxically become an excuse for "task- or goal-centred, relatively short data collection exercises in which many researchers engage" (Day, 1991, p. 537). When outside researchers prefer observation protocols, teachers being observed have little or no chance of reflecting on their own thinking. The researcher takes responsibility for analysing the data collected. This inevitably presupposes prior standards of quality, as Robinson (1981, pp. 74-5) points out in his analysis of Flanders’ observation schedules (1970). The Collaborative Researchers’ opinion is that scholars should give up predefined notions of what
excellence in teaching might be (Elbaz, 1991; Day, 1991). This is how Brown and McIntyre have expressed this opinion:

Our research could not be planned in relation to any theoretical model of teaching such as inquiry-oriented teaching or mastery learning. Studies which are built around such models must interpret and identify ‘good teaching’ in ways which reflect the requirements of those theories. But because our purpose was to discover and understand the implicit theories which teachers have and use to guide their own teaching, pre-conceived theoretical models of teaching could only interfere with the realization of our goal (Brown et al, 1993, p. 23).

What is noteworthy about these propositions is that they give evidence that Collaborative Researchers are in tune with general postures that emerged within applied qualitative research in the 1970s. The attitude in question is summarized thus in a recent research review:

There has been a significant reexamination of the observer-observed dyad erected by Descartes and reexamined by Kant. Both the observer-observed dualism favoured by Cartesians and the observer-observed dialectic activated by neo-Kantians have been questioned. In extreme cases, critics have sought to reduce the observer-observed dyad to a unity. The freedom of thought and action of the privileged observer is transferred to the less privileged subject of the observation. Similarly, the assumed disinterest of the observer is rejected, along with the passivity of the practitioner (Hamilton, 1994, p. 67).

Among critics of this disposition there are some who are particularly devoted to reexamining the professional role as well as the professional development of teachers. They seem to be divided in two big groups. Those who attempt to reduce the observer-observed dyad to a unity seem to focus their attention on the practitioner, who they consider to be 'action-researcher'. Those who have not gone so far as to make observer and observed one, propose means of giving voice to the observed, turning them into subjects of the research, instead of mere objects of it. Both groups adopt the reflective-practitioner metaphor proposed by Schon (1983). While the former group proposes that reflection on action is much more meaningful when action is undertaken as a form of research, the latter maintains that reflection on action can be illuminated by the study of particular episodes and events, both factual and mental, lived by the practitioner. It is interesting to note, though, that in both cases teachers are seen in a much more holistic way than in research of reflection in action of the teacher interactive thoughts tradition, which focused on teachers’ cognitive processes (Shavelson et al, 1981).
Although this is not necessarily a rule, each of those groups of Collaborative Researchers has its own and separate roots. The proponents of educational action-research come from the teacher-as-researcher movement which started within curriculum studies in the UK in the mid-seventies (Stenhouse, 1975). The roots of the other group are multifold; in any case, some influential scholars now advocating the study of teachers' life history (Pope, 1993; Calderhead et al, 1994) have in the past adopted a cognitive approach to research of teachers' thinking. Some of these undertook studies of teachers' interactive thoughts and decisions, adopting a psychological perspective (Calderhead, 1981). Others, adopting an epistemological perspective, undertook studies of teachers' beliefs and implicit theories, making clear the research tradition to which they were affiliated: "the choice of intuitive theories as a focus of investigation represents an epistemological stance consistent with the qualitative-interpretative approach" (Pope et al, 1986, p. 154).

4. Collaborative Biographies

The cohort of scholars now advocating the study of teachers' life histories centres its attention on teachers as individuals, as is characteristic of an interpretive model of research. Their concern is "to enable participants in such research to gain from the experience of reflection and clarification of their thinking in anticipation of further action" (Pope, 1993, p. 24). Their emphasis, however, is not on a knowledge base - teachers' fixed body of understanding. It is on the intuitive and the implicit structures of thought which presumably ground personal acts and decisions. In other words, teachers are seen as reflective rather than reactive, and eager to change both their reality and their own self where necessary.

Another feature shown by this group of researchers is the assumption that teachers' cognitive processes and behaviour are eminently temporal. That is, they evolve - and do so not only according to successions of lived experiences but especially through the changing interpretations of those experiences. In that sense, their studies aim at more than an identification, understanding or modelling of those cognitive processes. They aim to identify teachers' and student-teachers' processes of knowledge growth, strategies of analysis and reflection, and the interaction of personal, institutional, supervisory and activity factors in these processes (Calderhead et al, 1994). The adoption of the metaphor human-as-storytellers (Howard, 1988), therefore, is now widespread within this branch of the Collaborative Research cohort. Pope, for instance, acknowledges that her own inclination is towards autobiographies:
The telling of and reflection on autobiographic narratives can make conscious for the teacher the images, knots imperatives, core constructs and experiential metaphors forming part of the teachers' professional lore. It can be emancipatory in the sense that the telling of the story liberates an understanding of its power. By making the tacit articulate it can be critically appraised (Pope, 1993, p. 25).

Autobiographies and life histories differ from case studies and ethnographic research in that they involve the collaboration of both the researcher and researched. One thing some have in common is the recognition of the value of conflicts faced by teachers in their professional practice (Pope, 1993, p. 25). However, for the Collaborative Researcher these ‘knots in thinking’ are not merely intellectual discussions and strategies to be evolved but are ‘subjectively’ experienced as anger, anxiety or stress (idem ibid); hence their concern with the presence of current everyday classroom problems described by teachers in their discussions. Elbaz’s argument about ordinary and extraordinary teachers follows the same lines:

In looking at ordinary classrooms, sooner or later something extraordinary happens; something moves us to feel appreciation, respect, anger. These reactions are personal, but they are grounded in our understanding of teaching as a practice within a social setting, of the values we believe it should foster, of the traditions we want to see preserved. And these can be formulated and subjected to dialogue, among ourselves and with teachers. In this process we uncover and give legitimacy to the extraordinary that is within the ordinary (Elbaz, 1991, p. 8).

The agenda set out by this cohort of scholars is, in many respects, in accordance with the one I have set myself. Firstly, there is the importance we all place on collaboration, which is an attempt to break the observer-observed mould. Secondly, the assumption that the feelings one has in relation to classroom events are revealing of understandings, values and beliefs. Thirdly, the common recognition of the value of conflicts in teachers' professional practice. Finally, the common proposition that one's conceptions of oneself as teacher are grounded biographically and that work contexts either enable or limit human development.

Where I adopt different perspectives to that of scholars focusing on teachers’ life history, there are differences between the paradigms each of us adopt in our approach to research. The dividing line is the significance each of us places on the interpretation of those feelings, conflicts and work contexts. For me, the
interpretation of them is not sufficient in itself; no matter whether the interpretation is made by outsiders or by teachers themselves. Reality might distort consciousness, besides being defined by it. Educational practitioners (both teachers and teacher educators) need to learn how to overcome distorted understandings, particularly when these reflect conflicts and tensions endemic to their own practice. Research, I would contend, can suggest ways in which people should change what they are doing, rather than simply encourage them to change the ways that they think about what they are doing. These are relevant points and demand further attention. In the next chapter, I look at the relation between reality and consciousness, focusing on the insight Freire gives into that question (chapter 2, section D). Later, I will return to the second point, about the purpose of research being to foster changes of behaviour, as well as changes of attitude (chapter 3, part I).

5. Collaborative Research on Student-Teachers’ Knowledge

As discussed above, Collaborative Researchers interested in teachers’ thinking who approach this issue through the study of teachers’ life history tend to adopt an interpretive paradigm in their work. While some openly declare the adoption of this paradigm (Pope, 1993), others suggest its adoption in their eclecticism (Calderhead et al, 1991; Calderhead et al, 1994). Calderhead is working in this programme of research though focusing on student-teachers’ experience of training and the interplay of it and the student-teachers’ conceptions of classroom practice (Calderhead et al, 1991; Calderhead et al, 1994). For some time this has been an area of interest for Calderhead and those working with him, their contribution being noteworthy especially regarding the role of reflection in the initial education of teachers (ITE). In part, this special interest in ITE distances me from this particular school of research. Its prominence, however, makes a critique necessary.

What immediately stands out in Calderhead’s recent work is its scale. Although not necessarily working with large samples (twenty student-teachers in Calderhead et al, 1994, for example), his studies comprise a great variety of data collection procedures (semi-structured interviews, video-analysis by student-teachers, classroom observation, student-teachers’ agreement/disagreement rating of statements about teaching, interviews with student-teachers’ mentors or supervising teachers and with the course leaders in the college for cross-comparison with student-teachers’ statements). This eclecticism naturally requires personnel to undertake the various data collections and analyses but, more importantly, it depends on student-teachers being available and willing to
contribute. These studies also spread over long time-spans (two academic years in Calderhead et al, 1994). The advantages of such scale are obvious. Although it cannot be said that such a scale is the sole reason for the quality of results obtained, it does play a part in it, as does the involvement of a team of researchers. Certainly the research experience of these scholars and their serious commitment to improving teacher professional development is responsible for the quality of their propositions.

There are two points I would like to make about Calderhead’s work. The first concerns his interest in understanding the process of professional development in early training. The second, the significance he attributes to what student-teachers themselves regard as significant.

In his effort to understand the process of professional development in early training, Calderhead has adopted a host of different routes; from identifying student-teachers’ alternative orientations to learning to teach, to identifying differences in the processes of knowledge growth amongst student-teachers (Calderhead et al, 1994). As he acknowledges himself, his studies are exploratory and open to shifts in their foci according to the interests and concerns of the student-teachers being "studied" (Calderhead et al, 1994, pp. 1-2); hence my reference to them as Collaborative Research. However, the emphasis of Calderhead’s studies is somewhat distinct from that of my own research.

Calderhead, writing with Shorrock, stated, for instance, that one of the aims of his research project is:

> to develop a fuller understanding of the processes of professional development in early training and to consider its consequences for the design, organisation and assessment of pre-service training (Calderhead et al, 1994, p. 1).

Statements such as this indicate that Calderhead places great importance on the understanding of the processes of professional development. They are statements which also suggest that the design, organisation and assessment of pre-service training are conditional to that understanding. The aim of my research is not to understand these processes of professional development as in Calderhead’s studies. As I discuss later (chapter 3, part I), it is my belief that the design of in-service teacher education and training is not solely conditional on an understanding of the processes mentioned. Although such understandings might be of prime importance in ITE, they do not seem to have the same importance for in-service education. I suggest that this is so because, in dealing with practising teachers, I believe it is
more important to encourage the confrontation of the practical and personal knowledge of these practitioners with the formalized knowledge held by course leaders. Neither of these parties have definite answers to teaching problems. Yet, both are likely to have valuable suggestions of solutions for such problems. In that sense, this confrontation seems to depend less on the sort of understandings with which Calderhead is concerned and more on the significance teachers seem to place on certain events and processes. The identification of such 'significance' leads me to the second point I would like to make about Calderhead’s work. I should say, however, that some of the points I make here will be further elaborated after I discuss Freire’s philosophy of education, in the next chapter.

It is interesting to note the factors which Calderhead and Shorrock bore in mind while analysing interview transcripts. This analysis aimed at identifying significant events or processes that appeared to explain the professional development of the student teacher over the two year period (Calderhead et al, 1994, p. 2). The authors focused first on important influences on teachers’ practice (past educational experiences or personal images of teaching, for instance). However, the other focus of their analysis, has greater bearing on my research. It is related to the significance that students themselves seemed to place on certain events or processes (Calderhead et al, 1994, p. 2). Although this is not the emphasis these authors give to this factor, I would like to argue that they have been attentive to student-teachers’ discourse in a different and special sort of way when looking at the significance student-teachers place on events or processes. This is evidenced by the authors producing a summary of their research results through a list of themes. It is understood that the full analysis of the data collected takes the form of a series of case studies (Calderhead et al, 1995), but that these are meant to inform the discussion of those themes in their list. The themes in turn are meant to generate debate with fellow teacher educators on the authors’ findings and propositions for ITE reforms. As I have said, in dealing with practising teachers, it seems important that course leaders are able to contrast the practical and private knowledge of these teachers with the formalized knowledge about which the in-service professional development programme is concerned. Calderhead and Shorrock’s use of themes to discuss their findings and propositions with their peers parallel my own use of ‘Generative Themes’ as a means to enter into meaningful dialogue with practising teachers.

6. Action Research as a Collaborative Research Agenda

As I have said, of the researchers interested in teachers’ thinking and action there
seem to be two main groups which, facing the theory-practice contradiction of teacher professional development, have tried to solve the observer-observed dilemma of research. The group just described maintains that reflection on action can be illuminated by the study of particular episodes and events - both factual, actual events, and mental ones - lived by the practitioner. They propose to solve the observer-observed dilemma by giving voice to the observed, whose feelings, conflicts and work contexts they seek to interpret and understand. The second group is constituted by those who attempt to reduce the observer-observed dyad to a unity. Researchers of such inclination tend to focus their attention on the practitioner and propose that reflection on action is much more meaningful when action is undertaken as a form of research. In a word, they suggest that teachers should become 'action-researchers' (Carr et al, 1986; Whitehead, 1989; Elliott, 1991).

Some proponents of action research make it into a form of teacher professional development. Elliott (1993b), for example, has discussed the relationship between 'understanding' and 'developing' teachers' thinking in an article he ends with this motto of the action research movement:

the terms 'research' and 'development' come to represent not so much different activities as different dimensions of a single unified activity, in which 'the outsider' is both a teacher educator and a researcher and 'the insider' is educated through research. It is this single unified activity which we call action-research (Elliott, 1993b, p. 206).

Taken out of context, this statement - apart from the reference to action research - conveys my own philosophy towards the research undertaken in this present study. Indeed, if action research were to be defined by this passage, I could say that I am undertaking a form of action research myself. Elliott's own words following the passage above would reinforce this. Drawing on Kitchener and King's (1991) seven forms of development of 'reflective intelligence' in individuals, he contends that when research into teachers' thinking operates at particular levels of reflection it constitutes a form of educational action-research. Since I do not think this is in fact the case, I ought to state where I feel the differences lie.

Action-research is in itself controversial, even if one leaves aside the early attempts in the USA to put into effect Lewin's ideas regarding the resolution of social problems by developing theory and practice (action and research) together (Lewin, 1946 cited by Carr, 1994). The present British action research movement,
originating from the teacher-as-researcher movement which started within curriculum studies in the mid-seventies (Stenhouse, 1975), is itself divided. This disunity has a particular bearing on the present study. I have made use of Carr and Kemmis’s (1986) frame of reference to define parameters for my overview of research on teachers’ thinking and action. Elliott, however, criticises these authors (Elliott, 1987) precisely for their use of Habermas’s theory of ‘knowledge-constitutive interests’ to distinguish three different types of action research: technical, practical and emancipatory (Carr et al, 1986, p. 202; Elliott, 1993b, p. 197). His criticism clearly signals one important difference between Carr and Kemmis’s attitudes towards knowledge, and towards the production of knowledge. Elliott does not seem to accept the proposition that any reduction of the social sciences to the explanation of subjective meanings fails to recognize that the subjective meanings that characterize social life are themselves conditioned by an objective context that limits both the scope of individuals’ intentions and the possibility of their realization (Carr et al, 1986, p. 135). Such attitude can be inferred from this passage where, endorsing Gadamer’s (1975) criticism of Habermas, Elliott states:

I cannot see why practical reflection, which is interested in how to act consistently with the values embedded in our social traditions, need not require us to think critically about values. Habermas tends to assume that social traditions are unchanging mechanisms of ideological suppression from which human beings need to be emancipated. For Gadamer social traditions can be far from dynamic and changing, and inasmuch as they are it is because the values they transmit are continuously reconstructed on the basis of practical reflection. In other words practical reflection incorporates the critical as an intrinsic dimension. According to Habermas the emancipatory interest incorporates the practical interest but also transcends it. From a Gadamerian point of view the critical aspect of reflection does not serve an emancipatory interest in the sense of emancipation from social tradition. Rather as an intrinsic feature of practical reflection it serves an evolutionary interest (Elliott, 1993b, p. 197).

Without entering into too philosophical a debate it is important that I highlight practical points of Elliott’s conception of action research which relate - in endorsement or contrast - with my views on studying teachers’ thinking and action and on teachers’ professional development.

Where I agree most with Elliott, as I have already said, is in his proposition that ‘research’ and ‘development’ should represent not so much different activities as
different dimensions of a single unified activity. Later I will demonstrate how, as ‘outsider’ I pose myself the double role of teacher educator and researcher. I expect that my volunteer teachers, ‘the insiders’, are motivated by this research to change what they are doing. This, they themselves declare, is a source of anxiety for them. I do not believe that the only way for teachers to change their perception of what they are doing is by conducting their own research.

Like Elliott, I avoid research which explicates teachers’ thinking purely in terms of its content, mainly for two reasons. First, I do not think that teachers’ knowledge is either obvious to the senses - and therefore observable - or known indirectly through references they might make to theories or philosophies of education while planning or in classroom interaction (Elliott, 1993b, p. 204). These, as I have said, are the main interest of the more cognitive agendas for research on teachers’ thinking, placed on the apex opposite the critical edge of the positivist-interpretive-critical triangle, in figure 2, page 22.

The second argument is that I think my own interpretation of teachers’ thinking might be problematic. My reasons for this assumption are twofold. First, I would have to rely on teachers’ own introspective accounts. I do not think that teachers are infallible authorities on their own mental processes (Elliott, 1993b, p. 205). Therefore collecting their thoughts as if these provided the sort of ‘technical’ information useful, for instance, in designing an initial teacher training course, does not seem to be satisfactory, in my view. Besides, I am not a disinterested collector of information about teachers and their teaching. On the contrary, I have my own convictions and intentions regarding teaching and these make me judgemental about teachers’ accounts of their thoughts and actions regarding their teaching. My interpretation of teachers’ thinking is, therefore, problematic because of my own previous experience as a teacher in post-fourteen education.

I also turn away from research which explicates teachers’ thinking purely in terms of the justificatory reasons they provide for their interpretative acts; as Elliott does. I do not assume that teachers’ knowledge is idiosyncratic and subjective (Elliott, 1993b, p. 205). I believe teachers do think reflexively about the way they personally construct knowledge and practice. However, I would not adopt the relativist position apparently shared by those studying teachers’ implicit theories and beliefs, and even some of those who focus on the study of teachers’ life history and biographies. Such relativism leads to a tolerance of different beliefs, and that tolerance might in fact fail to contribute towards the professional development sought. Let us assume that teachers, when called upon to justify their
interpretation of practice, do so only in terms of idiosyncratic rules. If that is so, I would argue that the challenge for teachers to relate their idiosyncratic rules to formalized propositions for similar practices, or even to formalized theories, does not come amiss for their professional development.

I begin to disagree with Elliott, however, when he maintains that research should view teachers’ interpretations of their professional world as mainly personally constructed. He presumes that teachers not only are capable of providing justifications for their own interpretations but also understand how they are personally constructed as objects of consciousness (Elliott, 1993b, p. 206). My disagreement is based on the assumption that personal construction is not the only type of legitimate interpretation of the world. Indeed, I assume that some of the subjective meanings that characterize teachers’ interpretation of practice are themselves conditioned by an objective context and that teachers’ existing forms of communication may be distorted by prevailing social, cultural or political conditions (Carr et al, 1986, p. 135). In other words, people’s self-understanding of what they are doing might, at times, be illusory or deceptive. One explanation of how and why this occurs is that individuals may be conditioned by ‘naive consciousness’; more about this in the next chapter (section D). Another explanation is that certain social mechanisms (language, customs, coercions, traditions) operate to bind people to irrational and distorted ideas about their social reality. These kinds of explanations can deny the validity of the individual’s own explanation of what he/she is doing (Carr et al, 1986, p. 96).

I must acknowledge, however, that by viewing teachers’ interpretations as personally constructed one has the advantage of contesting the stances discussed earlier. After all, in this case the researcher will not only reflect about evidence in the light of certain standards of enquiry, but will also think about the ways in which "the interpretations and standards are constituted by consciousness" (Elliott, 1993b, p. 206). This in turn implies that the researcher should reflect about the biases which frame his/her own interpretations of teachers’ interpretations. Such an attitude seems, in fact, to be a common characteristic of those I refer by the term Collaborative Researcher.

As I have said, Collaborative Researchers can be distinguished by the way they propose to solve the observer-observed dilemma. There are those who seek to interpret and understand the observed, giving voice to this so that he/she can express his/her feelings and conflicts together with the complexity of his/her work context. But, there are also Collaborative Researchers who attempt to reduce the
observer-observed dyad to a unity, proposing that reflection on action is much more meaningful and thus suggesting that teachers should become 'action-researchers'. The former seem more reluctant to stop trying to understand teachers' interpretations; perhaps because they distinguish 'research' from 'development', probably considering research on teachers' thinking and action as a source of raw material for the development of teacher education programmes. Action researchers, on the other hand, represent 'research' and 'development' as two dimensions of one single activity, not as different activities. This latter attitude seems a suggestion that understanding of the insider's interpretations is not only relative, it may even be unnecessary; their professional development taking place with the development of their 'wisdom of practice'.

Elliott himself suggests that by aiming to understand teachers' interpretations of their practice, outsiders in effect hinder their own chance to achieve higher levels of thinking about that practice and about the thinking teachers relate to it. Referring once again to Kitchener and King's seven-level hierarchical scheme of development for 'reflective intelligence', Elliott discusses how outsiders could improve their own interpretations:

One would expect a high degree of reflexive self-awareness on the part of a researcher who presumes that his/her interpretations of interpretations are personally constructed. Such level 6 or 7 thinking will imply that interpretations of teachers' personal constructions of meaning are achieved in dialogue with teachers (Elliott, 1993b, p. 206).

It is interesting that, although he places great importance on dialogue between researcher and teachers, Elliott does not in fact enter into dialogue with them. In a footnote to this passage he acknowledges this flaw. It seems to me, however, that his failure - as he himself puts it - to involve himself in dialogue with the two teachers is symptomatic of his personal convictions. Elliott is capable of proposing that "when research into teachers' thinking itself operates at levels 6-7 it becomes a form of teacher development" (Elliott, 1993b, p. 206). But, as an advocate of educational action research, he 'stands this claim on its head' to give way to this form of self-enquiry which is Action-Research. Indeed he does this with his own proposition about the potential of dialogue. In my view, this is all disappointing since we are left only with the hope that teachers' own interpretations will be sufficiently insightful for practice to gain new meanings and, perhaps, be improved. I believe that, if outsiders are to try and find a way out of the hazards in the double hermeneutic of interpreting teachers' interpretation - rightly problematized by Elliott (1993b, p. 203) - then dialogue should be considered as a possible channel.
to do so. This course of action would clearly involve some challenges.

For both outsiders and insiders, the challenge of entering into dialogue would essentially lie in living with the differences of focus between their respective constructions of practice. Each party has to attempt this. At the same time, each should try to deepen further his/her own construction in face of the other’s. For one reason, the challenge for the outsider seems even greater: the outsider needs to learn to do without an understanding of the insiders’ interpretation of practice. If in fact willing to enter into dialogue, the outsider needs to acknowledge that this is not necessarily preceded by his/her own understanding of the insiders’ interpretation of practice. Indeed, his/her dialogue with insiders might be only accompanied by his/her effort to make sense of the insiders’ interpretations of practice. Challenging as this might be, the outsider has resources on which to draw in order to accomplish it. The outsider possesses a view of practice and of the interpretation of this by the insider which is informed (a) by his/her own experience, (b) by the experience of other practitioners with whom he/she has already entered in dialogue and (c) by his/her background reading of research reports, theoretical and philosophical accounts related to the practice and interpretation concerned. Being aware of the weight of this background in his/her own interpretation of the other’s interpretations, the outsider could try to withdraw him/herself from any interpretation at all. The question is, would this then be a dialogue?

Letting an arsenal of ideas fall on the practitioners’ head is certainly not a very collaborative approach on the part of the expert teacher educator. However, pretending that those ideas are not there does not make the dialogue collaborative either. Yet dialogue seems to be the way forward, as Collaborative Researchers in general seem to be suggesting. Therefore there is a clear challenge for those interested in pushing thinking forward here. How can dialogue between practitioners and experts be prepared and carried out? How can it be done in a way that distinguishes ‘naive consciousness’ from ‘critical consciousness’? How can dialogue allow practitioners to learn ways of overcoming their own distorted understandings as well as make sense of the understandings of educationists, subject experts and curriculum designers who care to enter into dialogue with them?

Elliott rejects the possibility of critical research in teachers’ thinking on the mode of Habermas’s critical social science (Elliott, 1987). Arguably, he does not credit the idea that social, cultural or political factors condition and limit one’s
construction of reality. Hence, in figure 2 (page 22), his proposition of action research could be placed on the edge which represents the practical view of teaching and the interpretive approach to educational research. Probably his conceptions of action research belong somewhere along that line, near the corner where it meets the critical paradigm edge of the positivist-interpretive-critical triangle.

From Elliott's account of research into teachers' thinking and of teacher education, the proposition emerges that teachers' professional development might follow from dialogue. His own view is that "teachers as 'insider researchers' will want to discuss their interpretations of evidence with their tutors" and that "the tutors become participants in a collaborative research process" (Elliott, 1993b, p. 206). I would suggest that there are other ways in which dialogue might be professionally emancipatory. In the following section I begin to give shape to my proposition. Looking at Carr and Kemmis's account of critical action research, I find reasons to endorse the requirements, they contend, need to be met for educational research to be considered 'a science of human praxis'. At the same time, it becomes clear that action research, even if critical, is not the only form of collaborative research to meet the requirements mentioned.

E. For a Problematizing Collaborative Research Agenda

As discussed in section C above, Carr and Kemmis (1986) propose critical action research as a particular way in which curriculum studies could relate to the professional role of the teacher. They argue that their particular conception of action research fulfils the conditions of a 'science of human praxis', which they describe thus:

Any science of human praxis must embody values and interests, both as objects of enquiry and as knowledge-constitutive interests for the science itself. The study of praxis (informed, committed action) is always through praxis (action with and for the critical development of understanding and commitment); it embodies praxis in the form of an interest in improving praxis (Carr et al, 1986, p. 192).

Critical educational science, as they say, claims that the very purpose of critical self-reflection is to expose and identify self-interests and ideological distortions. Therefore, within critical action research, as Carr and Kemmis view it, the practitioner sets out deliberately to examine where his or her own practice is distorted by assumptions, habits, custom, precedent, coercion or ideology that are
taken for granted. The action researcher sets out to improve particular practices, understandings and situations by acting in a deliberate and considered way in which understandings and values are consciously expressed in praxis. The action researcher deliberately analyses the correspondences and non-correspondences between understandings, practices and the structure of educational situations, and searches for contradictions within and between them (Carr et al, 1986, p. 192).

Although I endorse all these objectives, I do not see critical action research as the only form of research for education which offers this way of enacting a critical educational science. In order to argue for an approach other than action research, I will first analyse what Carr and Kemmis judge necessary before research for education can be considered critical research (Carr et al, 1986, p. 179). I will then argue that my alternative of research on teachers' thinking and action also meets these criteria.

Below is a list of the requirements that a coherent educational science must be able to meet; as Carr and Kemmis (1986, p. 179) concluded, these requirements satisfy Habermas's notion of a critical social science. In order that research for education can be considered critical research:

* A dialectical view of rationality needs to be adopted.
* Teachers' interpretive categories have to be used as the basis for 'language frameworks' that teachers can explore and develop in their own theorizing;
* Teachers' 'naive consciousness' needs to be overcome. Teachers should be given means to analyse the way their own practices and understandings are shaped by broader ideological conditions;
* Those aspects of the social order which frustrate rational change need to be overcome. Teachers and others should have the opportunity to become aware of ways in which this can happen;
* The dialectical unity of educational theory (reflection) and educational practice (action) needs to be achieved.

As far as Carr and Kemmis are concerned, critical action research meets these criteria. It is necessary, though, to highlight the fact that theirs is a preoccupation with the professional role of teachers, particularly concerning teachers' interaction with students. Whenever the word 'teacher' is used in the bulleted list above, this preoccupations with their role is at the background. This suggests that if we reason in terms of teachers' professional development, a rephrasing of the requirements
above might be on order. In this case, we would be concerned with teachers' interaction with more experienced colleagues or, indeed, teacher educators. In this respect, as I am concerned with the latter scenario, it might be convenient to put both sets of actors side by side: in these circumstances we talk of teacher educators' interaction with teachers. The preoccupation, therefore, is with the professional role of teacher educators. The items in the list above have to be reconsidered to see whether or not the expression 'teacher educator' should replace the word 'teacher'. I would suggest that there is no need for rephrasing the requirements above.

Naturally the main target-audience for Carr and Kemmis's Becoming Critical is teacher educators. In that sense, these authors' proposal that it is only teachers who can research their own praxis implies that the role of teacher educators is to foster critical action research. As a practitioner in teacher education, however, I do not think I should be denied the opportunity to research my own practice; I should be permitted to engage in critical action research myself. In that case I would not follow Carr and Kemmis's suggestion. I can see that it is possible not to encourage my teachers to undertake critical action research and yet to try to observe the requirements listed above. The reason I would not endorse action research is simply because I see a window of opportunity elsewhere. This alternative has also been seen by Carr and Kemmis but has been discarded by them, as the following passage illustrates:

The essentially dialectical relationship between retrospective explanation or understanding and prospective action can be understood in terms of Marx's 'revolutionizing practice', Habermas's 'conduct of political struggle', or Freire's formula of 'problematization-conscientization-praxis'. It may, however, be understood in the context of educational action research... (Carr et al, 1986, p. 186).

It seems to me that an element of challenge should be present in the process of professional development of teachers. The conflicts a teacher faces in the context of critical action research can play this role; action research can be challenging. However, Freire's formula of 'problematization-conscientization-praxis' seems more promising in many respects. These will be detailed in the next chapter; a summary, however, seems appropriate. The form of research for education to involve Freire's formula can thus be checked against Carr and Kemmis's requirements of critical research.

Firstly, Freire bases his approach on a form of dialogue which is intrinsically
dialectic; he calls this ‘dialogicity’. In essence, Freire suggests that in dialogue one construes a situation better than in solitary reflection. This proposition is also made by action researchers; however, Freire’s process of problematization, being based on dialogicity, focuses people’s reflection on their own ‘language frameworks’ from the start. As discussed later, this is made possible by recourse to Thematic Investigation of the interpretive categories of those to be educated. The investigation is conducted by those in charge of educating the others with their collaboration. Secondly, Freire suggests that the inequality of the two parties’ backgrounds, perspectives, analytical tools, involvement in the action concerned etc, can be a bonus. Each party’s ‘naivety’ about the other’s theory and practice will necessarily be a topic for reflection. Both will have the opportunity to move to a state of ‘critical consciousness’, experiencing, in different measures, a process of conscientização.

Thirdly, praxis is of utmost importance in Freire’s pedagogy. So, in a transference of this pedagogy to the realm of teacher education, teachers and teacher educators alike will have the opportunity to become aware of how those aspects of the social order which frustrate rational change may be overcome. This is essentially because the transference of Freire’s pedagogy to the realm of teacher education has the potential to promote the dialectical unity of educational theory and educational practice. This can happen particularly if the parties have a common will to learn. As far as teacher profession development is concerned, this does not mean the teacher seeking a quick fix to problems of practice the so called expert has to offer. The teacher who wants to learn is one willing to establish a dialectical relationship between retrospective explanations or understandings and prospective action. Here, it is important to note, retrospective explanations or understandings can refer either to the teacher’s own or to those introduced for consideration by the teacher educator, which case the possible sources of inspiration would be theoretical or formalized propositions about the teaching practice. For the teacher educator, a desire to learn could translate into an open-mindedness, a disposition to critically ‘test’ these theories, principles and scores of precedents he/she has available to frame practice. To resume, this Freirean approach can be a dialogue where the personal knowledge the practitioner possesses and the formalized knowledge the ‘expert’ introduces are dialectically contrasted and confronted.

This study aims to elaborate this proposal, first by putting forward arguments to support the adoption of such a practice. I will further elaborate the proposal showing how, as a particular sort of ‘expert’, I think the tensions it involves can be
balanced. This is the tension between, on the one hand, imposing the formalized knowledge I would like to put forward for some teachers to consider and, on the other hand, respecting their self determination and 'personal' knowledge. The next chapter contains the philosophical basis for this proposition. I will then consider problematization as a form of critical collaboration between subject expert teacher educators and practising teachers.

**F. DILEMMAS AND PROPOSITIONS**

A sentiment has been noted in the science education literature that teachers need to be understood, if not heard, in order for school science to promote meaningful learning among its pupils. Collaboration is a word being used to impart the idea pervading this area of study. In contrast with the attitude of the teaching projects era, scholars now acknowledge, first, that the classroom teacher plays a non-negligible part in the science education of pupils, and, second, that, as scholars, they lack some of the knowledge and practical experience teachers may have to offer, hence paying attention to what teachers think and do.

On the other hand, a growing conviction has been noted in the literature concerned with teachers' thinking and action that it is counter-productive to attempt to adopt a 'neutral observer attitude' in this field of research. Inevitably, the researcher's interpretation will interfere, rendering useless any attempt to remain objective. Besides, it is argued that the research results which this attitude of neutrality yields are of little relevance for practitioners.

Collaborative agendas of research on teachers' thinking and action appear as an alternative to 'traditional research', as they do in the science education area. Since the observer-observed dyad is regarded as problematic/inadequate, in establishing channels of communication one tries to bridge the gap between observer and observed. Consequently, these collaborative agendas of research adopt more holistic stances than previously - mainly cognitive, approaches. Thinking and action are thought of as *praxis*. Besides, the intervention of biographical, affective, cultural and other such aspects are also considered in the attempts to understand teachers' *praxis*.

Collaborative agendas of research give priority to the use of qualitative research methods and centre attention on - as well as trying to foster - teachers' reflection. Teachers are considered to be reflective-practitioners, whose reflections and actions might not be solely rational, premeditated or even conscious. Nonetheless, these professionals reflect on their actions and on the thoughts which might...
intervene when conducting those actions, and the more one reflects the better one carries out one’s obligations and fulfils one’s own intentions.

I share with Collaborative Researchers a number of assumptions. Namely:

* Although purely cognitive research on teachers’ thinking might provide useful information for teacher education, the professional development of teachers depends on insight about other dimensions of teachers’ thinking and action. Affect, which, especially in primary school, is an integral part of teaching, is but one example of these dimensions.

* The improvement of current school practice seems more likely to result from a constant collaboration between the university sector and school practitioners. School practice, as a social activity, needs permanent revision and sometimes reshaping. As there are ‘no perfect sages, nor utter ignorances’, those concerned need to combine their different qualities to obtain better results in these tasks.

* The professional development of teachers, as well as of teacher educators, is an integral part of such a process of improvement, constant revisions and occasional reshapings.

As even in the most pioneering works in this area there is room for further innovation, I have given thought to where these might be possible. This is what I have found and how I think innovation could be introduced:

* In their effort to communicate with practitioners, scholars, critical as they are of the neutrality of positivist observers, counter this attitude with an attitude of almost unreserved attention to the voices of those practitioners. This seems to deny the practitioners the benefit of constructive criticism.

By problematizing teachers’ definitions and conceptions, the educational researcher may do teachers some good. It is not altogether reasonable to assume that any alternative interpretations of teachers’ own practice will be well received. Such interpretations might in fact be perceived as an emotional threat to the individual’s conception of himself/herself and be discarded as ‘unrealistic’, ‘ridiculous’ or ‘irrelevant’. However, if these alternative interpretations are not presented but used to formulate questions about teachers’ own interpretations, they may give rise to true reflection.

* Some scholars are so concerned with teachers’ understanding of their own thinking and action that they regard further development of these
teachers' praxis as dependent on that understanding. Despite their insistence that educational realities are subjectively structured, rather than objectively given, these scholars in a sense contradict themselves when they pursue the methodological aim of describing social reality through the voices of teachers in an, apparently, neutral, disinterested way.

For both the teacher and the teacher educator, it is important to understand thinking associated with teaching. However, it may be that the ways in which teachers characterize their own actions are in conflict with what they are really doing. In other words, teachers' understandings and explanations of what they are doing may be no more than rationalizations that obscure the true nature of their situation. Research can explain how and why this occurs; for example, showing how social processes such as language and the processes of cultural production and reproduction shape our experience of the social world. Within this mode of enquiry, individuals' own interpretations can be critically reconsidered and reassessed through the contrast of these with alternative explanations, the latter necessarily disconnected from those meanings and actions the same individuals under enquiry provide as explanation. In short, the gap between interpretation and the reality of the facts is not necessarily the result of conceptual confusions which, once revealed, will demonstrate to people the rationality of their actions. It may be that the 'faulty' beliefs that give rise to the gap in the first place are a reflection of real conflicts and tensions endemic in the practice itself. As Carr and Kemmis put it, "it may be that it is the social reality that is irrational and incoherent rather than the individual's conception of social reality" (Carr et al, 1986, p. 98).

* Other scholars maintain that the practitioners' research of their own action is the best means to make their reflection meaningful. The preference of these scholars is to let teachers meet their own challenges.

Worthwhile though this option might be, it does not seem to exhaust the possibilities teachers have for reflection. Practice might be challenging but, invariably, the challenge of a situation has to be perceived for it to be considered a challenge. The perception of a challenge is dependent on the knowledge and the experience of the person perceiving it. In other words, action research, like self-reflection, may not explore the individual's full potential, either as a reflective or as an active practitioner.

The way I envisage this debate to be driven forward is by focusing on the concept of dialogue, as employed by Paulo Freire. If, as Freire proposes, dialogue is
construed as being different from an encounter where interlocutors meet in conversation merely to exchange experiences or impressions, then it becomes distinctively dialectic; hence the term 'dialogical' encounters.

Inspired by the work of Freire, I not only claim that through some such encounters it would be possible to establish a dialogue between a teacher and an 'other'. I also suggest that through these dialogical encounters a critical collaboration between these parties can start. In the next chapter I set down those ideas of Freire that support this proposition. Later I will myself take on the role of an 'other' engaging in dialectical dialogue with teachers. To stress the potential this approach has to promote this form of dialogue between different people, I have chosen primary teachers as interlocutors and primary science, particularly physics topics, as the subject of conversation. I have to say that I do not have any knowledge or experience of primary science teaching other than as a student. Details of these arrangements for these encounter, as well as the results, take up the chapters which follow chapter 2 on Paulo Freire.
CHAPTER 2

PAULO FREIRE: A PHILOSOPHICAL FRAMEWORK

A. FREIRE: MYTH AND REALITY

B. THE 'METODO PAULO FREIRE'
   1. Analysis of the Dialectic Nature of the 'Metodo Paulo Freire'

C. FREIREAN PARADIGM
   1. Radicality and Democracy
   2. Dialogicity

D. PROBLEMATIZATION
   1. The Underlying Sociological Premises of Problematization
   2. Limit-Situation, Problematization and Conscientização
      The states of consciousness
      Awareness and limit-situation
      Challenges, problematization and conscientização
      'Distance' as a key element of conscientização
   3. Conscientização in Contrast with Enlightenment
As stated in the previous chapter, I am interested in pursuing a dialectic form of enquiry on teachers' thinking and action. This enquiry will, I hope, be the basis for an equally dialectic teacher education programme. In such a programme, science education experts and school teachers would exchange views on the teaching of science and eventually begin to change those views. Hence, both the preliminary enquiry and the actual programme to follow should provide opportunities for teachers, as well as for experts, to review their theories and practices. The literature contains scarcely any study that has such objectives. This study has such objectives for it was inspired by the work of Paulo Freire.

Freire's ideas and the concepts they involve were expressed by him through his critical consideration of one particular pedagogical situation: adult literacy programmes. Freire's approach to adult literacy became known as 'Metodo Paulo Freire'. It is described here, briefly, for the purpose of arguing for a dialogical collaborative research agenda. Neither the description, nor the short discussion of key concepts in Freire's pedagogy, do justice to the significance of his work. It is difficult to evaluate the impact Freire's ideas have had on contemporary educational thinking worldwide, considerable though as it has been. To try and illustrate this I shall begin by discussing the myth surrounding his work.

**A. Freire: Myth and Reality**

Many authors have noted that the work of Paulo Freire is particularly significant in that it highlights the political nature of education. Freire says there is no such thing as a neutral education process, meaning that whatever the purpose or the approach or the emphasis or the content of education it will always involve values. If those who are in charge of conducting this process are not conscious of the particular values being passed on, so much the worse for them; values are necessarily being transmitted anyway. Connolly, for example, expressed this opinion thus:

The importance of Paulo Freire lies in the emphasis he gives to the hitherto ignored political nature of education. He sees significant implications in this regard, not only for the third but also for the first world. His thinking demonstrates the power of education as a liberating force. To achieve this however, the oppressed require their own pedagogy. It is through offering other models for teaching and learning that Freire produces radical alternatives to the existing narrative forms of education. He believes neutrality always conceals a choice. There can be no neutrality in human praxis, and so education is either for domestication or for liberation. If it is for liberation then the very methods and techniques in use for domestication must be
Remarks about the political nature of Freire’s pedagogy and the use of words such as domestication and liberation or, on the other hand, liberalization and anarchy have been a dividing line between acolytes and anti-Freireans. Seen from the outside, such a quarrel seems familiar; it resembles the disputes between left- and right-wing politicians. From inside, one sometimes has the impression that neither party has fully grasped the potential of Freire’s ideas. But nowadays we are constantly hearing the argument that it is necessary to give voice to ethnic and social minorities, to the dispossessed, to the physically impaired, to the less able, and so on. These concerns are now commonly referred to by the term ‘political correctness’. The use of this term highlights the fact that political preoccupations do not only concern political beliefs or ideology. In the times that we live in, it is particularly important to review Freire’s message about the political nature of education. By doing so, we can be made aware how much potential his proposals in fact have.

There is, indeed, a renewed interest in the ideas of Freire, which are now usually considered apart from their application to adult literacy. It is possible, for instance, to find works where scholars adopt a Freirean perspective and focus on the new social movements (peace, environment, ecology, women’s rights, social justice, rights of the disabled, of prisoners and so on) (Findlay, 1994). However, this will not stop people from saying that this is just an afterthought; that Freire - as Marxist and radical Catholic - is simply promoting socialist, Christian or any other ideology. Without denying that propositions of this kind are provocative, or even that Freire is indeed a ‘revolutionary Christian’, I would still argue that Freire’s words should not be dismissed on the basis of their being directed solely towards the liberation of oppressed masses in Third World countries of undemocratic regimes.

The concept of ‘oppressed’ - as our politically correct times urge us to acknowledge - is elastic. Therefore, Freire’s *Pedagogy of the Oppressed* (1972) is, today more than ever, open to review and likely to encompass a much broader range of contexts than the ‘niche’ of adult literacy education. This will be noticed in publications which extend his thinking to contexts distinct from illiteracy and which are not easily characterized as ‘niches’ (See McLaren et al, 1993, McLaren et al, 1994). Indeed, this extension of his work now covers a range of issues as wide as Indian and refugee education (Gaudiano et al, 1994); community worker training (Hope et al, 1984); mathematics education (Frankenstein, 1983; Gerdes,
1985; D’Ambrosio, 1985, 1990; Frankenstein et al, 1994); science museums conceptualization (Scheiner, 1991); theology (Cooper, 1995); scenic arts (Boal, 1980; 1990) etc.

Although this is quite a catalogue of references from a variety of areas of study, it does not provide an evaluation of the significance of Freire's ideas to contemporary thinking, or at least to education. In fact, such an evaluation demands a re-examination of Freire's ideas which, in turn, certainly justifies a separate study. Indeed, this task is one undertaken by a number of authors (Beisiegel, 1982; Torres, 1993; Elias, 1994; Giroux et al, in press). Freire himself has recently published *Pedagogy of Hope* (Freire, 1992) which is a 're-encounter with the Pedagogy of the Oppressed'. This has recently been available in English, though only in the USA (Freire, 1994a). Nonetheless, here in Britain, Taylor (1993) has published a book worth noting. First because it provides a biographical sketch of Freire's life, an account of the context within which he worked and a review of the texts which he has produced, in particular *Education: the practice of freedom* (1974) and *Pedagogy of the Oppressed*, Freire's first two books. Secondly, it elaborates criticisms of Freire. Before discussing those criticism, however, I want to highlight the contexts which have led Freire to gain international prestige and become "a myth in his own lifetime" (Further, 1985, p. 301).

Three experiences have been noted as particularly influential on Freire's conceptualization of the pedagogic process (Beisiegel, 1982; Taylor, 1993): (a) the influence of his first wife, Elza - herself an elementary teacher and practising Catholic; (b) his involvement in *Comunidades Eclesiais de Base* (Basic Church Communities) - one of the cradles of what became known as Liberation Theology (Boff, 1986, 1988; Câmara, 1969); (c) his job as co-ordinator of a programme concerned with education at SESI (Social Service for Industry). Other aspects of Freire's life that have also been influential to his work include the fact that he lived in North-East Brazil - one of the most backward areas of the country, marked by truly appalling social conditions (Castro, 1952) - and that, being the son of a civil servant father, he had an urban middle-class education, becoming a lawyer, only to learn that that was not to be his true vocation.

It was those experiences that led Freire to work as an educationist with labourers, peasants and fishermen. This work, in the late fifties and early sixties, was brought to the attention of the nation's government. Despite the burden which illiteracy represented for the country, the solution offered by Freire posed a threat to the conservative, mainly rural, elites of Brazil. His 'method' proved to be too efficient...
and, to a great extent, revealing of injustices. In a word, it was a method for combating illiteracy which threatened the interests of those whose power or wealth depended on the ignorance of the people. Its implementation by the government of the time was the final act to upset the already enraged the military, the Brazilian ruling classes and the 'owners of the world' from the North (Freire, 1992, p. 243). Through a coup d'état the government was taken over by these forces on March 31st, 1964 (see Skidmore, 1967). Freire naturally became persona non grata and had to flee, to live in exile for over fifteen years. He was then 43 year old.

Freire has always been determined not to teach literacy in a perfunctory way. He has too much sympathy with his students for that. These are adult workers and Freire cannot conceive of teaching them like children. He contends that the use of children's reading 'primers' with adults relies upon them "donating to the illiterate words and sentences which really should result from [the illiterate's] own creative effort" (Freire, 1974, p. 49). Freire is conscious of the frustration experienced by adults learning to read from primers prepared as if they were aimed to teach children to read and write. Such books are invariably based on repetition of sounds; their authors choose the words for reading exercises regardless of the relevance of these words to readers. Inevitably, adults being taught with such primers read phrases like 'Grace saw the grape'. As Freire notes, "it requires patience indeed, after the hardships of a day's work (or a day without work), to tolerate lessons talking of Graces and grapes if you never knew a Grace and never ate a grape" (idem, p. 43).

The second reason to avoid teach literacy perfunctorily is important for my present argument. Freire, empathising with peasants and other workers, understood that they see reading and writing as both useless in view of their lifestyle and beyond them, their brains - so they say of themselves - not being forged for such activities. He therefore introduces a discussion of the concept of culture before the first literacy lesson - or Culture Circle, as he calls it instead. The effect of this discussion on students is noteworthy. They begin to value literacy. They realize it is an important tool, and not only to read what has been written by the literate. They begin to consider literacy as important to express their construction of the world, to express their own culture. They realize that by writing about their experiences - as well as reading what others wrote about theirs - they can enhance their perception of the world.

So, when it comes to noting the association of written codes with objects - objects to which people refer in speech - the process is no longer mechanical. The
semiological essence of it, which is now understood, allows those peasants to relish associating syllables to sounds they produce when speaking the words now seen in writing. The next step, which is to write syllables to represent those sounds they want to utter, is now one they are aching to take. The result, as one can imagine, is more than mastering the skill of putting pen to paper, the aim of conventional literacy programmes. Freire's students feel enlightened by the process. The various metaphors they have used to refer to their experience of it are the best expression of the distinctiveness of Freire's approach. These people show that suddenly a kind of veil that usually wraps one's mind, falls away and one becomes able to see much more clearly the way things work. Naturally, among these things are the social injustices of which that sort of people are the victim; hence the threat of such a literacy programme. Reactions such as that in Brazil in 1964, and in so many other countries where Pedagogy of the Oppressed was banned or boycotted, come as no surprise.

Whether Freire was the purveyor of literacy or the politician of pre-literacy, as Taylor (1993) contends, is an issue which might be absorbing for some of Freire's critics. I am not, however, going to concern myself with it. In any case, Beisiegel (1982) and Ana Maria Araujo Freire (after Freire, 1992, note 46, pp. 239-41) give evidence that the educational aim of Freire in the years that preceded his exile was primarily to enable those adults to read and write. Whether it was due to his success in achieving that, or to his co-ordination of a national literacy campaign which was cut short before it failed (Freire, 1995b, pp. 65-7), or indeed to a combination of both, as Freire was exiled he had chance to elaborate on his practice. The books that came out of this reflection, as well as the opportunities to work as visiting Professor at the Center for Studies in Education and Development, Harvard University (see Freire, 1970a; 1970b), and at the World Council of Churches, Geneva, made him, his practice, his ideals and educational ideas known worldwide. As Freire himself declares:

I write about what I do. In other words, my books are as if they were theoretical reports of my practice. In the case of Pedagogy of the Oppressed, I started to write it exactly when I left Brazil and went into exile. From afar I began to take stock of Brazil and therefore to take stock of and analyse my earlier practice, discovering in it things that the new context of borrowed reality was making me discover. So there was a moment, naturally, when I began to arrive at a more radical understanding of my own work. Pedagogy of the Oppressed appeared as a practical, theoretical necessity in my professional career (Torres et al, 1994, pp. 102-3).
In short, some features of his work were emphasized - if not actually perceived - during the process of writing those theoretical reports of practice. This might fuel the several debates about Freire and his work: the extent to which he is an educator (Freire, 1992, p. 9); whether or not he is a Marxist (Mackie, 1980); the extent to which his pedagogy is full of contradiction (Taylor, 1993, p. 147). It might even serve those who maintain that teachers reflect on practice, as opposed to in practice, in order to argue their thesis. The fact of the matter is that these debates are still heated a quarter of a century after *Pedagogy of the Oppressed* first appeared. This book has been translated into more than eighteen languages (according to the 1990 reprint of it by Penguin Books) including English, German, Italian, Spanish, Korean, Japanese and French, and has run to more than thirty-five reprints in Spanish, nineteen in Portuguese, and twelve in English (Torres et al, 1994, p. 100). Moreover, Freire is a member of UNESCO's International Jury, having received the 1987 Peace Prize from this organization. He has also received honorary degrees from seventeen universities around the world, as well as awards and other prizes for his work (Freire, 1995a, b). All this work has revolved around the teaching of reading and writing to adult illiterate workers; of a process which became known as 'Metodo Paulo Freire' and which I will now proceed to describe.

B. THE 'METODO PAULO FREIRE'

As I have said, it was through a programme for teaching reading and writing to adults that Freire produced alternatives to the common narrative forms of education, as Connolly (1980, p. 70) says, or ‘transmission forms’, as I prefer instead. In this present study, concepts elaborated by Freire are transposed to the context of teacher education. With a view to discussing this transposition, a description of Freire’s method is necessary as an ‘advanced organiser’ of Freirean concepts. This section focuses on his method and sets the scene for the discussion of key concepts transposed from Freire’s works to this study.

The feature of Freire’s method which certainly makes it stand as a distinct kind of education is its emphasis on dialogue. Such a method is the antithesis of transmission conceptions of teaching. The best expression of this difference is Freire’s usage of the metaphor ‘Banking Education’ which depicts the transferss of knowledge to students as deposits into their heads. Freire proposes that the educator should enter into dialogue with the illiterate about concrete situations and offer him the instruments with which he can teach himself to read and write (Freire, 1974, p. 48). Therefore, Freire’s ‘dialogue about concrete situations’, especially when propounded as providing instruments for the ‘student’ to learn,
does not seem different from a 'child-centred' approach to teaching. Such a resemblance makes Freire's concept of dialogue rather more difficult to take in. However straightforward the relationship might seem, Freire is not propounding a learner-centred approach to adult literacy. He does propose that the learners' voices must be heard, as I will explain, but that is not the end of the story; indeed, it is not the end of the story for proponents of constructivist teaching either. For one to grasp Freire's concept of dialogue, and by extension that of dialogical education, therefore, his attitude needs to be clarified. In one of the books where Freire discusses his ideas and experiences with someone, he was confronted with this mistaken view that his ideas are not different from those of child-centred teaching (Shor et al, 1987, p. 171). Reaffirming that he views his dialogical 'teaching method' as part of a liberation pedagogy, Freire contrasted his conception of education with one of laissez-faire. If the following passage does not clarify the difference in question, then at least it points at a tension within Freire's proposal which should not go unnoticed.

the liberating educator can never manipulate the students and cannot leave the students alone, either. The opposite of manipulation is not laissez-faire, not denying the teacher's directive responsibility for education. The liberating teacher assumes a directive role necessary for educating. That directiveness is not a commanding position but is a posture of directing a serious study of some object in which students reflect on the intimacy of how an object exists. I call this position a radical democratic one because it attempts directiveness and freedom at the same time, without authoritarianism by the teacher and without license by the students (Shor et al, 1987, pp. 171-2).

Directiveness and freedom seem aims difficult to reconcile and I will discuss the way Freire deals with the tension this involves when I analyse his principle of dialogicity (section C ahead). In view of the difficulty of the theme, it is propitious that Freire provides an example of an application of this principle in practice. In his first books, Education the Practice of Freedom and Pedagogy of the Oppressed (written in this order but published in English, respectively in 1974 and 1972), Freire describes how he addressed the teaching of reading and writing to labourers, peasants and fishermen in Brazil. What then became known as 'Metodo Paulo Freire' is this sequence of steps for that pedagogic practice:

**Phase 1** Research of the vocabulary of the groups with which one is working.

**Phase 2** Selection of the generative words from the vocabulary which was studied.
Phase 3 Creation of the "codifications": the representation of typical existential situation.

Phase 4 Elaboration of agendas, which should serve as mere aids to the co-ordinators, never as a rigid schedules to be obeyed.

Phase 5 Preparation of cards with the breakdown of the phonemic families which correspond to the generative words (Freire, 1974, pp. 49-52).

Phase 1 of this sequence postulates that the exercise of education as the practice of freedom begins with the investigation of people's 'thematic universe'. As Freire proposes, in researching the vocabulary of a group, one selects not only the words most weighted with existential meaning (and thus the greatest emotional content), but also typical sayings, as well as words and expressions linked to the experience of the groups in which the researcher participates (Freire, 1974, p. 49). This 'Thematic Investigation' is aimed at defining the content of dialogues for the promotion of reading and writing. But it is also carried out with the purpose of liberation; liberation from ignorance and the oppression associated with it. Therefore, the importance for the teacher of identifying what constitutes 'limit-situations' for the learners lies in the fact that these situations tell the teacher about the relative emotional and existential weight particular words have for the learners. Chapter 3, part II, section B, 'The Focus of Interest', discusses how this feature may be transferred to teacher education, and therefore how be useful in this study.

In its second phase, this insight gained into the various weights which mark the learners' vocabulary combines with parameters from theories in the domain of communication for the teacher to elect words which are most likely to be generative of meaningful reflection. It is in this phase that the generative words to be used in the programme should emerge. However, teachers are not meant to draw on their personal inspiration to obtain such words, no matter how proficiently they might construct a list of them. The words ought to emerge from the learners' vocabulary elicited in the field study (Freire, 1974, p. 49). Having come to the surface, though, such words do need to be selected and organized. For this to be done, a well defined set of criteria must be adopted by teachers. According to Freire, three sets of criteria respond to this need. They are phonemic richness; phonetic difficulty; and pragmatic tone. As Freire points out, Maciel (1963) has shown that these criteria stem from semiology or, as some circles prefer to call it, semiotics; the general science of all systems of signs through which communication can be established between human beings (Barthes, 1967; Eco, 1976).
the best generative word is that which combines the greatest possible ‘percentage’ of the following criteria: syntactic (phonemic richness, degree of complex phonetic difficulty, ‘manipulability’ of the group of signs, the syllables, etc); semantic (greater or lesser ‘intensity’ of the link between the word and the thing it designates), the greater or lesser adjustment between the word and the thing designated; and pragmatic, the greater or lesser tenor of conscientização which the word potentially carries, or the grouping of socio-cultural reactions which the word generates in the person or group using it (my translation from original, Freire, 1967, p. 114).

In phase 3, once teachers have become acquainted with students’ reality and have analysed this reality according to their own criteria, they now move on to choose the best representation of that reality. In fact, what they have done is to ‘de-code’ that reality, finding there what may constitute fundamental themes associated with such reality. At this point, it is necessary for teachers to re-present these themes codified to the students; teachers will undoubtedly do this according to the theories in which they believe and the experience that they possess. When the students receive this from the teacher, they first feel at home and then, as the teacher problematizes that which was once just given reality, they feel challenged.

These representations function as challenges, as coded situation-problems containing elements to be decoded by the groups with the collaboration of the co-ordinator. Discussion of these codifications will lead the groups toward a more critical consciousness at the same time that they begin to learn to read and write. The codifications represent familiar local situations - which, however, open perspectives for the analysis of regional and national problems. The generative words are set into the codifications, graduated according to their phonetic difficulty. One generative word may embody the entire situation, or it may refer to only one of the elements of the situation (Freire, 1974, pp. 51-2).

In chapter 3, part II, section D, ‘The Analysis’, the parallel to phases 2 and 3 in this study is discussed as the analysis of teachers’ discourse is designed.

The principle that guides phase 4 is that of using the practical and theoretical knowledge one expects students to learn, in order to code students’ own actions and understandings. This phase involves a process in which a particular strategy is used to link the various themes. Through the whole exercise, one must pose the existential, concrete, present situation people are living back to them as a problem. This challenges the learners because the programme co-ordinator requires a
response from them - "not just at the intellectual level, but at the level of action", as Freire explains (1972, p. 85).

A picture of the codified situation, for instance on a transparency or photographic slide, is projected with the generative word which represents it. The co-ordinator only calls attention to the word when the group, with his/her collaboration, has exhausted the analysis (decoding) of the situation. The word is then presented alone and after that separated into syllables. Portuguese is a syllabic language; people who speak it learn to read and write by being presented with its basic phonemes. This process could follow - as is usually the case - the pattern of 'primers' for children: with phonemes being presented one at a time, probably following the alphabet. The lesson about 'Grace' and the 'grapes', mentioned earlier, is an example of this. Freire, in his approach, chooses rather to use to dialogue. The practical effect of this is that his teaching method of reading and writing, though apparently trivial, proves to be quite revolutionary.

Freire retains the splitting up of words from Portuguese into syllables, or rather phonemes. However, he does not introduce the words according to an alphabetic order of syllables. Adopting semiological criteria (as mentioned in phase 2), he organizes the way generative words are presented. Freire himself does not claim to have deliberately searched for such backing from semiology. In very much his own style, he says that he tries to find words "whose syllabic elements offer, through re-combination, the creation of new words" (Freire, 1974, p. 49); hence calling them 'generative'.

Teaching men how to read and write a syllabic language like Portuguese means showing them how to grasp critically the way its words are formed, so that they themselves can carry out the creative play of combinations (Freire, 1974, p. 49).

So, once recognized, the syllables are isolated; their phonemic families visually presented, first in isolation and then together, to arrive at the recognition of the vowels.

The card presenting the phonemic families has been called the 'discovery card'. Using this card to reach a synthesis, people discover the mechanism of word formation through phonemic combinations in a syllabic language like Portuguese. By appropriating this mechanism critically (not learning it by rote), they themselves can begin, with surprising ease, to create words with the phonemic combinations offered by the breakdown of a trisyllabic word, on the first day of the program (Freire, 1974, p. 53).
This method of giving literacy to adults is, in the words of the author, an "instrument of the learner as well as of the educator" (Freire, 1974, p. 48). It certainly represents an alternative to 'domestication' or 'cultural invasion', but, as may be seen, it cannot be confused with an attitude in which the responsibility for directing the educational process is not assumed by the educator. This practice of Freire's identifies the interests of the students, but does so with the clear intention of challenging these. The purpose of this is to get students to reflect on rules that would otherwise go unnoticed, or else would be learnt by rote but have their importance virtually disregarded. Later, when analysing Freire's principle of dialogicity (section C), I will discuss the way he deals with the tension between directing the educational process and respecting students.

1. Analysis of the Dialectic Nature of the 'Metodo Paulo Freire'

Providing such a brief presentation of Freire's 'method' I run the risk of underrating his work. I therefore want to comment on a contemporary critique of it and thus avoid that risk. I will also take this opportunity to further examine Freire's ideas and evaluate their significance from points of view distinct from those already expressed.

In a serious analysis of the 'Metodo Paulo Freire', Taylor (1993) pointed out some contradictions in it. Some of Taylor's points are relevant, but, as I will argue, they are not all consistent with what Freire has proposed himself. Taylor provides a '(re)introduction to Freire' to claim that the 'Metodo Paulo Freire' is a radical reinvention of classical pedagogy. Taylor argues that Freire loves his classroom, that for him, the learner is not just someone who needs to learn: he or she is also someone who needs to be taught. So Taylor claims that Freire looks for "an enlightened learner who could 'name his or her own world' through dialogue with an enlightened teacher" (Taylor, 1993, p. 148). In that sense, according to Taylor, a contradiction within Freire's literacy method is evident. Taylor summarizes it thus:

Freire has codified the oppressed culture of the learners, but he seems never to have codified the oppressive culture of the literate educators, except through the one important image of Banking Education. If the reciprocity of dialogue is to be respected, should there not have been some opportunity for the participants of the Culture Circle to ask that the educators reveal a picture-codification which is typical of their lives and culture and that they declare what generative words they use to decode their world? (Taylor, 1993, p. 148).

The absence of such equilibrating disclosure, according to Taylor, shows that the
rhetoric which announced the importance of dialogue, engagement, and equality, "did not match in practice the subliminal messages and modes of a Banking System of education" (Taylor, 1993, p. 148). Taylor’s conclusion is that Freire’s approach does not differ in kind from a Banking System. It is unfortunate that this view might be the result of a flawed translation of Freire’s text. This certainly will not make the debate of Taylor’s opinion conclusive. Taylor has drawn on a wide and diverse range of sources to write his book. Presumably, therefore, his criticism is not grounded only on this flawed translation.

By saying that participants in the Culture Circle do not have an opportunity to contemplate the culture of the literate educators, Taylor seems to have overlooked Freire’s suggested criteria for the selection of generative words and for their later organization. Phase 2 of Freire’s ‘method’ describes precisely the use of semiology to that end. Being the general science of all systems of signs through which communication can be established between human beings, semiology seems to correspond to the description: codification of the culture of the literate educators. As sub-areas of semiology, syntactics, semantics and pragmatics provide explanations, rules and images which help us to understand how we, the literate, ‘code’ the world. Such sub-areas of semiology explain how words are formed and how they evolve; how very different are the functions of words in the phrases we form with them; they also explain our conventions in the use of words and phrases. Complex though semiology can be, this seems to be as good a picture of our literate culture as one can hope to obtain.

As I have said, one possible reason for Taylor not seeing in Freire’s proposals any codification of the culture of the literate is the flawed translation of this passage, already quoted above (page 59):

the best generative word is that which combines... the following criteria: syntactic... semantic... the greater or lesser adjustment between the word and the thing designated; and pragmatic criteria, the greater or lesser tenor of conscientização which the word potentially carries... (my translation from original in Portuguese, Freire, 1967, p. 114).

Taylor used the translation below. In it the translator seems to have interpreted the word ‘pragmatico’ as the adjective ‘pragmatic’, referring to the practical, rather than theoretical, way of dealing with things. The passage in fact makes reference to the area of linguistics known as ‘pragmatics’. This is the discipline whose object of investigation is the meanings that people receiving a message attribute to the signs
it contains; thus, the study or analysis of linguistic signs as they relate to the human user and his behaviour \((\text{Oxford Dictionary})\). As it can be seen by comparing the passages I have underscored, this meaning is not imparted by the translation to which Taylor had access.

The best generative word is that which combines... the syntactic criteria... the semantic criteria... the greater or lesser correspondence between the word and the pragmatic thing designated, the greater or lesser quality of conscientização which the word potentially carries... (Freire, 1974, p. 51).

As I noted above, such inaccuracy in the translation of Freire should not be overrated. First, because Taylor had access to many other texts of Freire and related sources. Second, because immediately before this passage, Freire makes reference to his own criteria for choosing generative themes. In the passage quoted above, Freire makes reference to Maciel's (1963) reflections about his (Freire's) own criteria. But before that, Freire states his criteria and includes: pragmatic tone, which implies a greater engagement of a word in a given social, cultural and political reality (Freire, 1974, p. 51). This should leave no doubt about the use Freire makes of the word 'pragmatic' and, by extension, about the importance of semiology for him. Taylor, however, does not seem to acknowledge this fact.

This attitude of Taylor's seems to stem from his thesis that Freire is a politician of pre-literacy rather than a purveyor of literacy (Taylor, 1993, p. 149). Such criticism is demonstrated in the passage where he expresses concern about a lack of symmetry in Freire's proposal for codification of cultures and the suggestion that there should be a 'picture-codification' of what is typical in the lives and culture of literate educators. Taylor clearly refers in this passage to those pictures on transparencies Freire used in his first encounter with his 'students' in the Culture Circles (Freire, 1974, pp. 61-81). As I have said, to avoid teaching literacy perfunctorily, Freire introduces a discussion about the concept of culture before the first literacy lesson. The set of pictures Freire used for this purpose can indeed be considered as a pre-literacy scheme. Although somewhat strategic for the achievement of students' conscientização, this scheme aims to 'whet the appetite' for the actual study of reading and writing. As already seen, for peasants and other labourers literacy can be construed as useless and beyond them. It seems, however, a gross misunderstanding of this proposal, to attribute less importance to the literacy programme itself. To judge from the attention Taylor has given in his book to the initial pictures, compared with the attention given to the actual literacy process, he seem to have failed to understand the whole of Freire's literacy programme - let alone Freire's attention to pragmatics; or, indeed, his use of
In his analysis of the 'Metodo Paulo Freire', Taylor draws parallels between this and Look and Say literacy programmes. Criticizing Freire's available lists of generative words as consisting only of nouns, Taylor argues that the lists in Look and Say literacy programmes are more adequate than those of Freire. This present study is not about adult literacy, nor about semiology or any of its sub-areas. It so happens, though, that Taylor is in fact using a syntactic criterion to criticize Freire. Restricting lists to nouns, as in the examples Taylor has of Freire’s lists, or including verbs, prepositions or adjectives, is a decision to be made by the co-ordinator of the Culture Circle. If this person agrees with Taylor that syntactic criteria should take precedence over semantic or pragmatic criteria, then the lists would have to contain different classes of words. This would not, however, contradict Freire’s own propositions. Taylor might have found examples of misuse of Freire’s criteria but certainly not have actually contested the validity of them, or their use.

To sum up, if Taylor’s attempt to contradict Freire are to contribute to a more critical reading of the proposals of the Brazilian educationist, it is mainly for one reason. Taylor has drawn attention to the fact that Freire’s reference to syntactics and semantics is not clear. Freire does see these sub-areas of semiology, together with pragmatics, as sound criteria for choosing generative words for his literacy programme. In that sense, these disciplines together constitute a representation of the literate culture of which the literacy programme co-ordinator is a representative.

Taylor suggests, quite rightly, that the codification of the literate culture would provide an equilibrating disclosure for an educational programme which propounds the importance of dialogue, engagement and equality. This is a suggestion which meets the plea for cultural contact made by Freire and his followers, myself included. The following passage, for instance, reinforces the importance of representing the literate culture for the accomplishment of a dialogical education. Here, however, the plea for cultural contact is much clearer when the need to escape the opposition oppressor/oppressed is pointed out.

Dialogue is a relational stance that necessarily challenges current post-modern practices of substituting concrete and lived discourses of cultural contact with simulacra and pastiche. If 'liberating' or 'critical' pedagogy is directed only to the oppressed, cultivating only the importance of knowing the logic and culture of the dispossessed and marginalized, it implicitly puts the educator in the
position of the dominator. Consequently, it does not escape the Cartesian rationality of merely reversing the binary opposition of colonizer/colonized. For this reason we insist that it is as necessary to know and understand the culture of the dominator and the social relations and material relations which inform it as it is to know and understand the culture of the dominated. We see, then, a need for a dialogic education not only among the ‘oppressed’ but among and between classes, groups, and nations of oppressed and oppressors alike (Gaudiano et al, 1994, p. 137).

This call for dialogical education prepares the ground for the next section, where I unravel those Freirean concepts pivotal to my use of his philosophy of education. There, I start this unravelling precisely with Freire’s very notion of dialogue. However, this is a good opportunity for me to highlight the fact that my concern, in this study, is the same as scholars like Gaudiano and de Alba quoted above. In times of political correctness, like our own, it becomes clear how elastic the concept of ‘oppressed’ can be. Transposing Freire to areas of education distinct from adult literacy, to different forms of social interaction, and, more importantly, to both First and Third World contexts, we are making an effort to free ourselves from our own cultural prejudices, while also trying to avoid falling into the trap of fanaticism, or that of promoting polemics rather than engaging in dialogue.

I believe that to free ourselves from prejudices, it is as necessary to know and understand our own culture (including the social and material relations which inform it), as it is to know and understand the culture of those dominated by us. For that reason, in my MPhil (Vaz, 1989), I restricted myself to the study of physics teaching projects and other efforts to contribute to school teaching made by the science education community. When I transpose Freire’s ideas to teacher education, I am therefore concerned to represent the culture I inherit from this community. In order to do this I have used a heuristic model I devised a few years ago. This model, which I call the Tetrahedron of Principles, will be described when I discuss the way the data analysis was planned in the design of the investigation conducted in the present study (chapter 3, part II, subsection D.5). As stated in the previous chapter, I am not undertaking an interpretive study of teachers’ implicit theories, life history or even action research, for it seems these would not allow me to know much more than the logic and culture of practising teachers. My concern was to study the praxis and related reflection of these teachers with reference to my own culture. I did this expecting that at a later date I could challenge practising teachers to make sense of the cultural capital of the science education research community.
C. Freirean Paradigm

Once the method that represents Freire's practice has been presented, the content of his own 'theoretical reports' of it can be now introduced. The ideas underlying Freire's practice are organised in this section in the following manner. The ideological and philosophical framework within which Freire works is introduced in the section entitled 'Radicality and Democracy'. In 'Dialogicity', a summary view of Freire's main ideas is given and some implications for teacher education and research on teacher thinking are discussed. The argument for dialogue, which for me is Freire's chief contribution to the educational debate, is especially highlighted.

1. Radicality and Democracy

I am convinced that we have never needed radical positions, in the sense which I understand radicality in the Pedagogy of the Oppressed, as much as nowadays. For us to transcend, on the one hand, sectarianisms based on unique and universal truths; on the other, the 'pragmatic' adaptation to the facts, as if they had become unchangeable - so much to the taste of modern, the former, and modernistic positions, the latter - we have to be post-modernistically radical and utopian. In a word, progressive (Freire, 1992, pp. 51-2).

By suggesting that directiveness and freedom should be reconciled, Freire is proposing the adoption of a radical-democratic stance in education. As Gaudiano and de Alba (1994, p. 137, quoted above) also contend, the pursuit of a democratic approach to education would not be genuinely democratic if educators, however well-meaning, were only concerned to listen to those being educated. Once they adopt a radical-democratic stance, educators will not only listen to learners, seeking to understand them, but will assume the responsibility for directing students to reflect on relevant issues. The tension embedded in such a proposition is clear: the fact that the teacher is directing makes the proposal seem rather 'directive'; on the other hand, the fact that the teacher is listening to learners does not seem to make the activity any more democratic than 'good teaching', where teachers customarily ask questions of students. In other words, there is a tension between this proposal 'not being different from a Banking System' and it being nothing more than a 'reinvention of classical pedagogy'. In that sense, the example Freire provides through his own pedagogic practice is insightful.

As we have seen, the radically democratic step taken by Freire was to question who decides what is relevant and why. There lies the political nature of education.
Someone has to decide the content of education and this decision ought to be based on some criteria. To say that these decisions can be based on 'neutral' criteria, let's say technical ones, is a deception. Underpinning 'technical' criteria is inevitably some form of ethics. Moral values, beliefs, principles and rules result from social, and therefore cultural, conventions and traditions. The content of education is thus decided by custom, necessity or ideology. Although this can be impossible to change, it does not necessarily need to go unnoticed. That is the attitude Freire proposes we review.

Whilst, traditionally, educatees are unaware that the content of their own education results from decisions of the kind mentioned, in a radical democratic approach this is made clear. Hence, the radical democratic educator, who still possesses a broader knowledge base, does not ignore the fact that he/she might not be able to comprehend the learners' knowledge and experience. In other words, the radical democratic educator listens to his or her educatees, first to learn what they know; second to learn things about those educatees and about their world that he/she could not learn by her/himself; and, third to find out what he/she her/himself does not know. Besides, adopting such a stance, the educator does not withdraw from speaking to her educatees. She does not withdraw from assuming a directive attitude, for instance to start a debate by induction. As Freire has said,

In fact, all education has an inductive starting point - directive - in which the educator as an individual person or as a collective - while a subject, while an collective intellectual - almost always takes the initiative of starting the process. [...] Both, the 'domesticating' and the 'liberating' educators, both start out inductively. My impression is that the greater dose of truth of the latter, in comparison with the former, overflows from the very critical understanding of reality and soaks itself in a deep belief on the educatee. These two educators will distance themselves from each other, will characterize themselves as completely different things, to the extent that the former never will overcome the moment of induction, he will, on the contrary, reaffirm it more and more. This is what leads him to domesticate. He will do his own reading of reality, always in his own way, and according to his interests. The latter, instead, will overcome the moment of induction, he will have to kill the induction and resurrect it as cooperation, as communion (Freire in Beisiegel, 1982, p. 285).

This shows why I have identified myself with Collaborative Researchers working with teachers' thoughts and actions. But it also explains why I still find I am able to
criticize some of them. When seen from a radical democratic stance, to co-operate (act together) and by extension to collaborate (work together) are actions which imply the achievement of difficult balances, as I explain shortly. In the case of education, as in the case of educational research, there are two parties, each with its own function in the common task of knowing more. As Freire frames these situations, the functions of each party might be different, but their aims should not be so. The preoccupation with both the process and the content of educational practice, as well as of research practice, stems from the subtleties of the matter. Let me leave for now the discussion of how I have conducted my research from such a stance and continue with an elaboration of Freire’s educational practice.

With regard to Freire’s literacy programme, his response to a preoccupation with content is observed in the procedure adopted to choose the words for the programme. This choice is not made by counting the words used most frequently by people, as Look and Say programmes (Otto et al, 1976) would do (see Taylor, 1993, p. 78). It is not made that way, because then it would not necessarily contain highly emotional or existential aspects of the lives of educatees. These aspects are important in a radical democratic approach to education. The importance is not that educatees would appreciate the care with which educators choose the programme content of education, although, of course, this is invaluable for a good relationship between them. Apart from this, it is important for other more radical reasons. First, it highlights the fact that an ideology is needed for such a choice to be made. The fact that in this case such an ideology is radical democratic is not concealed, but neither need it be depicted as superior. It is simply presented as the choice most appropriate according to the educators’ ideology. Second, when it contains words of highly emotional and existential significance for educatees, the fact that reading and writing is a personal - as well as social - act becomes clear. This, as I said earlier, is very motivating for educatees.

However, the most radical reason for Freire to proceed as he does to obtain a list of words is sometimes overlooked. By conducting his literacy programme the way he does, Freire responds to that other preoccupation mentioned above; that with the process of education. What one observes by focusing on this aspect of his practice is that Freire re-defines the roles of each party involved in the educational process. The educatees’ consciousness (on the first point above) and their motivation (on the second) are likely to enable them to contribute to the education of the educator. The educator's own comprehension of the process of learning to read and write is bound to be elaborated by the sophistication of the educatees’s
participation in it. Indeed, the educator's grasp of the criteria he/she applied when choosing the list of words in the first place, can be enhanced. This can happen for the simple reason that the educator's interpretation of canons of syntactics, semantics and pragmatics may be challenged by the personal knowledge, as well as practical experience, of educatees. But it might well be due to that practical knowledge challenging the theoretical propositions themselves, as opposed to the educator's interpretation of them. There is no reason for students' ideas or experiences not to undermine the very theories of an established discipline or area of knowledge. Hence, the attitude of attempting to listen to the students, to respect their common sense, is adopted for a radically distinct reason: the acknowledgement that the systematized knowledge the educator is there to present - of which he/she is a representative - has limitations.

Possibly, it was the conviviality always respectful that I had with "common sense" - in addition to the certainty that its transcendence depends of it being acknowledged - that has made me never dismiss or simply diminish it. If it is not possible for one to argue for an educational practice that is contented in moving around "common sense", it is also not possible to accept an educational practice which, nullifying the "made knowledge of experience", start from the systematized knowledge of the educator (Freire, 1992, pp. 58-9).

Whilst this challenge to the establishment and its canons might not sound very likely while peasants learn to read and write, by conducting this study I am implicitly arguing that it is likely that, say, primary teachers, when meeting science education experts in order to 'learn' to teach science, can challenge the dominant conception of science education. This, I presume, could happen in encounters between a science teacher educator and any practising teacher of science, at least if a radical democratic approach to science teacher education was adopted. As in the case of Freire, I contend that what results from such radical democratic experiences are 'untested feasibilities' for what otherwise would be virtually insoluble problems.

Thus, considering the adoption of a radical democratic stance for the study of teachers' thoughts and actions involves returning to a point I made earlier: Freire's ideas and proposals are similar to those of Habermas. The critical social science proposed by the latter also focuses on interests and sees conflict and tension rather than consensus as a central feature of social life. Both authors maintain that the identification of conflicting interests is more revealing than approaches traditionally adopted in each one's field of work. Both base their arguments on a view of theory and practice which synthesizes these. Both have turned their
attention to language, arguing that this is central for the achievement of consciousness. And both put forward radical and utopian proposals for action, again, each one in his own field of work. To draw comparisons between liberation pedagogy and critical social science, or trace back the roots of similarities between them, is yet another task I do not think could be appropriately undertaken within the scope of this study. I have made use of aspects of Habermas’s critical theory to review the literature of teacher thinking research, as I want to make use of Freire’s pedagogy, rather pragmatically. I accommodate both critical theory and liberation pedagogy in this study because there are similarities between them. Besides, evidence of common roots between them is provided by each one’s analysts and critics (Carr et al, 1986; Gibson, 1986; Matthews, 1980; Taylor, 1993). Some examples of these common roots are Humanism and Marxism - especially the Marx of the Paris Manuscripts and the Theses on Feuerbach.

In order not to lose sight of the purpose of this study, therefore, I shall not delve into Freire’s pedagogy more than necessary. I shall do so only to accomplish the aims previously set out; namely, to consider the possibility of a critical study of teachers’ thinking and action likely to serve the purpose of devising a dialogical, problematizing science teacher education programme. Similarly, I have not delved into critical theory - nor into the relationship between this and liberation pedagogy - I take a pragmatic stance concerning the latter. I am going to provide working definitions of concepts which are used or developed by Freire in his proposals and are key to my transposition of these proposals to the question of science teacher education. As working definitions, they should not be taken as good descriptions of the concepts; at least not as Freire himself conceives them. They represent a personal and functional interpretation of those concepts. But first it is necessary to discuss the principle from which Freire’s radical democratic stance is distilled: dialogicity.

2. Dialogicity

Dialogicity is the basic principle guiding the whole of Freire’s educational practice. So far, we have seen that Freire argues that education has a political nature. Therefore, ideology, interest and tradition are necessarily involved in the choice of an education programme content. The very methods and techniques employed to implement such content reflect particular ideologies. By developing the principle of dialogicity, therefore, Freire stresses that there are various possible modes of communication in education. Dialogicity, as a principle developed for a truly radical democratic conception of education, clearly proposes that such
communication must be based on dialogue. Freire, in his thoughts on this issue, suggests that we reflect on, say, the semiological nature of words, for these are the basic elements of verbal communication. The passage where these reflections appear is long. However, it conducts the discussion about dialogue very clearly, justifying an abridged transcription of Freire's own text:

As we analyze dialogue, we discover something which is the essence of dialogue itself: the word. Within the word we find two dimensions, reflection and action, in such radical interaction that if one is sacrificed - even in part - the other immediately suffers. There is no true word that is not at the same time a praxis.

When a word is deprived of its dimension of action, reflection automatically suffers as well; and word is changed into idle chatter, into verbalism, into an alienated and alienating "blah".

On the other hand, if action is emphasized exclusively, to the detriment of reflection, the word is converted into activism. The latter - action for action's sake - negates the true praxis and makes dialogue impossible. Either dichotomy, by creating unauthentic forms of existence, creates also unauthentic forms of thought, which reinforce the original dichotomy.

If it is by speaking their word that men transform the world, dialogue imposes itself as the way by which men achieve significance as men. Dialogue is thus an existential necessity. This dialogue cannot be reduced to the act of one person's 'depositing' ideas in another nor can it become a simple exchange of ideas to be 'consumed' by the discussants. Nor yet is it a hostile, polemical argument between men who are committed neither to the naming of the world, nor to the search for truth, but rather to the imposition of their own truth (Freire, 1972, pp. 75-7).

Dialogicity, therefore, contrasts itself with education by transmission. This, claiming neutrality and technical reasons for proceeding with transferrals of knowledge, promote domestication, conformity and dependence. In the transmission of knowledge, there may be communication but, when there is, it happens in only one direction: from the one who 'knows' to someone who does not know. The deficiency in that knowledge, experience or wisdom the 'one who knows' possesses - it is suggested - handicaps those 'who do not know'. The way knowledge of the formal disciplines being taught is valued in education by transmission turns the teacher into the subject of the act of teaching. The student, as he/she lacks that knowledge, is a mere object of that act. Freire maintains that education should consist in another form of communication, one in radical contrast with that described above.
Dialogue is an I-Thou relationship, and thus necessarily a relationship between two Subjects. Each time the 'thou' is changed into an object, an 'it', dialogue is subverted and education is changed to deformation (Freire, 1974, p. 52).

However, as will be discussed later, the proposition is not that dialogical education should aim at individual enlightenment. The argument is not that students are sources of wisdom, who will remain in darkness unless someone gives them the chance of discovering that wisdom. It is not by listening unreservedly to students that one will in fact enter into dialogue with them.

Education principled on dialogicity cannot be reduced to a mere teaching act or a simple learning experience. In a dialogical education, action and reflection are lived by both teacher and student while they make the joint effort to know one object, one aspect of the world, one portion of reality. One such process requires quite a change of attitude from the person who will, at the end of the day, make it happen: the teacher. Freire discussed this change in an interview with Beisiegel. From this interview, this author transcribed a long excerpt; it is from there that the words from Freire which I quote below were drawn. In this interview, Freire discusses the relationship between the conductive activity of the 'debate coordinator' with the conditions of existence of educatees. Justifying the transcription of the rather long passage of his conversation with Freire, Beisiegel says:

Freire's pedagogical practice became 'dialectic', that is, in this case, this practice began to find in the 'oppressed' the concept that this person had in him/herself of him/herself. Paulo Freire invented and put in practice procedures which to some extent forced this singular invasion of the very creature (Beisiegel, 1982, p. 284).

Freire, indeed, proposes an invasion of the individual. But that is not an ordinary, authoritarian kind of invasion. As Beisiegel noted, it is deeply dialectic. Freire departs from a strong opposition to non-directiveness. He argues that non-directiveness leads to spontaneism and guesswork. His concern is that teachers disrespect their students when they leave these to guess the concepts, the explanations, in short, the knowledge teachers already possess and want the students to acquire. Essentially what Freire argues is that the learning experience, as it takes place in education, should be a gnosiological experience rather than a psychological one. This argument, incidentally, is basically the same as that of Kelly (1963, p. 16), discussed in the next chapter. Here is how Freire has developed it:

In my understanding, education is above all a theory of knowledge in practice.
If that is what it is, it is not possible to admit any pedagogic situation which would not also be a gnosiologic situation. All them are. If it is a gnosiologic situation, it has a subject which knows an object that needs to be known. The question that is posed now is 'who knows?', and who knows is no longer only the educator. In the pedagogic situation the one who knows is the educator, but also the educatee. But knows what? There has to be an object that presents itself to both. If this object presents itself to one only, which is the educator, this object becomes a possession of the educator, and the educator's tendency is to do then precisely what is done nowadays: transfer knowledge (Freire in Beisiegel, 1982, pp. 284-5).

So, for Freire, first, the object that needs to be known should not be presented only to the teacher; second, provided the previous condition is satisfied, there is never only one educator in education; the student also educates the teacher. This form of dialectic dialogue is a difficult one to undertake. It implies finding a point of equilibrium between tensions of different kinds. Looking at the main ideas of Freire cited in this section, one notices that there are two distinct dimensions where these tensions can be located: the means of communication and the interlocutors involved in it. I believe a graphic diagram will make this proposition clearer. I make this representation allegoric, so that it also highlights the difficulty involved in trying to achieve the equilibrium aimed at by Freire.

Figure 3 represents communication in education as a surface, like that of a smooth rock whose shape resembles that of a pyramid, but here the sides are curved. The reason for the surface sides to be made curved is that the summit is supposed to be a point where it is possible to stand, unstable though the equilibrium there might be. The four faces of the pyramid are aligned with the two dimensions where tensions involved are located. There are two axes representing these dimensions; one for the means of communication and another for the interlocutors involved in it. Dialogicity is the principle which makes it possible for someone to promote education balanced on the summit; of course, the equilibrium will be obtained by the adoption of a radical democratic stance.

Basically, Freire's principle of
dialogicity says that, by adopting a radical democratic stance, one manages to balance the tensions of a dialogical process of education. As depicted in figure 3, there are four ways to slip off balance in such a process; the four sides of the pyramid. The effort to avoid one slope may lead one to fall down the slope opposite. In other words, with recourse to this allegory, we notice that it is possible to analyse the dangers of a process of communication by the pairs. There are two tensions involved in a dialogical education, those represented by the two perpendicular axes: communication and education.

Freire suggests that what tips the balance along the ‘communication’ axis, is the cornerstone of verbal communication: the word. This has to be present, but must be used sparingly. The teacher may silence himself/herself and put too great an emphasis on practice. That way he/she turns education into ‘activism’. Or, he/she can stress reflection, forget the reality and let ‘verbalism’ prevail.

Along the ‘education’ axis in figure 3, two are the dangers to be avoided. There are two parties of interlocutors involved in education: teacher and students. Their participation in this process has to be balanced. Both have to be equally active, but it is the teacher who holds the balance of their participation. Hence, if he/she turns too much to the side of the students, according to Freire the process falls onto ‘spontaneism’. If, instead, he/she directs too much, it falls onto ‘domestication’ or ‘indoctrination’.

Uneasiness, therefore, must be the main reason for the dialogicity principle not to be widely adopted twenty-five years on from the publication of Pedagogy of the Oppressed. It must be so, since Freire even provided the example of how to make a dialogical education possible. This is not usual practice, as has been acknowledged elsewhere:

Unlike many educationalists who construct an epistemology in vacuo and then propose it as a guide to teaching, Freire’s epistemology itself emerges out of the process of reflection upon his own experiences in knowledge transmission and acquisition (Matthews, 1980, p. 82).

His own example therefore gives encouragement for the difficult aim of finding the balance between all the tensions involved in a radical democratic approach to education, and by extension, to educational research. Looking more closely at ‘Metodo Paulo Freire’, we can now note that Freire based the teaching of reading and writing not only on the principle of dialogicity but also on what could be described as a technique. This is termed by him problematization. The next section
delves into this 'technique' and also discusses some of the concepts involved in its application.

D. PROBLEMATIZATION

The simple but fundamental technique of problematizing is the antithesis of Banking Education which seeks solutions or gives answers. It consists of daring to interrogate what is given, bringing into question known structures, and examining conventional or taken-for-granted ‘explanations’ of reality. It discovers and then reacts to possibility of ‘contradiction’, identifying ways in which things can be said, done, or exist differently (Taylor, 1993, p. 73).

According to Freire, for education to be dialogical (based on dialogue) as well as dialectic (taking into consideration tensions and contradictions), it ought to be problematizing. Problematization is the posing of problems by the teacher for the purpose of promoting dialogue with students. However, problematization is a very peculiar form of problem-posing. To problematize is not simply to ask questions. It does involve asking questions but in such a way that these questions allow the debate to acquire momentum, rather than leading it to a deadlock. This process is not aimed at simply satisfying the teacher’s curiosity, neither is it meant to be a sort of quiz game. When the dialogical teacher problematizes a situation or an issue for its discussion with students, he/she has to raise thought-provoking questions - questions which do not test students’ level of understanding and knowledge; which instead of defying, challenge them; which stimulate them to make use of their understanding and knowledge to face what they begin to regard as more than mere valid points; questions that are essentially provocative and captivating. As discussed earlier, one of the difficulties then is to avoid going down the road that leads to guesswork.

The idea of problematization being a technique that is imparted must, therefore, not be misinterpreted. Simple though it really is, problematization challenges the teacher to apply the difficult dialogicity principle, just discussed. Its challenge, in essence, lies in balancing all the tensions described in figure 3 (page 73): reflection versus action, on the one hand, teacher-centredness versus student-centredness, on the other. In that sense problematization requires a number of things from educators. First, to find out about the world, the reality of those to be educated, as they construe it themselves. Second, to frame these constructions with the analytical tools and theories she, the educator, has available and considers important for educatees to learn in order that they improve their own analyses and constructions; that is, in order that they know more. Third, to identify ways in

CHAPTER 2

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which things can be said, done, or exist differently in order to contradict the educatee’s taken-for-granted ‘explanations’ of reality. A good way to understand problematization is to consider it not as the posing of problems but as the countering of interpretations of given phenomena or propositions.

1. The Underlying Sociological Premises of Problematization

In truth, a correct interpretation of Freire’s problematizing educational practice requires the appreciation of underlying premises and assumptions for such practice; of the dialogicity principle guiding it; and of the ideological stance which underpins all these. Freire discusses the underlying sociological premises of problematization throughout his work. However, since Freire’s style of writing is not one of a conventional academic, his publications do not provide his readers with conventional pointers to his ideas or with inventories of his sources of intellectual influence. Since he writes about his own practical experience, Freire does not necessarily cite authors whose ideas relate to his own. Besides, given his Brazilian roots, Freire reserves the right to conduct a form of intellectual syncretism, combining apparently incompatible sources of inspiration. I do not reserve the same right for myself, but I acknowledge that an inventory of sources of influence to Freire’s work is beyond the scope of this study. Such intellectual genealogy has been traced by Beisiegel (1982) and Taylor (1993), among others, and I make no pretence that I could outshine the study of this issue by these authors. In addition, my review of Freire is more utilitarian and therefore less profound. Nevertheless, it is because I am not oblivious to Freire’s intellectual pedigree that I recognize the importance of at least mentioning some premises and assumptions which might help one to better understand the problematizing educational practice which has so much influenced this present work. Hence, in an effort not to digress too much from the main purpose of exposing those ideas of Freire that are crucial to my study, I will briefly discuss here Freire’s conception of history and culture and his ontology of human beings.

For Freire, a human being’s nature is historical.

Humans are beings who transcend themselves, who move forward and look ahead, for whom immobility represents a fatal threat, for whom looking at the past must only be a means of understanding more clearly what and who they are so that they can more wisely build the future (Freire, 1972, p. 72).

So, for Freire humans are beings aware of their incompletion whose ontological vocation is to be a Subject who acts upon and transforms his world, and in so doing
moves towards ever new possibilities of fuller and richer life individually and collectively (Shaull, 1972, p. 12). Human beings treat not only their actions but their very self as the object of their reflection (Freire, 1972, p. 87). For them the world constitutes a 'not-I', once they set themselves apart as an 'I'. Their world is historical and "serves as a mere prop for the 'being in itself'" (idem, p. 87). Human beings are challenged by the world; which is a configuration that confront them. They then, upon reflection and perceiving these challenges, must take risks. Human beings do not merely 'note' the signs which indicate such risks, they give "decision-making responses" to them (idem, p. 88).

Human beings, according to Freire, infuse the world with their creative presence by means of the transformation they effect upon it. Unlike animals, Freire says, human beings "not only live but exist"; here, the implication of 'live' is survival only and 'exist' is a deeper involvement in the process of 'becoming' (Freire, 1972, p. 88; Freire, 1974, p. 3). Hence an anthropological concept of culture; where a distinction is made between the world of nature and the world of culture (Freire, 1974, p. 46). Freire sees "culture as the addition made by men to a world they did not make; culture as the result of men's labour, of their efforts to create and re-create; culture as a systematic acquisition of human experience (but as creative assimilation, not as information-storing)" (idem, p. 46). It is animated by this anthropological concept of culture, and making reference to Marx (1964, p. 113), Freire asserts that human beings differ from animals whose "productive activity is subordinated to the satisfaction of a physical necessity which is simply stimulating, rather than challenging" (Freire, 1972, p. 90). And he continues: human production, which consists not only of tangible objects "but also social institutions, ideas and concepts" (idem, p. 91), might result from their activity and yet not belong to their physical body. When one's production has this attribute it gives "a dimension of meaning to the context, which thus become a world" (idem, p. 90). And those capable of such production are, according to Freire, necessarily aware of themselves.

2. Limit-Situation, Problematization and Conscientização

The sociological and anthropological premises discussed above give an idea of the context within which the process of conscientização operates. In proposing his radical form of democratization of knowledge, Freire first, ascribes transcendentental meaning to human relationships and, second, stresses the humanist dimension of culture (Freire, 1974, p. 46). Now is a good moment to lay out the dynamics of such a process. I start with a description of the stages of consciousness. From this, I explain the transitions from one stage of consciousness to the next.
The states of consciousness

Freire considers that men and women can be characterized by two states of consciousness. The first state he describes as 'semi-intransitive'. Freire suggests that people of semi-intransitive consciousness can only apprehend problems within their sphere of biological necessity, and are therefore impermeable to challenges outside this sphere. A sign that someone is in this state of consciousness is that the person confuses his/her perceptions of the objects and challenges of the environment. In this case the person is not able to apprehend causality (Freire, 1974, p. 17).

On the other hand, a person who is perceptive; who is able to interpret the causes of events and of behaviours; who responds to suggestions and questions arising in his/her context; who is capable of entering into dialogue with other people; this person, according to Freire, is in a 'transitive state of consciousness'. There are two stages of 'transitive consciousness', according to him. An initial stage of naive consciousness and an advanced stage of critical consciousness. As my purpose is to adopt Freire's theory in the realm of teacher education, let me describe the state of transitive consciousness and discuss the characteristics of teachers in both stages of it (Cf. Freire, 1974, p. 18). Teachers in the first stage would probably tend to:

* over-simplify problems;
* be nostalgic about the past;
* underestimate children;
* have a tendency to gregariousness;
* have little or no interest in investigation;
* give fanciful explanations for his/her own failures, as well as for the failures of pupils;
* show fragility in their arguments;
* have a strongly emotional style;
* practise polemics rather than dialogue.

In contrast the critically transitive consciousness of teachers would probably be characterized by (Cf. Freire, 1974, p. 18):

* depth in the interpretation of problems;
* the adoption of causal principles rather than magical explanations;
* the testing of their 'findings' and by openness to revision;
* the attempt to avoid distortion when perceiving problems and to avoid preconceived notions when analysing them;
* a refusal to transfer responsibility;
* rejection of passive positions;
* soundness of argumentation;
* the practice of dialogue rather than polemics;
* receptivity to the new for reasons beyond mere novelty, and the good sense not to reject the old, just because it is old.

In sum, conscientização is the process of evolution of consciousness from a semi-intransitive state to a transitive state, and then from the stage of naive transitivity to that of critical transitivity.

**Awareness and limit-situation**

Freire thus describes this evolution. In fact, besides describing it, he also explains what causes the process of conscientização and suggests ways to foster it. According to Freire, what sparks the process to start is the perception by the individual of an imbalance originating in some external nuisance. It is interesting to note, however, that Freire considers that the same original situation is perceived in different forms, according to what stage of consciousness the individual is in. Certain events or situations can catch individuals in such a way that they review their assumptions and beliefs, as well as their actions. Situations that are circumstantial and affect certain people at a particular historical moment are of particular importance. These, as Freire says,

> once perceived by men as fetters, as obstacles to their liberation, stand out in relief from the background, revealing their true nature as concrete historical dimensions of a given reality (Freire, 1972, p. 89).

When a situation gains historical dimensions, it becomes a limit-situation, which means it makes people feel they 'have their backs to the wall', on a particular geographical scale - local, regional, national, or even global. It is interesting to note that people perceive events as limit-situations depending on their stage of consciousness. I will give some examples to help explain this concept.

Let us take the issue of language usage. We live in times of non-discrimination and political-correctness. Depending on one's level of consciousness, language usage...
can be perceived (a) as a limit-situation, (b) as an obstacle to genuine egalitarianism, or (c) not be perceived as a problem at all.

Someone with a critical transitive consciousness appreciates that language usage is determined by social structures and social customs. However, this person may nevertheless refuse to acquiesce to demands for unconditional changes in the use of words. Such a person can do so, for instance, on the basis that by changing the form of discourse you do not guarantee a chance in the essence of it - people’s attitudes or ideas. On the other hand, someone with a naive transitive consciousness will probably adhere to slogans which promote unconditional condemnation of discriminatory language. In this case, the person may have one of at least two dispositions. First, the person may have little or no hope that people’s attitudes regarding this issue can ever change. Second, the person may envisage dramatic solutions, such as a review of the whole way language is used (vocabulary, grammar etc), and may propose the enforcement of these changes in schools, for instance. Finally, there are those who simply ignore such debate, people who probably are too concerned with their own daily activities, businesses and personal problems to worry about the language they use. These may be either people who toil away to make a modest living, or they may be people who are distant and detached from the affairs of ordinary life.

Challenges, problematization and conscientização

In order to illustrate this last point, it is interesting to note that Freire, once reacted as if his own speech was not discriminatory. That is how he responded when he first faced other people’s concern about gender biased language. Although concerned with all these issues of equality, cultural oppression and so on, Freire wrote his first books as grammar required: with masculine nouns, pronouns etc. In other words, he wrote without taking notice of the male-centrism of the prose. Soon after Pedagogy of the Oppressed was first published in (American) English (Freire, 1970), Freire received many letters pointing out the contradiction. At the time, he considered that such concern applied only to those North-American societies; that in Portuguese, masculine is not used in a discriminatory way and when one says ‘men’ one means ‘men and women’ (Freire, 1992, pp. 66-68). Freire’s own conscientização took place as he reflected on the truth of these latter assertions; and he only reflected on this issue as a result of the letters of complaint.

This story cogently illustrates the dynamics of conscientização. Moreover, it also introduces the concept of problematization. Freire, at one point, had a semi-
intransitive consciousness regarding issues of language usage. Maybe due to his
endeavours in promoting adult literacy on a national scale, maybe because he was
toiling away in exile, Freire was distant and detached from the affairs of ordinary
life. Only when he was challenged by North American women, was he led to reflect
on his language on a more historical plain and to apprehend the causality
underpinning Portuguese grammatical rules. As soon as he became open to the
challenges in question he reached a transitive consciousness. Once Freire had a
disposition towards dialogue and an openness to revision of his own attitudes, he
soon reached the stage of *critical transitiveness*. Nevertheless, Freire briefly showed
signs of naive-consciousness, when, for instance, he rejected the charges of bias
and male-centrism, over-simplifying the problem in question.

'Distance' as a key element of conscientização

The situation described clearly indicates that the process of *conscientização*
involves the awareness of two types of *distance*. First, the gap between discourse
and action, as illustrated by Freire's contradictory usage of discriminatory
language, for instance. Second, the gap between people, especially when they are
at different stages of consciousness. In the example above, as far as gender
discrimination was concerned, Freire's consciousness was not critical, and the
consciousness of his North-American female readers was.

I have focused the discussion of problematization on the interaction between
people, rather than on people themselves, precisely because the notion of
'distance' is central to the concept of *conscientização*. In the episode discussed,
Freire was not aware of the contradiction between his ideas and the form of the
very text that conveys these ideas. He became able to see that contradiction when
his attention was drawn to his own actions; when someone with a different level of
awareness tried to establish a dialogue with him. I return to this issue of 'distance'
in chapter 3, where I discuss it in relation to the present study and the question of
teacher professional development. However, I would like to underscore two
important points about the focus being on the interaction rather than on the
people who interact. First, I suggest that Freire and his interlocutors are at
different stages of consciousness; however, I do not discuss the reason for that.
Second, although I suggest Freire goes through transitions in stages of
consciousness, I do not explain why these transitions are such that he reaches a
more advanced stage of consciousness, rather than acting the other way round.
While not ignoring these aspects, I am not preoccupied with them; at least not in
terms of the actions of particular people and their corresponding causes.
The entire system created by the interaction between Freire and his female interlocutors can be understood in terms of the sociological premises discussed earlier (section D, heading 1). Freire and his readers differed in their awareness about the problems associated with language usage because of their cultural differences. As mentioned above, culture is conceived as a systematic and creative assimilation of personal and collective experiences (Freire, 1972, p. 46). Due to different experiential realities North American women had developed critical transitive consciousness, while Brazilian women still had not. By the same token, transitions of consciousness occur because human beings treat not only their actions but their very selves as objects of reflection (Freire, 1972, p. 87). And such transitions lead to an advanced stage of consciousness because, as discussed above, humans are beings who move forward and look ahead (Freire, 1972, p. 72).

3. Conscientização in Contrast with Enlightenment

In view of the premises on which Freire bases his practice, in addition to the principle of dialogicity and the radical-democratic stance he adopts, the aims of his pedagogy should not be confounded with those of some schools of thought. In particular, the assumption that conscientização entails the pedagogical practice Freire proposes needs to be understood. For this to happen, it is important to distinguish this practice from that of progressive schools of thought which see the autonomy of the individual student as a measure of democracy and empowerment.

There are progressive schools of educational thought which propose pedagogies where the teacher is ‘a resource-person’, ‘an accessible helper’ who untangles knots when students get lost; and where the students themselves establish their own learning contracts, being responsible enough to follow these and ask for help (Shor et al., 1987, p. 109). In sum, concerned with ‘self-directed learning’, they seek to promote ‘self-development’, ‘self-empowerment’. Their aim is that students should be able to organize themselves and become independent from teachers. This conception of democracy and empowerment is distinct from Freire’s:

When I am against authoritarian position, I am not trying to fall into a laissez-faire position. When I criticize manipulation, I do not want to fall into a false and nonexistent non-directivity of education. For me, education is always directive, always. The question is to know towards what and with whom is it directive. This is the question. I don’t believe in self-liberation. Liberation is a social act. Liberating education is a social process of illumination. There is no personal self-empowerment. Even when you individually feel yourself most free, if this feeling is not a social feeling, if you are not able to use your recent...
freedom to help others to be free by transforming the totality of society, then you are exercising only an individualist attitude towards empowerment or freedom (Shor et al, 1987, p. 109).

Besides returning to the question of directiveness discussed earlier, the passage above makes it clear that Freire recognizes the necessarily social nature of thought. One notices that this recognition shows how much Freire’s theory of knowledge and conception of language bear marks similar to those found in Vygotsky’s work. Examples of these similarities are the relation between intellect and affect (Vygotsky, 1986, p. 10); the role frustrations and difficulties have on thought processes (Idem, pp. 29-30); and the role of signs or words in the solution of the problems one confronts (Idem, p. 106). These similarities, however, are not a result of Freire reading Vygotsky, as he points out himself (Freire, 1995b, p. 63). Both authors, therefore, contend that the mind has an active and constitutive role to play in conceptualizing the world. In addition, they do not see the structures of the mind in innate, ahistorical and asocial terms, which can be inferred by the importance they attach to the role of language in the shaping of our mind. However, it is concerning the implications to adult education, in particular, that Freire’s epistemology reveals particularly important unfoldings of the social nature of thought. As Matthews has noted:

It is the understanding that thought is social which enables us to appreciate why Freire’s central notion of ‘conscientisation’ is not equivalent to Enlightenment. The former arises out of public, social practices; the latter is often taken to depend upon private, reflective isolation. Because conscientisation occurs among real men and women, who live in real social structures, Freire correctly says that ‘it cannot remain on the level of the individual’[Freire, 1974, p. 147] (Matthews, 1980, p. 87).

In the same mode as Matthews, I see many implications for epistemology of the thesis that consciousness is social. In this sense, I find the kind of considerations Matthews draws about such implications elucidating:

much contemporary anti-empiricist writing in epistemology and philosophy of science is preoccupied with giving accounts of the frameworks with which our observations are made and our theories formulated. Ludwig Wittgenstein’s arguments about the possibility of private language, Thomas Kuhn’s work on the function of paradigms in science, Stephen Toulmin’s account of conceptual populations are all witness to the richness and heuristic worth of the thesis Freire enunciates (Matthews, 1980, p. 87).
Besides, I also agree with this author when he argues that it is unfortunate that psychologists studying concept acquisition and the like have ignored the thesis that consciousness is social. I agree especially with his claim that Piaget is the most notable of these psychologists. This argument extends the similarities between Freire and Vygotsky that I mentioned above. As is well known, it was because Vygotsky was critical of Piaget that he introduced frustrations and difficulties in his clinical interviews.

In order to determine what causes egocentric talk, we organized the children's activities in much the same way Piaget did, but we added a series of frustrations and difficulties. [...] by obstructing his free activity we made him face problems. In the same activities without impediments, our coefficient of egocentric talk was even slightly lower than Piaget's. It is legitimate to assume, then, that a disruption in the smooth flow of activity is an important stimulus for egocentric speech. This discovery fits in with two premises to which Piaget himself refers several times in his book. One of them is the so-called law of awareness, which was formulated by Claparède and which states that an impediment or disturbance in an automatic activity makes the author aware of this activity. The other premise is that speech is an expression of that process of becoming aware (Vygotsky, 1986, pp. 29-30).

As Matthews has noted, advocates of discovery learning overlook the active role the mind plays in knowledge acquisition. Hence, this discussing of the issue. Matthews sums this up saying that "people never simply see, or simply experience, or simply discover. They always see, experience, and discover particular things depending upon what is already in their heads" (Matthews, 1980, p. 88). Freire stands apart from those schools of thought mentioned above because he acknowledges that it is pointless simply to ask people to observe. His is not a discovery method. Freire is aware that people have to be directed to observe particular types of things. Moreover, he argues that the teacher or co-ordinator of debates needs to know what will constitute a frustration or a difficulty for the particular people he/she is addressing. As Matthews continues, "the quality of worthwhileness of observations will depend upon the quality of the theories, of world views, which people bring to bear on their researches" (Matthews, 1980, p. 88). The improvement of such quality should be the aim of radical democratic teachers. For it to happen, as I have said, the 'codification' of people's world view is necessary. According to Freire, the process of abstraction depends upon, and creates, images, symbols, ideas, and concepts that are, in one form or another, representations of concrete reality. In the next chapter I explain how I transferred Freire's experience with the
codification of adult illiterate peasants to obtain the codification of the primary teachers' world of science teaching.
CHAPTER 3

THEMATIC INVESTIGATION OF TEACHERS' STRATEGIC KNOWLEDGE OF SCIENCE TEACHING

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      The construct system
      Experience, learning and interpersonal construing
   2. Repertory Test
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C. CHALLENGES AND DIALOGUES

D. DISCOURSE ANALYSIS AND OTHER INVESTIGATIONS
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E. SUMMARY
The inspiration for this study has come from my experience as teacher educator on INSET programmes, and the difficulty I had communicating with those in the school world: classroom teachers. The aim of this empirical investigation is to identify some friction points between the ways non-specialist teachers and science educators conceive the science education of school pupils. The specific group of non-specialists considered is that of primary teachers. The identification of these friction points, as discussed here, tests the proposition that an approach to the difficulties of communication between those parties, based on Freire's problematizing education, will redress the imbalance of that relationship. Besides, this approach bypasses the difficulty of understanding teachers' rationale for their actions while still granting teacher educators resources to promote the professional development of these practitioners.

The empirical work here is spelled out in three parts. Part I is entitled 'Research Purpose'. As I say, this is an investigation of the points of friction between the ways practising teachers and science educators conceive the science education of school pupils. These points of friction will be characterized as cultural or ideological differences. Since the use of the words 'culture' and 'ideology' might be misleading, the meaning they have here is clarified right at the beginning of the chapter. There then follows a discussion of their implications for an enquiry such as this.

Part II is entitled 'Research Design'. This is divided into five sections which are, respectively: section A, 'The Sample', about the population from which volunteers have been drawn; section B, 'The Focus of Interest', a definition of data used; section C, 'The Approach', the research methodology employed; and section D, 'The Analysis', a discussion of the data handling. Finally, section E provides a summary of main points discussed in part II.

Part III is entitled 'Research Implementation'. It begins by describing the teachers who were interviewed in section A, 'The Sample of Interlocutors'. Section B, 'Repertory Test Approach', details the 'interviews'. Section C, 'Challenges and Dialogues', considers the different sources of data and how they were analysed. Section D, 'Discourse Analysis and Other Investigations', gives especial attention to the analysis of teachers' reflections on the results of data collection. The last section of part III shows a flow diagram of the empirical work conducted, with a summary of the data collection and analysis process.

Although the investigation is an empirical feature of the present study, its targets and design do not follow the conventional form of an empirical work as the outline
above might suggest. While the outline might be seen to conform to the standards of logical empiricism, as will become evident by the content of the sections ahead, the empirical work that is conducted here is based on a realist epistemology. It is, therefore, concerned with the extent to which a certain educational theory is actually useful to explain the situation in question. It is only, to a lesser extent, an interpretation of the observed phenomena.

I. RESEARCH PURPOSE

The previous two chapters provided, first, an account of the area of study within which this present study can be located and, second, an overview of the Freirean philosophy with which I work. Those chapters discuss issues in broad terms. This chapter narrows the discussion to make clear the scope of the research conducted. In order not to conflate a discussion of its purpose with a description of the research design, implementation and analysis, this first part focuses only on the purpose of the investigation, leaving the description of the other aspects to be dealt with later.

An rehearsal of the main points made in the last chapters makes a useful introduction to a discussion of the purpose of the research.

A. RESEARCH ON TEACHER THINKING FROM A FREIREAN PERSPECTIVE

As Allman (1994, p. 148) describes Freire’s work, it was based on Marx’s concept of ideology: Freire saw education as a form of cultural action for people’s conscientização. Freire showed that Brazilian labourers, besides being obviously socio-economically oppressed, were subject to a more subtle form of oppression: a disregard for their world-view, an indifference to their culture. By revealing this, Freire made it clear that educators might be unaware of the fact that they are conducting education as domestication. Freire has shown that this is what teachers will be doing unless they deliberately choose to conduct education for liberation.

Freire argues that a literate culture shows in the way literate people see the world, in the way they represent the world and in the value they attribute to reading and writing. The ability to read and write gives literate people the opportunity to have wider perceptions of the world; for instance, it allows one to live the experiences, and become familiar with the knowledge, of people one could never meet in person. However, using Marx’s critical concept of ideology, Freire shows that those who have the ability to read and write cannot appreciate how the illiterate perceive
the world. They may be tempted to argue that without such abilities one cannot have a critical perception of reality. However, since there are illiterate adults who show such a perception, the argument does not hold up. While not saying that educators should eulogize peasants’ life and illiterate culture, Freire shows, among other things, the importance of recognizing the differences between this life and culture and that of literate teachers.

My reason for exploring Freire’s response to the challenge of conceiving a liberating literacy programme for adults, is that I believe science educators face similar challenges when asked to address practising teachers, particularly when these are non-specialist in science. The current pressures on teachers are well known. They now have greater responsibilities, not only in view of changes in lifestyles, generally and in family life. In addition, they are expected to have knowledge of a wider range of topics; demanded to manage bigger classes; requested to account for their performance. In an unprecedented way teachers now lack time, particularly time to reflect on what they are doing and why. As a result, they usually develop a ‘naive’ or ‘magical consciousness’ about teaching (see chapter 2, section D).

Given that school science has grown more important, strategic or simply desirable, scholars have been commissioned to conduct research to inform practising science teachers, and thus improve pupils’ learning. Although many of those conducting this research are former science teachers, due to the peculiar nature of the academic work they now undertake, they slowly distance themselves from current practising teachers (see chapter 1, section A). This, of course, does not occur only to scholars I here refer by the term science educators. In the following passage, for example, Alexander comments on the state of teacher education for primary teachers:

Training and teaching have become two separate worlds. The ivory tower/chalk face, theory/practice rhetoric symbolises not merely an institutional gulf but a linguistic and intellectual one. Educationists agree on the need for dialogue, but dialogue presumes a common language of discourse. Dialogue also depends upon mutual acceptance of the need for self-critique.

The character of the training process and of teaching must both be regarded as problematic (Alexander, 1984, p. 4).

Science educators have become involved in programmes to provide teachers with the variety of pedagogic knowledge considered more adequate for the teaching of science. It is then that the differences, here described as ideological, between the
two groups of educators will show. In a sense, the core of these differences is that science educators usually base their proposals on research findings and formalized reflections in the form of psychological, as well as pedagogical theories, and philosophical studies. As this investigation shows, practicing teachers, in contrast, rely more on what we can call their *wisdom of practice*. They constantly have recourse to cases they either lived, were told or could imagine to judge the value of a proposition, formalized or otherwise. Such difference in attitude between science educators and practising teachers results in what Alexander has described as a linguistic and intellectual gulf.

As I discuss later in this chapter (part II, section A), the case of primary teachers is particularly interesting to study. The distance between this group of teachers and science educators is even greater. Since primary teachers would not normally have a scientific background, they usually lack content matter knowledge in this area; worse still, they seldom have a positive disposition towards science, especially towards physics or chemistry (Morrisey, 1981; Carre et al, 1990). The distinction I make here relates to teachers' 'membership' (or not) of a scientific culture, as is well illustrated by the discussion in *The Two Cultures* by C.P. Snow:

> The intellectual [and practical] life of the whole of western society is increasingly being split into two polar groups. At one pole we have the literary intellectuals, at the other scientists, and as the most representative, the physical scientists. Between the two a gulf of mutual incomprehension - sometimes hostility and dislike, but most of all lack of understanding. They have a curious distorted image of each other. Their attitudes are so different that, even on the level of emotion, they can't find much common ground (Snow, 1959, pp. 3-4).

Similarly, the problem I see is that primary teachers do not share with specialist teachers of science a number of values, principles, attitudes, practices - apart from not having the same knowledge of science. The lack of scientific knowledge, in particular, is indeed problematic as far as some of the targets of primary school curricula are concerned. But the gulf between science educators and primary teachers is perhaps even more problematic; at least if we acknowledge that the latter group of educational practitioners ought to be autonomous and critical practitioners. In the event of science educators addressing primary teachers, say, within in-service professional development programmes, the linguistic and intellectual gulfs to which Alexander refers take the form of an ideological gap. As a result, these encounters may become the stage of real clashes of culture; a prospect not very appealing. I will come back to the case of primary teachers later.
1. Teacher Training Counterpoint

As I have said, I do not consider that teacher education can be reduced to training. Of course, this reduction can be attempted, as indeed is presently being suggested in the UK amid a considerable debate about initial teacher education (Evans and al, 1992) - a debate in which, incidentally, the ‘competency’ movement (Devlin, 1991; Whitty et al, 1991) also plays a leading part. Initial teacher education is, however, an arena that is distinct from in-service teacher education, to which I refer by the expression *teacher professional development*.

In disapproving the attempts of reducing initial teacher education to training, I naturally reject the idea that teacher development could be based on simple transmission of knowledge. I will attempt to refute the proposition that science teacher education is simply a matter of lectures on pedagogic skills and processes appropriate to its teaching, or on the content of science - in case the programme is aimed at non-specialists. I am convinced that, where a ‘banking’ approach is used in teacher training, it does not empower those teachers to attain the targets to which they are asked to aim. This seems to me to be true in particular where science teacher education is addressed to practising teachers, who already have good classroom experience. Having already tried to foster among pupils an interest in science, curiosity, a spirit of enquiry, logical reasoning etc, these teachers will already have developed a picture of the tasks involved in the job. In a word, they have reached the state of ‘transitive consciousness’ (see chapter 2, section D), they have a discernment about the nature of the task involved. For science teacher educators to dismiss this ‘consciousness’ is, as Freire has put it, to risk ‘banking’ or simply ‘preaching in the desert’:

> We must never merely discourse on the present situation, must never provide the people with programs which have little or nothing to do with their own preoccupations, doubts, hopes, and fears - programs which at times in fact increase the fears of the oppressed consciousness. Their view of the world reflects their *situation* in the world. Educational and political action which is not critically aware of this situation runs the risk either of "banking" or of preaching in the desert (Freire, 1972, p. 85).

Concerning primary teachers in particular, there is evidence that in-service education and training (INSET) of them in the realm of science fails to achieve the improvement of primary school children’s knowledge, understanding and attitude towards science (Carre et al, 1990, OFSTED, 1995). This present study is concerned with why this might be; in particular with a critique of INSET which is
seen to lack a full appreciation of teachers' present stage of consciousness and fail to exercise the dialogicity necessary to the further advancement of this consciousness. Such critique presupposes the suggestion of a radical democratic alternative, which indeed I will provide. It is important to emphasize, however, that I am not suggesting that mine is a general response to the challenges of science teacher education. Any response to problems such as the clash of cultures we see in teacher professional development requires a critical analysis of the specific context in which it is to be applied. Paulo Freire has, in my view, a great deal to teach us in that respect. In this study I support this argument through discussion of his ideas and an investigation of what Freire has termed people's 'thematic universe': "the reality which mediates men, and the perception of that reality held by educators and people" (Freire, 1972, p. 86). The last part of this study is dedicated to this latter undertaking.

As a study of critical (radical-democratic) underpinnings, the present work aims to inform and guide the practices of teacher educators by indicating actions that these practitioners can take to overcome problems and eliminate difficulties; hence the proposition of an alternative approach to science teacher education. In fact, the search for an alternative form of teacher education was the initial motivation behind this study. In addition, such preoccupation has been influential in the planning and undertaking of the whole research. So, the form of teacher education I propose is important, for it makes clear why a particular methodological approach has been adopted here, at the expense of others. The final form envisaged of this 'dialogical' science teacher education is not the central point of the study, but some aspects of it takes shape in the final chapter.

2. Neutrality of Research

It follows from the discussion so far that I do not see any possibility of conducting educational research where an attitude of neutrality is adopted towards values. Freire is sufficiently clear about the possible consequences of aiming at impartiality. To have undertaken research on teachers' knowledge, on teachers' attributions, or on teachers' planning would have placed this research on the positivist side of my chart (figure 2, page 22) illustrating the field of research on teachers' thinking and action. Those who adopt a positivist approach to research do claim that researchers must be neutral. Had I adopted a positivist approach in this investigation, I would be obliged to overlook everything that does not lend itself to objective observation. The focus would probably be on particular psychological features, such as teachers' attitude to science and science teaching...
(see Morrisey, 1981; Riggs et al, 1990) or thought processes, such as teachers' planning (see Clark et al, 1986). While not wholly dismissing the contribution such studies can make to an analysis of teaching and to the professional development of teachers, I do find their contribution limited. I consider that teachers' feelings are an integral part of their praxis and consequently need to be contemplated. In not doing so, one goes against the grain of teachers' conscientização, by not envisaging their liberation through critical reflection.

If teacher education programmes have little or nothing to do with teachers' own preoccupations, doubts, hopes, and fears, as Freire warns, these programmes are more likely to increase the fears of these agents of change than to empower them to implement the actions necessary for change to take place (Freire, 1972, p. 85). From this perspective, research programmes designed to inform teacher education should provide insights into the affective realm of teachers' thoughts as well. To some extent, this is the aim of researchers studying teachers' implicit theories or teachers' biographies, studies I have placed along the interpretive border on my chart of the field of research on teachers' thinking and action (see figure 2, page 22). In these studies, subjective features of teachers' thinking are valued as influential on their thoughts and consequently on their teaching: teaching is considered as a fluid process or activity. In other words, educational reality is seen to have an open, undetermined character.

From the philosophy I adopt here, teaching can be seen in almost the same way as those latter scholars, though my research approach takes on a different character. Like them, I would also treat that which counts as knowledge as being problematic, no matter whether it is pedagogic or content matter knowledge - a distinction I will discuss later in this chapter (part II, section B). In this Freirean mode, education is essentially a political activity taking place against socio-political backgrounds and, therefore, projects into the kinds of futures one hopes to build. Consequently, teacher education is not simply a matter of personal development, but is instead a social activity with social implications. For this reason, although defending the importance of grasping the meanings that educational practices have for teachers, I do not consider this interpretation sufficient in itself. I believe reality is defined by consciousness but I also believe reality can distort consciousness. The passage below helps to make this point; its author, a studious analyst of Freire's work, is particularly concerned with the extent to which Freire's educational philosophy is based on Marx's writings.

One of Freire's most important contributions to education or any form of cultural action for socialism and to Marxism itself, stems from his
understanding of Marx’s theory of consciousness and his negative or critical concept of ideology in which ideology, or ideological, refers neither to a ‘system of beliefs’ or ‘false consciousness’ but to explanations, or actions and symbols based on such explanations, which are partial and fragmented and thereby distorted. Freire shares Marx’s concern about ideology, and what Freire also calls, a ‘naive consciousness’ (Freire, 1974) can serve to sustain an oppressive social formation. Freire’s contribution is an analysis of how to be with the people so that they can develop [a critical] way of thinking. However, one of Freire’s primary concerns is about how the ideology of the oppressors can continue to affect even those who have a critical perception of reality (Allman, 1994, p. 148).

So, as someone wanting to create opportunities for practising teachers to develop a critical (dialectical) way of thinking about science education, I must necessarily listen to their explanations about wider matters concerning school science. I have to become familiar with their current practices (actions), as well as with the arguments and metaphors (symbols) they associate with such explanations. In that sense, similar to interpretive approaches to educational research, my research does aim to identify teachers’ interpretations of reality. However, unlike scholars of interpretive (relativist) inclination, I do not give special emphasis to those personal interpretations. Those interpretations, as I have said, can result from a naive consciousness. In face of this fact, one could try to understand why these particular interpretations are partial, fragmented, even erroneous or false. As a rule, this would mean focusing on the cognitive dimension of people. There is an alternative though: to avoid the cognitive route.

3. Private and Collective Dimensions of Self

Another important point to consider here is whether the investigation should focus on teachers’ idiosyncratic or, instead, societal dimensions. The empirical portion of this work illustrates in a small way the advantages in studying common arguments and metaphors used by a group of teachers who have similar backgrounds and are experiencing the same sort of professional pressures and challenges. The individuals contacted for this study have been approached because they supposedly have among themselves similar ideas about schooling, and in particular about science education. Besides, they were in the process of experiencing a very specific professional challenge, more about this later.

I thus refrain from inferring teachers’ idiosyncratic interpretations, as I study their discourse. By focusing on their common arguments and metaphors instead, I can
identify themes they associate with science teaching as a group. Following Freire (1974, p. 49, quoted on page 58), it can be assumed that these themes have a great emotional content and are, therefore, weighted with existential meaning. If these themes are meaningful for teachers they can be helpful in promoting teachers’ reflection and self-criticism regarding their own praxis. The themes could then be analysed with the purpose of devising instrumental prompts (generative themes) to make these discussions cover issues of science educators’ concern.

Being weighted with existential meaning (and therefore emotional content), and then incorporated into a dialogical teacher education programme, themes emerging from this study will eventually challenge teachers to reflect critically on their praxis. Moreover, these themes are likely to be pointers to ‘distorted’ (partial and fragmented) interpretations of this reality. This is because such themes are related to teachers’ emotional accounts of their personal experience teaching science. Each individual teacher of science experiences a personal exposure to reality; that is, to the challenges of teaching science to particular pupils. In this sense, these experiences are personal, unique for any one teacher. While being personal, they are naturally partial and fragmented experiences of science teaching. According to a relativist ontology "realities are apprehendable in the form of multiple, intangible mental constructions, socially and experientially based, local and specific in nature" (Guba et al, 1994, p. 110). But even from a radical constructivist perspective, one would accept that elements are often shared among many individuals and even across cultures; otherwise any form of communication would be deemed impossible.

On the other hand, when the experiences in question are the specific experiences of science teaching in primary school, the form and content of teachers’ mental constructions of them are bound to have common, ‘societal’ features. There are many commonalities between primary teachers’ traits; between the characteristics of the pupils addressed by those teachers; between the topics of science each teacher focuses when he/she teaches this subject; and between the forms of those addresses. This might not prove the existence of an objective reality beyond the myriad of phenomena we can describe. However, plastic though these phenomena might be, over time their perception can be shaped by a number of social, political, cultural, economic, ethnic, gender and other factors. So, in effect, for all practical purposes, what is apprehended is ‘real’. A reality which cannot be described as objective but could be described as historical; in other words, a reality "crystallized (reified) into a series of structures that are now (inappropriately) taken as "real", that is, natural and immutable" (Guba et al, 1994, p. 110).
The experiences of one particular teacher are likely to be conveyed by that teacher with arguments and metaphors common to many other teachers working in similar circumstances. This view alone would move me squarely into the territory of Collaborative Research. Scholars of such inclination see teachers in a more integrated and, therefore, holistic way (Pope et al, 1986). For that reason, the personal accounts of teachers’ own experiences, reflections and interpretations are valued by Collaborative Researchers. Yet, perhaps by favouring interpretive approaches to research, these scholars apparently do not portray teachers as much more than individuals in their work. Besides seeing teachers as individuals, I also see them - all of them, not only those working in primary school - as representatives of a group, a particular cultural group; that is how they are being portrayed in this study. As stated before, I do not deny teachers’ psychological traits or epistemological processes; nor do I want to argue that such features from the private domains of an individual’s self have little or no influence on the quality of a teacher’s teaching. Likewise, I do not deny that, for their teaching to be of quality, it is important that teachers have a certain level of content matter knowledge and access to appropriate teaching materials. My main argument is that by not taking into account primary teachers’ ideological facet - in the sense that ‘ideological’ has been defined above - one oversimplifies the analysis of these practitioners’ praxis. In this sense, the focus on teachers’ ideology aims to demonstrate how much the current lore about teachers’ thinking gains in colour with the study of this, hitherto little emphasized facet. Besides, I believe that the failure to take this into account might be one of the main causes of science educators failing to communicate with teachers in INSET programmes. The case of primary teachers is an example. When science educators’ attempt to communicate fails, these practitioners have difficulty changing their level of content matter knowledge of and attitude to science; this difficulty expresses itself in these teachers’ performance when teaching the subject.

4. Strategy and Purpose of Enquiry

It follows that seeing teachers more as members of a culture than as individuals denies the use of strategies of enquiry commonly adopted by collaborative researchers: case studies, biographical studies, action research. These strategies promote interaction between and among investigator and respondents, as the term collaborative suggests. However, they aim to elicit the various individual constructions which, refined through such collaboration, are then interpreted using hermeneutical techniques, being eventually compared and contrasted through a dialectical interchange. "The final aim is to distil a consensus construction that is
more informed and sophisticated than any of the predecessor constructions (including, of course, the etic construction of the investigator)" (Guba et al, 1994, p. 111). Instead, I aim for a more critical and, therefore, dialogical form of enquiry. Given my eventual intention to elaborate a 'problematising primary science teacher education programme' based on Freire's pedagogy, his methodological strategy appears as a natural model for me to base my search for raw material on.

The methodology of that investigation must likewise be dialogical, affording the opportunity both to discover generative themes and to stimulate people's awareness in regard to these themes. Consistent with the liberating purpose of dialogical education, the object of the investigation is not men (as if men were anatomical fragments), but rather the thought-language with which men refer to reality, the levels at which they perceive that reality, and their view of the world, in which their generative themes are found (Freire, 1972, p. 86).

As Guba and Lincoln have noted, in dialogical and dialectical methodological strategies such as this, the nature of enquiry is transactional; i.e. such strategies require the investigator and the subjects of the enquiry to establish a dialectical dialogue between themselves.

That dialogue must be dialectical in nature to transform ignorance and misapprehensions (accepting historically mediated structures as immutable) into more informed consciousness (seeing how the structures might be changed and comprehending the actions required to effect change) (Guba et al, 1994, p. 110).

The importance Freire attributes to actions and symbols associated with people's explanations of their reality stands out from his description of Thematic Investigation. The focus on the thought-language makes clear that the values of the investigators (and of their opposites) are assumed to influence the enquiry. So, rather than trying to elicit the various teachers' constructions from their discourse, by choosing teachers' thought-language as the object of study, this research ought "to uncover and excavate those forms of historical and subjugated knowledges that point to experiences of suffering, conflict, and collective struggle" (Giroux, 1988 cited by Guba et al, 1994, p. 110). In the context of science teaching, this means that the aim is to identify current practices (actions), arguments and metaphors (symbols) which teachers associate with their praxis. This is in greater accordance with the Freirean principles than a simple look at teachers' own explanations (in conducting their practices the way they do) in order to interpret teachers' patterns of professional behaviour. Those practices, arguments and metaphors teachers
associate with their praxis are likely to illustrate where their forms of knowledge are subordinate to the knowledge of science educators. They are likely to indicate where the ideologies of both parties conflict. Doing so, they essentially represent the themes which will generate the kind of (dialectical) reflection essential for a dialogical teacher education programme.

These themes, it is important to stress, illustrate where the forms of knowledge of the two parties in question differ. As discussed in section C below, Shulman's distinction between forms and categories of knowledge for teaching is being adopted here (Shulman, 1986a,b; 1987; Wilson et al, 1987).

Such strategy and purpose of enquiry denote a drive to emancipate those who are researched. The same sort of thrust can be noticed in research on teachers' thinking and action. Scholars studying teachers' life stories, for example, do not see themselves as observers describing teacher-the-object. Rather, they see themselves helping teachers-the-subjects to enhance their professional practice by raising their awareness of their implicit values, assumptions and tacit knowledge (Pope, 1993 p. 25). In other words, teachers are not seen as irreducible elements which simply 'are' for the sake of explaining teaching as a whole. From this point of view, the goal seems to be teachers' conscientização. But, as seen earlier, conscientização involves a perception of one's reality together with the (dialectical) contradictions within it. It does involve becoming conscious of one's own perception of reality, but it also involves being challenged by an 'other'; it involves having one's own reflections problematized by this 'other'; it involves analysing the extent to which custom, tradition and other such socio-cultural influences distort our perceptions. Research whose aim is to attain conscientização through this sort of problematization is instructed by a rational principle of enquiry, not an organic or holistic one, as in the case of Pope and Denicolo (1986) for instance. The rational principle which guides this study is the principle of dialogicity. This principle was spelled out by Freire and underpinned by a radical-democratic conviction; as I discussed earlier, alongside an allegoric representation of the tensions this principle involves (chapter 2, section C). Hence, although the present research aims "to enable [its] participants to gain from the experience of reflection and clarification of their thinking in anticipation of further action" (Pope, 1993, p. 13), it is different from its counterparts in a crucial way. Here, it is assumed that it is not necessary to understand why teachers conduct the teaching of science the way they do to attain the objective of improving teachers' further action. I will briefly dwell on this point to argue it in more detail.
B. THE RELATIVE VALUE OF UNDERSTANDING WHY TEACHERS TEACH AS THEY DO

Those who follow an interpretive approach to research on teachers' thinking and action, Collaborative Researchers in particular, tend to adopt an 'organic' or 'holistic' principle of enquiry (Pope et al, 1986). An organic principle of enquiry, according to Schwab (1964b), is unlike a reductive one: it does not suggest that one should try to explain a larger whole by summations, combinations and interactions of its constitutive parts. Instead, it instructs the researcher to treat the larger whole as simply 'being'. In this sense, the whole is not explained, it is just described. The various parts of the larger whole should be discriminated and 'explained' in terms of the contributions they make to it (Schwab, 1964b, p. 47). Such enquiries, therefore, usually lead to classificatory schemes. An approach to the question of science teaching from this point of view might be thought of in terms of the following hypothetical syllogism:

a) Science teaching is a complex activity impossible to be reduced to the sum of its parts. However, it might be possible to discriminate some of these parts; for instance, by looking at teachers' beliefs, implicit theories, customs, traditional practices, previous experiences, professional biographies etc. With the accumulation of results from studies of these elements, it will eventually be possible to understand their contribution to teachers' practice.

b) Educational researchers and teachers alike are capable of discerning the constitutive elements of teachers' knowledge for teaching and of suggesting which contribution these elements might have to practice.

c) Informed by such understanding, given the means and the opportunity, a teacher can interpret the reasons or causes of ill-fated teaching practices, and will therefore be able to change his/her own behaviour to have better results next time.

The reservation I have about this syllogism is not its basic hypothesis (a). The construction of teacher's knowledge for teaching as something intrinsically complex but which can be understood in terms of the contribution its parts make to the whole provides an important framework on which to conduct research. Even the assumption on premise (b) does not seem as problematic as the conclusion (c) that follows. Educational research is not normally used by teachers. But this is not because researchers, when they face the kind of dilemma Goodson (1994) calls a Devil's bargain, opt to do what is academically acceptable - never mind the utility of it. The difficulty lies in encouraging teachers to have a reflective practice; and
worse still, in making teachers change their reflective ability. Fenstermacher and Richardson (1993, p. 101) also point to this problem, providing referenced support for the argument (notably Clift et al, 1990; Grimmett et al, 1988).

The other's role in working with the teacher to reconstruct practical arguments is challenging and fraught with problems. There is a fine line between serving as the expert in practical reasoning, and perhaps in other areas of classroom life, while engaging the teacher in careful scrutiny of practical reasoning in ways that bring a measure of equality and mutuality to the relationship between teacher and other (Fenstermacher et al, 1993, pp. 110-1).

Fenstermacher and Richardson (1993) acknowledge that the notion of an 'other' as an important element in practical argument only appeared quite recently in their thinking. Basically, what they have found is that the effort and the expertise involved in the premise (b) of the syllogism above are significantly greater when an other is not present. They too, now inspired by the works of Habermas and other critical theorists, have reached the same conclusion as I have. They have come to recognize the importance of conversation and dialogue in the development of human understanding and the promotion of ethical conduct (see also Elbaz, 1988). Their attention to Freire in these matters should come as no surprise. As they say,

Freire has given explicit attention to the role of dialogue in the development of critical consciousness and addressed the role of dialogue in the context of education (Fenstermacher et al, 1993, p. 111).

The route to teacher development through a Freirean form of dialogue, however, does not simply provide a different conclusion to a syllogism instructed by an organic principle of enquiry. This route implies the adoption of a wholly different principle of enquiry. An enquiry based on a dialectic form of dialogue, which chooses teachers' thought-language as object of study - as in this case - is instructed by a 'rational' principle.

Rational principles forbid us to seek explanations by isolating bits and pieces of things, events, or characteristics. They ask us, instead, to talk in terms of an entire system. Furthermore, the system is usually a system of relationships treated apart from the things in the relationship. Thus, the system we are required to deal with is not only a system but an abstract system. We require, then, a language capable of coping with abstract systems (Schwab, 1964b, p. 49).

The present research does not isolate teachers' decisions, actions, beliefs, or any
other thing, event, or characteristic of the group of teachers which has been met. Not even individual teachers or their other (the researcher) were studied as isolated selves. The rational principle that has been adopted here asks the study to deal with the interaction between science educators and teachers as manifestations of an abstract system of relationships. The abstract system in question is the social structure within which these ideological conflicts exist and manifest themselves.

Based on the underpinning premises of problematization, this study assumes that changes in science teaching can be attained through the promotion of reforms in science teacher education. It works on the hypothesis that to look at possible points of conflict between the two cultures involved will empower science educators to achieve the aim of challenging practising teachers to reflect on the premises that ground their practical reasoning. Points of conflict are essential for educators who are willing to balance, on the one hand, spontaneism and domestication or indoctrination and, on the other, activism and verbalism (see figure 3, page 73). In the case of teacher education, the themes that result from this study should allow the balance between those Kroath calls the two antagonistic functions of teacher educators: "to confirm, to support and to provide authority on the one hand, and to challenge, to destabilize and to withdraw authority on the other hand" (Kroath, 1990, p. 5, cited by Fenstermacher et al, 1993, p. 111).

For circumstantial reasons, practising teachers lack opportunity to reflect on their practice. As a consequence, they probably possess a more naive or magical consciousness with regard to the purpose and nature of science education. They will therefore be the ones to change most their way of thinking and acting in the teaching of science. However, it is still important to consider the possibility that science educators may also review the premises on which they base their own praxis. This study, in its dialectical thrust, is an effort to reveal passages of primary teachers' discourse while in conversation with me. Of special interest are those passages where, because of my background as a physics graduate, post-fourteen school teacher and science teacher educator, I was tied up in knots, unable to decode what my primary school interlocutors were trying to convey. Apart from those passages, the following are also of interest here:

* passages where teachers' understanding of pupils' learning of facts or concepts of science seems naive or erroneous;

* passages where they present a construction of the nature of science which is, in some way, peculiar;

* passages where they suggest aims for the science education of school
pupils which conflict with aims established by science educators;

* passages where the way they construe the teaching of science is unconventional, or remarkable.

In the same way that volunteers for this research are regarded as representatives of a culture, as researcher I portray myself as representative of another culture; two cultures which are essentially those distinguished by C.P. Snow (1959). This is a study of the points of friction between these two cultures in a particular setting. The findings must show, at least partially, areas of misunderstanding in the communication between these cultures, which consequently hamper one or both sets of representatives in their efforts to improve the teaching of science in primary schools.

The main authentication of this study's findings will be drawn from external sources such as other studies about (Galton et al, 1980) and official reports on (CACE, 1967; OFSTED, 1995) the state and the ethos of school teaching, particularly with regard to primary science education. They have been chosen because they consist of accounts of the world of practising teachers, so to speak, made by other representatives of the academic world. Even though they may not emphasize the ideological differences I see as so important here, in their drive to identify the deficiencies of primary science teaching or to understand teachers' knowledge, these surveys and studies will reveal how those who conducted them interpret the features of primary teachers' teaching. So, their findings also reveal points of friction between what I refer to here as the two cultures.

C. SHULMAN AND THE PROFESSIONAL KNOWLEDGE BASE FOR TEACHING

This study, as stated earlier, is informed by a rational principle of enquiry. Therefore, it requires a 'special language' capable of coping with the abstract nature of the clash of cultures, in focus here. It is through this language that the question will be more precisely formulated. In this instance, the ideas of an influential scholar in the field of research on teachers' thoughts and actions will play an important role. Shulman and his colleagues (Shulman, 1986a,b; 1987; Wilson et al, 1987) have also followed a rational principle of enquiry in their studies. In this respect, Shulman's theoretical framework for the study of teacher understanding and transmission of content knowledge will shed some light on this requirement of a language for science educators to communicate with primary teachers. However, this will be discussed where the focus of interest of the present
study is defined. This section explores only Shulman’s contribution to the clarification of this study’s purposes.

In 1974 Shulman chaired the panel of the (USA) National Conference on Studies in Teaching that produced an influential report (National Institute of Education, 1975). This document formulated a programme of research on teachers’ thinking, enunciating a rationale for it, together with a definition of its domain of interest (Clark et al, 1986, p. 256). But it is for his perspective on teacher knowledge that Shulman has subsequently been widely quoted in the research literature of this field of study. He has proposed a theoretical framework which acts as a logical model for the components of the professional knowledge base for teaching (Shulman, 1986b).

In considering pedagogical knowledge and content knowledge as somewhat unalike, Shulman leaves the former aside and proposes a distinction between three categories of content knowledge (Shulman, 1986b, p. 9a):

* subject matter content knowledge;
* pedagogical content knowledge;
* curricular knowledge.

In fact, as he admits himself in other articles (Shulman, 1987; Wilson et al, 1987), he lacked consistency in attempting this list, so I focus on the idea as it appears in the article cited above (Shulman, 1986b), referring to his afterthoughts to clarify, rather than contradict, this. This framework for classifying both the domains and categories of teacher knowledge has become the basis for many, if not most, analyses of teachers and their expertise in teaching to be found in the literature of research on teacher thinking in the last decade. Rather less cited is the framework for classifying the forms of representation of teacher knowledge, which Shulman also presents in his seminal article. There, he suggests three forms of teacher knowledge (Shulman, 1986b, p. 10c):

* propositional knowledge;
* case knowledge;
* strategic knowledge.

Each of Shulman’s theoretical frameworks elucidates different aspects of the present study. Shulman’s categories of content knowledge, for instance, are important to explain how and why the core focus of this present study was chosen. On the other hand, both the purposes of this study and the methodological
strategies adopted in its empirical portion draw upon what Shulman has dubbed strategic knowledge (Shulman, 1986b, p. 12c). According to Shulman, this form of teacher knowledge is basically an articulation of the other two. The principles, values and practical maxims constitute one's propositional knowledge (Shulman, 1986b, p. 11); whilst prototypes, precedents and parables form one's case knowledge (Shulman, 1986b, pp. 11-2).

1. Teachers' Emotions and Strategic Knowledge

The purpose of the present study is to identify those primary teachers' practices, arguments and metaphors most weighted with existential meaning. That is, the actions (cases) and symbols (propositions) on which their explanations of science teaching are based. In order to access the elements weighted with existential meaning, special attention has been given to teachers' emotions. The adoption of Thematic Investigation as a strategy of enquiry accompanies the following assumption: the actions and symbols with great emotional content should essentially be connected to what Freire calls 'liberating actions' or their antithesis. Liberating actions are basically actions directed at overcoming difficulties, challenges, situations which limit one's actions. Interestingly, the various strategies adopted by teachers in actions of this kind are, according to the passage below, precisely what Shulman suggests as being teachers' strategic knowledge.

Strategic knowledge comes into play as the teacher confronts particular situations or problems, whether theoretical, practical, or moral, where principles collide and no simple solution is possible. Strategic knowledge is developed when the lessons of single principles contradict one another, or the precedent of particular cases are incompatible (Shulman, 1986b, pp. 12c-13a).

Naturally, Shulman recognizes that, given the ever-growing complexity of our times, teachers need to possess knowledge not only in the domains of pedagogy and content. It is ever more important to possess this in the form of strategic knowledge. Teachers certainly ought to respond adequately to the challenges of teaching but it is difficult to predict which challenges these will be. Shulman also rejects training as an answer to such challenges. Instead, he too proposes a dialectical answer for them:

I envision the use of case method in teacher education, whether in our classrooms or in special laboratories with simulations, video-disks and annotated scripts, as a means for developing strategic understanding, for extending capacities toward professional judgement and decision making.

These methods of instruction would involve the careful confrontation of
principles with cases, of general rules with concrete documented events - a
dialectic of the general with the particular in which the limits of the former and
the boundaries of the latter are explored (Shulman, 1986b, pp. 13a-b).

The suggestion of confronting principles with cases is especially appealing as far as
the present study is concerned. Shulman’s proposal involves confrontation, which
can be understood in dialectical terms and can be conducted as a form of
problematization in the mode of Freire’s pedagogy. Shulman, too, suggests that this
should be a confrontation of the general with the particular. In these terms, ‘general’
would mean science educators’ *propositional* knowledge and ‘particular’
be primary teachers’ *case* knowledge. It happens, though, that in the case of
secondary school teachers’ knowledge, analysed by Shulman, the relevance of
ideological differences between teachers and teachers of teachers can probably be
reduced without any great loss in the analyses. In the case of primary science
teacher education, the differences between the parties involved are not mere
differences in the level of information or sophistication of each one’s constructions.
These differences can be considered to be ideological. The cases one person
chooses to exemplify a principle, a philosophical commitment or a practical maxim
to another can sound as strange as anecdotes told by a foreigner to illustrate
regional differences between his/her fellow countrymen.

2. Strategic Understanding and Conscientização

The challenge, therefore, is to find ways to develop primary teachers’ strategic
understanding about science teaching despite the existing ideological and cultural
gap between them and science educators. The literature of teacher thinking in
general, as I have said, shows that research does not usually focus on such
ideological differences as I highlight. One possible way forward to explore this
challenge would be to use action research methods. Action research agendas for
separate research on teaching and teachers (reflection) from teacher professional
development (action). But nor do they seem to focus on differences between the
general and the particular. They do promote action-reflection, even allowing that
these can lead to investigations where practice-reflection is distorted by taken-for-
granted assumptions, habits, custom, precedent or ideology (Carr et al, 1986, p. 192). However, action research agendas tend to promote action-reflection
without introducing contradictions, without confrontation between the general
propositions of teacher educators and the particular propositions or prototypes,
precedents and parables brought in by student-teachers. In view of their
ideological differences, it is difficult to see how science educators' strategic knowledge can in fact foster primary teachers' strategic understanding without recourse to those contradictions or challenges. For this strategic understanding to develop and thrive, teachers engaged in action research (or their promoters) should not rest content with insightful analyses. These teachers need to actually change their praxis in the event of a meaningful reflection in and on practice. Unless action research promotes this, it can be regarded as mere navel gazing.

The purpose of teacher education, as Shulman suggests, is to foster strategic understanding amongst teachers in order that they may face the challenges of teaching as true professionals. Following Green (1971) and Fenstermacher (1978), Shulman argues for balancing tensions similar to those balanced in Freire's radical democratic approach to education and depicted by the pyramidal allegory presented earlier (figure 3, page 73). In Shulman's proposal, as in Freire's, there must be a balance between spontaneism and domestication, on the one hand, and activism and verbalism, on the other:

Educating a teacher is not a matter of inculcating a knowledge base in the form of a specific set of teaching skills and competencies. Rather, to educate a teacher is to influence the premises on which a teacher bases practical reasoning about teaching in specific situations. The premises serve to ground the decisions, not determine them (Shulman, 1986a, p. 32).

The acquisition of strategic knowledge for teaching, therefore, is essentially a process of conscientização: it involves acquiring an awareness of the 'rules of the game', as well as the ability to play with these rules. Teachers need to go through this conscientização in order to develop strategic knowledge in full. In this sense, the conception of teaching, as a profession, is as important here as the epistemology adequate for the acquisition of knowledge necessary for its exercise. Like Schwab, Shulman adopts the metaphor teaching as an art. This metaphor avoids both the image of it being essentially a technical activity, and that of it being solely a practical activity. Shulman has argued that if teaching is an art, its practice requires the three forms of knowledge he later dubbed propositional, case and strategic. Here is a passage he cites (Shulman, 1986a, p. 31) to support this argument:

Every art, whether it be teaching, stone carving or judicial control of a court of law... has rules, but knowledge of the rules does not make one an artist. Art arises as the knower of the rules learns to apply them appropriately to the particular case. Application, in turn, requires acute awareness of the
particularities of that case and ways in which the rule can be modified to fit the case without complete abrogation of the rule. In art, the form must be adapted to the matter. Hence the form must be communicated in ways which illuminate its possibilities for modification (Schwab, 1983, p. 265).

The teaching-as-art metaphor is in fact a blend of the two images of education mentioned: technical and practical. Consequently, it does not contradict these. As stated in chapter 1 (section C), three alternative images of teaching can be identified: technical, practical and strategic, each usually adopted, respectively, by each of the three approaches to research on teaching: positivist, interpretive and critical. The view of education as strategic is distinct from both the others, for it consider education as intrinsically political, as it is for Freire. This difference in conception of education distances Shulman from Freire and so distances Shulman’s investigation from my present study; though mainly in terms of methodological strategy. The final aim in providing teachers with strategic knowledge is common to both our initiatives; hence the similarities between the teacher education programmes each of us envisage. Basically, Shulman’s description of the three forms of teacher knowledge is functional and therefore helpful for the organization of these programmes. As to the differences between our methodological research strategies, a further word is necessary.

3. A New Departure in Shulman’s Research Programme

The research programme coordinated by Shulman (Wilson et al, 1987) is consistent with the image of teaching he adopts. In it, the advantages of positivist and interpretive approaches blend in a distinct research programme. Shulman - and his associates - conducted series of ‘planning-observation-reflection’ cycles, as well as biographical and knowledge interviews. This methodological pluralism is the response to aspects of research on teacher knowledge Shulman finds flawed: too great an emphasis on teachers’ ‘practical’ knowledge; or, instead, the complete absence of this ‘practical’ knowledge in studies of teachers’ subject matter content knowledge (Shulman, 1986b, p. 8; Wilson et al, 1987, p. 108). Critical of educational researchers for not providing a conceptualization of the professional knowledge base of teaching, Shulman offers one which is both empirically and theoretically grounded. The theoretical grounds are mainly the works of Schwab (1983) and Dewey (1938); as can be seen when Shulman analyses the way the work of Schwab relates with that of Dewey (Shulman, 1984). As to his empirical base, the object of his investigations is the subject matter knowledge held by novice teachers and the ways in which it influences and is influenced by the act of teaching.
The present study adopts a strategy of enquiry distinct from that of Shulman; its object of study is also somewhat different from his. Nevertheless, the conceptualization of the professional knowledge base for teaching contemplated here is not completely dissociated from Shulman's; this becomes clear as I discuss the role of my Tetrahedron of Principles (Vaz, 1989) later in this chapter (part II, section D). Shulman's object of study is the knowledge growth in teaching (Shulman, 1986a,b; Wilson et al, 1987, p. 110), which he investigates, not from the perspective of generic teaching skills that transcend specific subjects or topics, but by focusing on what new teachers know about their subject matter. So, some of his research questions, such as "how and why this knowledge is transformed during teaching or teacher education" (Wilson et al, 1987, p. 110), bear little relationship with the ones raised here. My focus is on the difference between the knowledge bases for the teaching of experienced primary teachers and science teacher educators. Since knowledge of science's facts and concepts constitutes the obvious difference between these two sets of practitioners, it has not been the focus of my enquiry. In the same way, generic teaching skills, which transcend this subject or its topics, have also been outside its scope. In a sense, this present study can offer (partial) responses to only one of Shulman’s research programme questions, which is: how is knowledge used in classroom instruction? (Wilson et al, 1987, p. 110). This question is only partially approached here, for primary teachers' ways of using this knowledge are only recorded when they differ from science educators'.

D. SUMMARY OF PURPOSES

This study borrows a number of concepts and ideas from Freire’s adult literacy programme and analyses their pertinence in the realm of teacher education. The recourse to Freire’s pedagogy and philosophy of education seems justifiable particularly in the case of primary science teacher education. In this particular case, the forms of knowledge (for teaching) of (primary) teachers and those of (science) teachers of (primary) teachers can be as different as the ways literate and illiterate adults construe the world are different. It is suggested that this analogy shows that such difference in the forms of knowledge can compromise the aim of providing primary teachers with a sound base for an independent, critical and creative praxis in science education. Such compromise is unfavourable to the education of truly reflective teachers and detrimental to the learning of science by primary school pupils. By assuming that the analogy applies, that science educators and primary teachers possess different forms of knowledge for science teaching,
the prospect of a problematizing primary science teacher education in the mould of Freire's pedagogy can be considered. Such a model for teacher education is guided by the principle of dialogicity and based on a radical-democratic stance. To accomplish this, therefore, an investigation of practices, arguments and metaphors of a group of primary teachers has been planned. This investigation, called Thematic Investigation, is designed to focus on the common experiences and shared understandings of these volunteers. In fact, the aim is to reveal the thematic universe, the meaningful thematics of the body of primary teachers of which my volunteers are representatives.

The themes contained in this thematic universe are basically propositions (symbols) and cases (actions) which form, respectively, teachers' propositional and case knowledge (Shulman, 1986b). It has been assumed that in order to investigate this, an effort must be made to help volunteers recall highly emotive passages of their experience in teaching science. Underpinning this assumption is the belief that critical consciousness entails situations in which one's principles are confronted, where no precedent or simple answer applies and new feasibilities are required. In these situations, teachers recall challenges and obstacles which reveal their level of strategic knowledge (Shulman, 1986b); the emotive passages reported are either examples of liberating actions - successful responses to the challenges - or their antithesis: examples of their frustration with the incapacity to overcome obstacles they face.

II. RESEARCH DESIGN

During the course of this research I have been willing to balance radicality and democracy: I do not claim neutrality, I take the side of teachers and do not resort to the authoritative language of academy nor assume an attitude of laissez-faire; I do not attempt to explain the actions of individuals, the roots of their thoughts, nor the relation between these aspects and the contexts in which individuals find themselves. I attempt to focus on their culture - the relationship between individuals and their contexts. Given that I consider the prospect of drawing on this study to formulate an in-service education programme, I do not maintain that I simply observe; I aim to pose problems and thus challenge volunteers to engage in meaningful reflection.

In the design of this research, the key concepts of Freire's Process of Conscientização determined several of its features. In this (second) part of the
chapter, those features are described together with constant reference to the concepts. Section A, ‘The Sample’, discusses the way I applied Freire’s concept of ‘limit-situation’ as the criteria to determine the universe sample from where to seek volunteers. As I have said, ‘limit-situations’ are situations in which the individual is trapped by events in such a way that he/she has little or no chance to avoid having his/her more basic values and beliefs challenged.

Section B, ‘The Focus of Interest’, defines what is considered as data in this study. The argument departs from the discussion conducted earlier about the role of emotions in the development of a professional knowledge base for teaching. In that early discussion strategic knowledge, one of Shulman’s forms to represent teachers’ knowledge, is shown to correspond to the complex of teachers’ liberating actions’, a concept Freire uses to describe people’s response to ‘limit-situations’. This section considers, therefore, the phases of Freire’s literacy method in the light of my intention to conduct a Thematic Investigation of teachers’ strategic knowledge, as opposed to an investigation of labourers’ vocabulary.

To conduct this investigation of meaningful themes in science teaching is to look for teachers’ propositions and cases. However, these are only the forms teachers use to represent their knowledge. Under Freire’s influence it would not be possible to take teachers’ forms of knowledge as data. It would be like choosing words like ‘grape’ and ‘Grace’ for a literacy programme, when the criterion for choosing them is the form gr + vowel + extra syllable, rather them what ‘grape’ and ‘Grace’ refer to, or what importance students give to them. Like ‘words’ in a literacy programme, ‘propositions’ and ‘cases’ in a teacher education programme may mean something different to teachers from what they mean to teachers of teachers. So - refraining from using the word ‘content’ because there could be a confusion with ‘content knowledge’ - it is important to know what is the matter or the substance that takes form when teachers resort to those ‘propositions’ and ‘cases’. Put another way, it is necessary to know what is in essence appearing in the form of a ‘proposition’ or a ‘case’. Put yet another way, it is essential to know the referents to which these ‘propositions’ and ‘cases’ refer. The challenge involved in doing this is like the challenge of translating hieroglyphs; one does not even know if, say, a principle or a maxim for teachers plays the same role in their discourse, as a principle or a maxim plays in the discourse of teacher educators. In short, for both parties to understand each other, they may need to resort to a third intermediate ‘language’, as was the case in the deciphering of hieroglyphs. That is the course of action I have taken. The ‘intermediate language’ in this case is Shulman’s domain of content knowledge for teaching.
With the identification of an ‘intermediate language’, a crucial problem in transposing Freire’s Thematic Investigation to the realm of research on teachers’ thinking and action is solved. However, yet another difficulty needs to be overcome: that of finding a method to approach teachers dialogically. It should be a method in which the subject of discussion may be broadly predetermined, but the actual topics not; which gives participants room for negotiation, allowing for problematization, for probing, and for increasing depth of reflection, as well as for evasion from intrusion. In section C, ‘The Approach’, my recourse to the Repertory Test as a methodological approach for data collection is justified. Here, the concept of ‘personal construct’, central to that approach, is compared with the concept of ‘generative theme’, central to Freire’s Thematic Investigation.

In section D, ‘The Analysis’, particular attention is devoted to the conversations-interviews triggered by Rep Test. I consider this my main data source. Here teachers are asked to reflect on their patterns of response to question-cards, their choice of criteria of comparison and consistency in the grading of these elements; so data stemming from other sources is included in the discussion. The analysis of these interviews requires careful consideration since the intention is not to understand, for instance, what causes teachers to show an inconsistency between their discourse and their practice. The aim of the study is to describe these inconsistencies, and also, the differences between the propositions of teachers and teacher educators regarding the teaching of science; the distinction between understanding and description is a topic under discussion here. Another topic concerns the demand to represent the culture of the investigator. Freire proposes that the investigator should have a well-established set of criteria to select and organize the ‘words’ that emerge from the study of the people’s vocabulary. In the case of literacy, these criteria stem from semiology, the science of all systems of signs and therefore a good representation of the culture of the investigator (see chapter 2, section B). To represent the culture of the science education community, I have used a heuristic model, called a Tetrahedron of Principles, which I devised some time ago (Vaz, 1989). This model will be described, together with a description of the work that gave birth to it.

After an initial reflection on the question of discourse analysis, language and the politics of emotion, finally, section E summarizes the whole discussion concerning the design of this investigation.
A. THE SAMPLE

The argument here is that the problems of communication between teachers and teachers of teachers do not arise because they are at cross-purposes. The problem of communication between them is not even because they talk about different things - that is, different students or different perceptions of the disciplines to be taught. I maintain throughout this study that these are not the main reasons for failures in teacher education. These possibilities exist and indeed may apply, but only if teacher educators possess too naive a consciousness about teaching or about teachers. What will become clear through this study, is, first, that there is a distance between what teachers think they are doing (or think about it) and what they are doing; second, there is a gap between the way teachers see teaching and learning, as well as education as a whole, and the way teacher educators see these issues. In fact, there is yet a third gap to be considered, though this is not analysed here. This is the gap between teacher educators' theories about learning and teaching - as well as propositions about education - and the way they expect teachers to learn, the way they teach teachers and the way they conceive teacher education as a whole.

The empirical enquiry I conduct here, therefore, aims to investigate teachers' discourse, to observe whether the anchors of their teaching - the principles, values and beliefs that compose their wisdom of practice - bear any relationship to the formal and generic propositions of teacher educators. This is done on a very small way. First, I only look at teacher education in the realm of science. In fact, only elements of this area pertaining to the teaching of physics are considered in any detail (see section B ahead). Second, primary teachers in England and Wales are chosen as the sample universe for the study. The advantages of choosing this particular population of teachers to study are mainly two. Firstly, they are primary teachers and primary teachers are non-specialist teachers of science. Second, when the study was being planned, primary teachers in England and Wales were being challenged by a government decree demanding that they introduce science as a core subject in the education of all pupils from the age of five.

By choosing non-specialist teachers of science for my study, I obtain a sample of teachers who do not have a great deal of knowledge of the subject matter in science in general, and in physics in particular. In fact, as non-specialist teachers of science, primary teachers in general have a certain aversion to scientific subjects (Morrisey, 1981; Carre et al, 1990). Such factors place them at a maximum distance from myself; I am a physics graduate and have a penchant for scientific
matters. Moreover, I have no experience teaching in primary schools. These differences between us are very auspicious. Having these factors to distance my volunteers from me, I simplify the task of demonstrating that in their wisdom of practice teachers show, in this case, elements of practical and theoretical knowledge generated through research in science education. This task is easier than it would be if volunteers were also physics graduates with a penchant for scientific matters, in which case it would certainly be possible to identify common knowledge. However, it would be much more difficult to pinpoint where both parties’ knowledge of subject matter for teaching differs; to identify which are the possible areas of conflict in the encounter of practitioners and theorists. In working with primary teachers, the methodological tools to be developed can be rudimentary and yet detect these areas of divergence, which in this case, are more noticeable. In other words, this choice of population for my study helps me to prove that the proposition about personal knowledge having hints of formal and generic knowledge is tenable.

The reason I sought volunteers in England and Wales is that the primary teachers of these countries have been challenged by the National Curriculum (DES 1987, 1989, 1991) to introduce science as core subject in their classes. The fact that these teachers have been thus challenged has a great emotional, and, consequently, professional impact on them. As I saw it, this curriculum had the potential to steer these teachers out of a modus operandi they had developed regarding the teaching of science. It would represent, to use Freire’s concept, a limit-situation for them. In so doing this curriculum introduction had the potential to undermine, in turn, a modus vivendi these teachers had reached with science teachers in general, and science teacher educators in particular. Ideological divergences would, then, show evidence that these parties actually belong to different cultures - the two cultures C. P. Snow (1959) talks about. Because I anticipated this would be a dramatic, historical moment, I had the feeling that it would be easy to find volunteers here, that they would be willing to reflect on their own practice and on the role of science in the education of pupils. This willingness would not only help to highlight their approaches to the teaching of science. It could lead primary teachers to produce solutions to questions of primary science teaching that could not have been imagined before; either by themselves or, particularly, by science educators. As Freire would describe it, these teachers would then produce untested feasibilities in response to the limit-situation.
B. THE FOCUS OF INTEREST

Shulman's (1986a,b; 1987) theoretical framework for the study of teacher understanding and transmission of content knowledge is usually adopted by scholars studying teachers' thinking and actions. This framework provides parameters to classify, on the one hand, the domains and categories of teacher knowledge and, on the other, the forms for representing that knowledge. According to Shulman's framework, therefore, the form of primary teachers' knowledge most germane to the purpose of pointing to areas of ideological conflict between those teachers and science educators is their strategic knowledge. As discussed earlier, this form of teacher knowledge is an articulation of the other two: propositional and case knowledge. Besides, strategic knowledge comes into play precisely when teachers confront theoretical, practical, or moral dilemmas (Shulman, 1986b, p. 12c-13a). However, one has to be able to make sense of teachers' language in order to use their strategic knowledge to highlight areas of conflict between this strategic knowledge and alternatives to it. In a word, it is necessary to translate their language into our own. This requires that the precise topics of the dialogues or conversations between volunteer teachers and investigator be clarified. This section deals with this area of interest.

In order to learn more, and learn better, about teachers' different forms of knowledge, as Shulman also contends, we need to focus on the teaching of particular topics. We cannot identify teaching competence with pedagogy alone. There are subject-specific aspects of pedagogy and, in order to teach, teachers do need to have this pedagogical understanding of the subject matter and of its topics (Shulman, 1986b, p. 7; 1987, p. 5; Wilson et al, 1987, p. 105). It is necessary, therefore, to precise the focus of interest in this study of primary teachers' forms of knowledge.

1. The Focus on Physics

In reading the literature of research on teaching, it is clear that central questions are unasked. The emphasis is on how teachers manage their classrooms, organize activities, allocate time and turns, structure assignments, ascribe praise and blame, formulate the levels of their questions, plan lessons, and judge general student understanding. What we miss are questions about the content of the lessons taught, the questions asked, and the explanations offered. From the perspective of teacher development and teacher education, a host of questions arise. Where do teachers' explanations come from? How do teachers decide what to teach, how to represent it, how to deal with problems
of misunderstanding? (Shulman, 1986b, p. 7a)

The first hurdle in this exercise of stating in detail the focus of interest of this study thus concerns the subject area whose teaching is to be explored. Science might be considered as a domain of knowledge by literary intellectuals and lay people, but amongst the scientific literate the distinction between each of science’s subjects is not only relevant but necessary. This distinction is most critical if we accept the premise that there are subject-specific aspects of pedagogy and then plan to engage in dialogue both the subject specialists and the non-specialists who teach this subject. If it failed to focus on the specialism of the former, the investigation would clearly drift away from the intended area of enquiry: the conflicts which distance these interlocutors. This, in turn, would frustrate any effort to eradicate or attenuate those conflicts and promote the changes which only a partnership between these groups would achieve. As a specialist intending to enter into dialogue with non-specialists, I decided not to conduct the present study on primary teachers’ teaching of science in general. Instead, I focus on those topics where I have some experience of teaching. This virtually confined our dialogues to those attainment targets of the National Curriculum for England and Wales concerned with topics of physics.

In a sense, it is not easy to separate the ideas of ‘physics’ from those of ‘science’ in respect of primary schools. In any case, for these teachers, the distinction between the teaching of physics and, say, the teaching of technology or chemistry, is somewhat blurred. The initial difficulty of separating ‘physics’ from ‘science’, however, did not constitute a strong enough reason for abandoning the decision to make the distinction throughout the study. The rationale for such a decision was firmly grounded in both Freire’s and Shulman’s accounts of, respectively, the process of conscientização and the development of strategic understanding for teaching - discussed earlier in this chapter. However, it is interesting to note the ideological nature of the differences between my volunteers and myself here, even though this may subvert slightly the logic of analysing the points of friction after the means to identify them are discussed.

Due to our different levels of knowledge of physics - that is, knowledge of the facts and concepts of physics - the experience primary teachers have teaching this discipline is nothing like mine or that of a lecturer in a university or even that of a high-school teacher. For instance, in his/her ‘teaching of physics’, a primary teacher would, for instance, rarely, if ever use algebra, which is commonplace in the teaching of this subject at a higher level. Incidentally, it is necessary to stress...
that the expression "primary teachers' teaching of physics" is being used here as a
shorthand. To be fair, the expression should be: primary teachers' (a) conduction
of practical investigations and other activities on topics in the domain of physics;
(b) discussion of their outcomes and the strategies that led to them; (c) fostering of
the development of attitudes and skills relevant for these investigations; and (d)
release of information to pupils of facts and ideas of physics related to all this" (see

There is however a less obvious line of argument to be followed in the analysis of
ideological differences between primary and specialist teachers. This particular
line of reasoning is one which focus attention on the problem of the organization
of disciplines (Schwab, 1964a, p. 15-21). This involves, for instance, the
competences and habits required for scientists to carry out their work and the
methods and modes of enquiry of the different scientific disciplines. From the idea
that scientists observe, hypothesize, design 'fair-tests', conduct these, draw
conclusions etc, primary teachers, in essence, argue that it does not matter if the
person studies the nature of neutrons, of polymers, or of amoebas. Since this
person’s works according to that ‘method’, showing a particular competence,
he/she is a scientist. From this point of view, the competences and habits required
from a scientist to carry on any scientific enquiry are apparently the same across
the board. There are two apparent reasons for primary teachers to develop this
point of view. First, due to their restricted scientific background, primary teachers
may be unsure on which subject matter each of the natural sciences works. Second,
perhaps influenced by Science National Curriculum Attainment Target 1 -

In any case, for these teachers, the distinction between the teaching of physics and,
say, the teaching of technology or chemistry, is somewhat blurred. In order to avoid
controversy, I decided to turn to the statements of attainment in the curriculum
documents and find what I would classify as physics. At the beginning of this study,
the 1989 version of the Science National Curriculum was still in force; there were
then topics of physics scattered throughout the seventeen attainment targets. In the
1991 version, it is the ‘Attainment Target Four: Physical processes’ which
encompasses most of the physics elements. For Key Stages 1 and 2, which
correspond to classes of pupils aged from 5 to 11, these are the topics which I
classify as topics of physics: light; sound; the place of Earth in space; the position
of the Sun and of the Moon in the sky (day and night, and seasons); magnets;
electricity; temperature recording; floating and sinking; moving toys (energy);
forces. ‘Weather’, which is a topic studied under the geography curriculum, was
also marked by some teachers as a topic of physics; it involves the measurement of
temperature and other issues related to physics concepts. At the same time, I
adopted an attitude of flexibility. I would insist as much as I could on the choice of
physics themes, but if volunteers argued that they needed to bring in other topics,
say, from the technology curriculum, I did not forbid this. I would just try to make
sure I understood the nature of the activity which was carried out. In short, I
eventually followed Freire’s principle of dialogicity, directing but not imposing, as
explained in chapter 2, section C.

2. Questions about the Content

Having decided to concentrate on the teaching of those topics listed above,
another question concerning the focus of interest of this study remains
unanswered: what are the questions about the content of the lessons taught in
primary school that could be asked? The idea is that, by choosing to deal with
topics of physics, the passages teachers recall of their experience teaching the
subject can later be decoded by the co-ordinator of the Thematic Investigation.
However, this is as yet somewhat vague. A sharper definition of the focus of
interest is still necessary. The decision to focus on teachers’ strategic knowledge
addresses that, but only in part. Teachers’ strategic knowledge, as mentioned
before, relates to emotional themes of their praxis. This is a requirement of the
methodological strategy adopted, but, as a form of knowledge, it only refers to a
way to represent domains and categories of teacher knowledge, domains and
categories which are yet to be characterized. In order to characterize that, it is
worth recalling the function these aspects of teachers’ knowledge are expected to
play in the investigation as a whole. I shall refer to the phases of the Metodo Paulo
Freire to do this (see page 57).

The study of teachers’ thought-language is, roughly speaking, a study of their
vocabulary. It therefore involves two steps: the identification of ‘words’ in their
‘vocabulary’, and the observation of their ‘use’ of this ‘vocabulary’. As Freire says,
people use words to name their world. So, words, here, are references to the world
of primary teachers in the restricted realm of physics teaching. In that sense,
priority has to be given to references that are meaningful to teachers; episodes
associated with specific feelings, for example. In addition, it would be convenient
for the investigator if such references constrained to a (thematic) universe with
which he/she is familiar. Primary teachers may have a lot to say about the teaching
of topics of physics and story telling or role play, but if the investigator does not
have knowledge or experience in this area of teaching, these will be curiosities
rather than themes for him/her to discuss in dialectic dialogue with teachers.

Together with this concern to determine the 'vocabulary' that is being studied is the concern to make teachers 'use' this 'vocabulary', for example, commenting why they make references to some episodes that are different from the references they make to other episodes. It is when teachers do this that the investigator can learn more about what functions certain examples, cases, anecdotes or parables have in the discourse of teachers. That is when the investigator can make sense of some of the propositions teachers make or values they express: the moment teachers' episodes gain life to the investigator, the moment 'words' are used to form phrases, and these are used to express opinions, strategies and knowledge.

So the process needs to start with teachers somehow expressing themselves and to end with the investigator identifying elements of teachers' knowledge and experience in their discourse. Such identification will happen as the investigator frames teachers' discourse with his/her own knowledge and experience. But which questions would start this process? How can the goal of finding themes that are meaningful (as far as teachers' strategic knowledge is concerned) and relevant (as far as science educators' formalized knowledge is concerned) be achieved? As I have argued in the previous section, these questions have to be about the subject of physics content knowledge, but that is still not helpful. Defining that as within the focus of interest of this study is important only to the extent that it makes clear that generic teaching skills that transcend this subject or its topics are outside such focus of interest. But if 'plain' pedagogic knowledge is not adequate for the study of teachers' knowledge for teaching, 'plain' knowledge of a subject matter is also inadequate for this purpose (Shulman, 1986b, p. 8b). At this point again it becomes apparent the contribution of Shulman's work to this study. The questions to ask teachers about the content of their lessons in primary school physics ought to relate to what Shulman calls 'content knowledge in teaching'.

Shulman characterizes 'content knowledge in teaching' dividing it into three categories: (a) subject matter content knowledge; (b) pedagogical content knowledge; and (c) curricular knowledge (Shulman, 1986b, p. 9a):

a) subject matter content knowledge goes beyond knowledge of the facts and concepts of a particular subject matter, thereby going to the structures of disciplines. Structures, in this case, are those which Schwab calls substantive and syntactic (Schwab, 1964a,b). The substantive structure of a discipline, broadly speaking, relates to the conceptual structure which guides the formulation of questions, planning of inquiries
and interpretation of emerging data within that field of knowledge (Schwab, 1964a, p. 12). The syntactic structure of a discipline, on the other hand, is, in synthesis, related to the way in which discoveries take place or the proof of assertions is sought (Shulman, 1986b, p. 9a-b).

b) pedagogical content knowledge goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching. The reference is to the most useful ways of representing topics which are regularly taught: the most powerful analogies, illustrations, examples, explanations, and demonstrations. The term also refers to a certain inside knowledge of the learning process: an understanding of what makes the learning of specific topics easy or difficult, conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (Shulman, 1986b, p. 9c-10a).

c) curricular knowledge is knowledge of everything available for the teaching of topics in the curriculum of one subject at a particular level. So, basically, it refers to schemes of work and instructional materials available, as well as rules of thumb about conveniences or inconveniences in choosing those schemes and materials in different circumstances of sensitivity, cost, safety, comfort, etc (Shulman, 1986b, p. 10a).

It is within this domain of teachers' knowledge for teaching that we can find a language capable of coping with the abstract nature of the clash of cultures, focused on here. If, through this language, we look at the different categories of primary teachers' domain of content knowledge in teaching related to physics, we will be able to formulate our questions. It will be possible to translate our abstract concepts (the principles, maxims and norms which form our formalized knowledge) into teachers' idiom. This translation is necessary, after all, as Freire notes:

Ordinary people do not do the kind of abstraction done by academics like us. Our abstracting makes us more and more distant from the concrete. When common people speak, they try to understand their experiences through parables, metaphors, and stories, which keep them close to the concrete. The stories that they tell are the way they respond to the questions we ask. On the other hand, they tell stories to express themselves in relation to the world, and to give expression to their world. The metaphors and parables substitute for concepts as we use them, with the advantage of being profoundly concrete in
comparison to the abstractness of an intellectual's language (Freire in Shor et al, 1987, p. 150).

Since I play the role of the academic in this study that involves dialogues with non-academics, it is important that I acknowledge the extent to which my language is abstract and try to overcome the potential problems my use of concepts can create. If teachers try to understand their experiences through parables, metaphors, and stories, as Freire suggests, they will probably keep themselves close to concrete episodes, they have experienced, personally or vicariously. As teachers do so, they are likely to provide me with a host of prototypes, precedents and parables. These, as Shulman suggests, may consist on raw material for their reflection and a way to introduce them to certain propositional knowledge (theoretical and practical principles) to be put forward on a teacher development programme:

remembrances of teachings past are valuable in guiding the work of a teacher, both as a source for specific ideas and as a heuristic to stimulate new thinking. But other kinds of cases exemplify, illustrate, and bring alive the theoretical propositions that are potentially the most powerful tools teachers can have. These are the prototypes within case knowledge (Shulman, 1986b. p. 12a).

Therefore, the recourse to 'content knowledge in teaching' as an 'intermediate language' both teachers and myself understand greatly lightens the task of choosing representations of teachers' typical existential situations to function as challenges, as situation-problems in a subsequent teacher education programme. The great problem of interpreting teachers' parables, metaphors, and stories is averted by this recourse to the thematic investigation of their teaching of science. As I discussed earlier in part I, section B, the aim of conducting this research on teachers' thoughts and actions is "to enable participants in such research to gain from the experience of reflection and clarification of their thinking in anticipation of further action" (Pope, 1993, p. 13). If, as Shulman suggests, my investigation unearths material that can function as:

* source for ideas;
* heuristic to stimulate new thinking;
* cases that exemplify, illustrate, and bring alive theoretical propositions.

I can afford not to understand teachers' thoughts. After all, it is teachers who have to gain from the experience of reflection. It is teachers who have to clarify their thinking in anticipation of further action. It is reasonable to expect that they do so as they are asked to explain certain patterns in their reference to 'cases' or their
use of 'propositions'. In contrast, to expect that teachers decide to change their premises and hence their practice as a result of an investigator presenting an interpretation of the thoughts and actions he/she has observed teachers using seems rather less realistic.

So, as long as a number of conditions are satisfied, a research strategy such as Freire's Thematic Investigation can provide precisely what is needed for teachers to effectively fulfil their reflective and critical nature. In the realm of science teaching, for this fulfilment to be accomplished, teachers need concrete and meaningful themes on which to reflect: parables, metaphors and stories which, as primary teachers, they recognize as organic to their own experience. These themes must enable those teachers to translate science educators' concepts into new propositions (Shor et al, 1987, p. 151), and this will lead teachers to entertain the possibility that there are ways of dealing with their old problems and difficulties that have still to be tested.

For the investigation of these themes to yield such asset of parables, metaphors and stories certain conditions must be satisfied. As mentioned before, those who volunteer to be representatives of their group must, first, be willing to dialogue in the manner described: being constantly contradicted and challenged. They must trust the investigator's assertion that his/her purposes are emancipatory. If possible, even some sort of empathy with the investigator is desirable. These are difficult conditions to satisfy. As indicated later, in some cases people's attitudes change when they realize what is actually required of them and what they will in fact take out of the exercise in the short run. It does help, though, if the investigator does not patronize teachers, treating them as objects. In a word it helps to avoid the contradiction researcher-researched Collaborative Researchers warn us about:

many researchers still appear to speak in the impersonal and apparently authoritative language of academy, where the indigenous participants seem to speak for themselves, but nearly always end up as illustrations, justifications, or typifications of the researchers' arguments or hypotheses (Day, 1991, p. 538).

Still concerning the focus of interest of the investigation, there are other conditions with which to comply. As I have said, the Thematic Investigation must focus on the domain of teachers' content knowledge for teaching. An effort must also be made to choose topics the content of which the investigator too has experience teaching. In order to focus on themes particularly meaningful to teachers in that field, it is important that challenges and obstacles teachers faced in the past are sought out.
In this type of episodes, teachers are normally required to use their strategic knowledge. As a result, these are themes which exemplify the 'forms' in which each of the general domains or particular categories of teachers' knowledge may be organized. However, within the domain of content knowledge, teachers' knowledge of the facts and concepts of the subject matter being taught should not be an issue in the investigation. This and the domain of (content-free) pedagogic knowledge do not help to distinguish teachers' and investigator's forms of knowledge for teaching and are, therefore, useless for the identification of generative themes.

There are yet more conditions to be satisfied in order to provide parables, metaphors and stories which primary teachers recognize as being organic to their own experience. Being mainly a research strategy, as opposed to a research method, Thematic Investigation falls short of methods for the empirical collection of data; that is, for the study of teachers' actual 'vocabulary'. In the next section, I analyse matters concerning the approach to volunteers that a research method must follow if it is to work within the methodological strategy of Thematic Investigation. The solution to this problem has been to modify Kelly's Repertory Grid technique; the reasons for that are discussed in the following section.

C. THE APPROACH

The employment of Thematic Investigation as a methodological strategy for the study of cultural and ideological differences between primary teachers and science educators provides a number of responses to the practical problems involved in such a study. This strategy allows me to promote a dialectic and dialogical investigation which helps those being investigated to interpret their praxis and, at the same time, helps the investigator to interpret his own praxis as a secondary interpreter. The discussion of this choice makes clear the nature and purpose of the research. It becomes evident that this research has a practical orientation; its purpose is to prepare the ground for eventual (dialectic and dialogical) exercises of reflection in which the partial, fragmented and, to some extent, naive or distorted nature of each person's interpretations can be elucidated.

Thematic Investigation also establishes the approach to the empirical data collection, and to the criteria for analysing these data. Leaving the latter to be dealt with in the section "The Analysis", I will begin by discussing the research method. The method adopted is Kelly's Repertory Grid Technique. In justifying this method, I must emphasize two points:
* this research is of a practical nature;
* its purpose is to test the proposition that an approach to difficulties of communication between people, based on Freire's work, can redress the imbalance of that relationship.

In that sense, Carr and Kemmis (1986) provide a cogent argument, pointing out that educational problems are essentially practical problems and involve gaps between the theory and practice of the practitioners concerned. I believe that people's interpretations of their own ideas and experiences are necessarily partial, fragmented and, to some extent, distorted. Nevertheless, when people are challenged to analyse the 'taken-for-granted', they can gain new insights to improve these interpretations. It is my view that this perspective of challenging those being 'studied', not simply understanding them, turns educational research into a 'critical', as opposed to 'interpretive', social science.

To concede that educational problems arise out of the ideas and beliefs of educational practitioners is not to accept that those ideas and beliefs must be true. Practitioners' beliefs and preconceptions ... always entail some minimal claims about the way things are that may turn out to be erroneous or false. Indeed, unless some distinction could be made between what practitioners think or believe they are doing and what they are doing ... there would be no educational problems as such. It is precisely because there is some difference between what actually happens when teachers engage in educational practice, and their more or less accurate understanding of what is happening that educational problems occur. In this sense, educational problems arise when expectations about practical situations are not congruent with the practical reality itself. In other words, an educational problem denotes a gap between a practitioners' theory and practice (Carr et al, 1986, p. 111-2).

Based on this analysis, the problem in question here is of a fairly complex nature, as will become clear in the discussion that follows. In fact, as figure 4 shows, it has multiple dimensions; it could even be argued that it presents a kind of fractal nature. In the first analysis, the problem in question is the gap between primary teachers' practice and their interpretations of their practice. In this case teachers' theories about science teaching are under scrutiny. However, there is another problem involved. In the second analysis, the
gap between science educators' practice as teacher educators and their interpretations of this practice is also part of the reality in question. Moreover, science educators' practice in teacher education involves dealing with the gap between primary teachers' theory and practice in relation to, say, science teaching. Therefore, science educators' theories have a bearing on their analyses of primary teachers' theories and practices, and consequently on the way science educators educate primary teachers. The complexity of the situation is clear: at one level there is the gap between teachers' theory and practice; at another level there is the gap between teacher-educators' theory and practice, and at a further level the first two levels are intertwined since the gap in teachers' praxis has some bearing on teacher-educators' praxis as well.

Freire's theory constitutes a rational principle for investigating the situation in question. Because such a rational principle underpins this study, it requires a 'special language' for its empirical enquiry (Schwab, 1964b, p. 48). This necessity points to the second reason why Freire's strategy helps to deal satisfactorily with the complexity of the question: it instructs us to focus on the very themes which make the relationship between primary teachers and science educators problematic. Instead of isolating the theory or the practice of either primary teacher or science educator, the investigation should be based on a systematic analysis of the conceptions employed in both teachers' and investigator's interpretations of one another's practice. In order to accomplish this, the object of study becomes the 'points of friction' between the forms of knowledge of both groups of practitioners: in this case, the differences between their cultural orientations.

Let me draw on a theory of semiotics to describe the scenario. Communicative situations are the sum of a set of interlocutors, an object of communication and a medium of communication (Eco, 1976, p. 94). It can be said that the points of friction in question manifest themselves when, as interlocutors of communicative situations, science educators and primary teachers find that their cultural differences make communication somewhat problematic. However, these interlocutors need to communicate for science teaching to be effective in primary school. The object of this communication will be each one's knowledge of teaching. This, in essence, is their content knowledge in science teaching; and the forms in which that knowledge is represented. So, the interlocutors are a teacher and a teacher of teachers, and the object is strategic knowledge, concerning the teaching of physics, in the domain of content knowledge for teaching. The component yet to be specified here is the medium of communication of such dialogues.
As has been noted elsewhere (Olson, 1992, p. 69), in situations such as this, outsiders cannot automatically assume that they understand teachers, nor can the latter assume that they understand the former. Yet, it is in (dialectical) dialogue that teachers and ‘others’ (Fenstermacher et al, 1993) can begin to understand each other effectively. Dialogue is not a common feature of educational research methods such as classroom observation, questionnaires, or structured interviews; at least not in the dialectical sense in which the term ‘dialogue’ is employed in Freire’s theory. Using orthodox methodological approaches one presupposes at least two things. First, teachers’ discourse, or their practice, provide essential sources of data for the study of teaching. Second, through careful and persistent study, it will eventually be possible to establish some relationship between thought and action, between theory and practice, complex though as teachers’ thinking and actions might be.

When used in isolation, any of the methods mentioned provide only a partial view of teaching, for they either focus on teachers’ thought or their action. This limitation is recognized amongst educational researchers, so that Shulman and Calderhead, for instance, work with their associates (Wilson et al, 1987; Calderhead et al, 1994) and resort to multiple methods. The reason for these scholars to use a multi-method approach is out of thoroughness, it is not simply for the sake of validating findings through triangulation. However, multi-method approaches are not always practicable because they require a considerable amount of time. Therefore, they are redolent of a particular kind of power relationship between researcher and researched where such demands can be made. Further, multi-method raise questions about the compatibility of the different methods. There is, of course, a further reason to avoid these standard methods in this study: the positive qualities of the Repertory Grid Technique.

Here, as in most studies of teachers’ thinking or practice, the empirical research is a result of the investigator’s determination to conduct it. My motivation for the enquiry and my role in conducting it is naturally distinct from that of my volunteer teachers. It is my responsibility to give the study character, if not direction, and to allow for openness and even randomness. In the final analysis, it is the responsibility of the investigator to make the research a collaborative exercise. The literature in the field of teacher thinking research gives insight into the potential Kelly’s approach (1955, 1963) has in this area. Kelly first adopted his methodology, the Repertory Grid Technique, for the study of personality within the field of psychology. Pope and Olson are but two working on teacher thinking research who write about the potential of Kelly’s approach in this particular area:
We argue that teachers views may be highly resistant to change and will advocate an approach similar to views expressed by Kelly as a means of encouraging teachers to reflect on their positions and the implications of their viewpoints for their practice in the classroom (Pope et al, 1983, p. 1).

Much of what teachers know is tacit - hidden behind a rhetorical facade not easily penetrated. Visionaries must meet with teachers in such a way that the 'deep structure' of practice is revealed. Clinical methods such as those of Kelly have promise here if they are used heuristically and non-manipulatively (Olson, 1992, p. 69).

It is interesting to note, as did Clark and Peterson almost a decade ago in a literature review, that the Repertory Grid Technique has been used particularly in the study of teachers' implicit theories (Clark et al, 1986, p. 259). The aim has been to make explicit and visible the frames of reference through which individual teachers perceive and process information (Idem, p. 287). This work, as shown in my chart of the teacher thinking research area (figure 2, page 22), generally adopts an interpretive approach to educational enquiry. Kelly's technique is not the only method used in these studies, nor have all of those who have used Repertory Grids in the past not used any other approaches. Some, such as Pope, moved towards a more critical approach to research, broadening her emphasis to include biographical methods, 'snakes' and concept mapping (Denicolo et al, 1990). Others, like Munby, who have explored Repertory Grids (Munby, 1984) to study teacher thinking and decision making, have moved beyond this (Munby et al, 1987, p. 508).

One common thread connecting these studies is the importance they give to conducting research on teacher thinking as a form of (dialectical) dialogue; as Freire would put it: conducting it without splitting the two moments of the gnosologic cycle, the one when you know the existing knowledge and that you create new knowledge (Freire in Beisiegel, 1982, p. 284-5). In teacher thinking research this notion is expressed in different forms, such as: the suggestion of exploring metaphors in teachers' language (Munby et al, 1987, p. 508), the proposal to analyse of critical incidents in teachers' professional biography (Denicolo et al, 1990, p. 158; Pope, 1993, p. 25), or the argument about the importance of conflicts which teachers avoid confronting (Olson, 1992, p. 78).

Olson (1992) partially supports his argument through Freire's ideas. He adopts a metaphor which depicts teaching as culture (Olson, 1988). His aim is to understand the constructions that both teachers and inquirer hold, aiming at consensus. He
claims to conduct a sort of anthropological work, thereby adopting a hermeneutical methodological strategy. In Olson's view, "classrooms are faraway places with strange customs" (Olson, 1992, p. ix).

Kelly's Repertory Grid Technique is adopted as research method here on the basis of two factors. First, its promise in fulfilling requirements concerning dialogicity. Second, because of the features and characteristics of the theory behind it. Let me, therefore, proceed with a brief evaluation of the significance of Kelly's work and a comparison between this work and Freire's.

1. Kelly's Theory of Personal Constructs

Kelly is the author of an alternative to behaviourist and Freudian genres of psychology as theories of individual personality. His is essentially an applied, as opposed to theoretical, psychology, one which is based on a structural theory. Kelly's Personal Construct Psychology (PCP) is an applied psychology because it focuses on the ways in which a person anticipates events, and proposes that one can free oneself from the domination of these constructions (Kelly, 1963, pp. 46-9).

So, as a psychology, it looks at the process which comprises one's personality, not the content of it. Consequently, as a theory it is not a tool for enlarging knowledge but a tool for thinking (Jahoba, 1986, p. 9), which is the same as saying that it works on the basis of a rational principle of enquiry (Schwab, 1964b, p. 48). Such enquiry, incidentally, is not limited to that which is called intellectual or cognitive: as distinct from emotive and conative. As Kelly himself has put it:

The psychology of personal constructs is built upon an intellectual model, to be sure, but its application is not intended to be limited to that which is ordinarily called intellectual or cognitive. It is also taken to apply to that which is commonly called emotional or affective and to that which has to do with action or conation. This classical threefold division of psychology into cognition, affection, and conation has been completely abandoned in the psychology of personal constructs. (Kelly, 1963, p. 130).

Kelly, as Jahoba (1986) points out, has with PCP provided not only a theory but also an approach. This makes his ideas applicable to a wide range of contexts, as it has been to learning organization (Thomas et al, 1985), science education (Pope et al, 1985), physics teacher education (Thomaz, 1989; Bastos, 1992) and, as mentioned before, teacher thinking research and teacher education (Pope, 1978; Diamond, 1980, 1988, 1991; Olson, 1980, 1992; Pope et al, 1983; Munby, 1984; Kompf et al, 1990). Just as wide as the range of contexts is the diversity of uses of
these ideas. This is due, basically, to the adoption of either his theory or his methodological approach, or a combination of both. It is as an approach, not as a psychological theory, though, that his ideas come into the fabric of the present study. Nevertheless, my use of Kelly’s approach is not as a free-standing research tool and therefore it is not subject to the criticism of "ignoring his thought and falling in the trap of method-fetishisms" (Jahoba, 1986, p. 8). Kelly’s approach dovetails with the directions given by Freire’s methodological strategy, a dovetailing which results from a match between their theories at crucial points; with the caveat that not all of their thinking overlaps. As Kelly himself has pointed out, constructive alternativism, his philosophical position, “falls within that area of epistemology which is sometimes called gnosiology - ‘the systematic analysis of the conceptions employed by ordinary and scientific thought in interpreting the world, and including an investigation of the art of knowledge, or the nature of knowledge as such’” (Kelly, 1963, p. 16). As discussed in chapter 2, section C, for Freire, too, any pedagogic situation is a gnosiologic situation (Freire in Beisiegel, 1982, p. 284). As the present research is being considered as a pedagogic situation, it is very appropriate to adopt as research method an approach designed to perform gnosiologic analysis.

Substantial discussions of Kelly’s work, PCP and Repertory Grid Technique usage abound (see for example Bannister et al, 1971; Fransella et al, 1977; Pope et al, 1981; Bonarius et al, 1981; Fransella et al, 1988). Broadly speaking, Kelly suggests we should look at ourselves as if we are scientists and products of our own creation. We are scientists in the sense that we can place our interpretations upon the world of events confronting us and, from these personal theories, derive hypotheses and make predictions about future events. We are products of our own creation in the sense that all our present interpretations are subject to revision and replacement.

No one needs to paint himself into a corner; no one needs to be completely hemmed in by circumstances; no one needs to be the victim of his biography (Kelly, 1963, p. 15).

What Kelly argues is that, although there is a real world of events, no one has the privilege of knowing it; all one can do is to place one’s personal constructions upon it. This thesis, coupled with Kelly’s criticism of the classic view of science, gives evidence that his constructive alternativist approach to scientific enquiry is a form of empiricism. Kelly’s criticism is directed at the view that the world is essentially knowable and each research finding is a fragment of knowledge or truth which adds to the body of theories for an eventual complete understanding of nature. It is
worth bearing in mind, however, that Kelly is particularly concerned with our psychological nature and, in that sense, opposes the stance of behaviourism. The image of him, one which has wide currency among psychologists, is summarized by the saying: 'Kelly has done away with motivation' (Fransella, 1981, p. 151). He has done so because he construes all living organisms as constantly on the move. Therefore, concepts such as drive, motive, stimulus, purpose, value, need or psychic energies, common in other theories of personality, are not considered necessary. Here, there is a dovetailing of Freire’s Thematic Investigation and Kelly’s elicitation of personal constructs. But let me first tackle the bedrock of Kelly’s psychology.

The nature of a construct

The concept of personal construct is central to Kelly’s psychology. This psychology, it is worth noting, is presented in the form of one fundamental postulate and eleven corollaries which elaborate the postulate. This is therefore the postulate of PCP: a person’s processes are psychologically channelized by the ways in which he anticipates events (Kelly, 1963, p. 46). Kelly’s attention to anticipation, as noted elsewhere (Tyler, 1978, p. 130; Jahoba, 1986, p. 6), denotes a forward-looking orientation and optimism, for it focuses, not on the collection of behaving objects but, rather, on the limitless domain of possibilities of a person’s psychological processes. This optimism and future-orientation is similar to Freire’s, especially where Freire talks of one seeing ‘untested feasibilities’ when faced with ‘limit-situations’.

It is common to stress that PCP is primarily focused on individuals. However, what is important to emphasize is the fact that no psychologist denies that every human being is unique. Many regard this fact as a nuisance which has to be eliminated from research. Jahoba has noted that, as a rule, psychologists eliminate uniqueness by random assignment to experimental conditions and reporting results as averages (Jahoba, 1986, p. 4). As Jahoba has noted:

Some psychologists consider case study presentations to be the only way of dealing with uniqueness. Kelly found a way to a quantifiable description of individual uniqueness. Instead of eliminating it by the straight-jacket of experimental controls, he goes out to discover it (Jahoba, 1986, p. 4).

Kelly describes a person through the constructs he/she uses. As he says, we anticipate events "by construing their replications" (Construction Corollary: Kelly, 1963, p. 50). By noting that some events are similar to each other in certain ways
and thereby different from others, we are able to anticipate future events. The
criterion used to make this distinction is a construct, in so far as it has two poles:
one which states the similarities between kindred events and another which points
to the differences between this cluster of events and others outside it. A construct
is only a construct if this dichotomy is observed (Dichotomy Corollary: Kelly, 1963,
p. 59). But a construct need not have a wide range of convenience; that is, it might
apply only to a restricted type of events (Range Corollary: p. 68). Neither does the
dichotomy feature of constructs imply inherent tolerance. A person will choose
between the poles of his/her dichotomies in favour of the alternative which seems
to provide the best basis for anticipating the ensuing events (Choice Corollary:
p. 64-8).

So, as Kelly puts it, "each construct represents a pair of rival hypotheses, either of
which may be applied to a new element which the person seeks to construe" (Kelly,
1963, p. 129). In this sense constructs allow for one’s free will at the same time as
they constrain one’s freedom of choice.

Constructs are pathways of freedom of movement. Because they are two-way
channels they provide freedom for the person who possesses them; because he
can move only along these pathways they represent restrictive controls upon
everything that he does (Kelly, 1963, pp. 129-30).

Needless to say, this feature of Kelly’s concept of construct is one of the grooves
for the dovetailing of his methodological approach with Freire’s Thematic
Investigation. In the text which follows, the importance of this dovetailing is
discussed.

The construct system

The metaphor ‘constructs as pathways of freedom of movement’ reveals the
potential of Kelly’s theory to handle the complexities of a situation such as the one
studied here. The idea it imparts is that at the psychological level personality is
complex but not chaotic. Personality, according to Kelly, is made up of constructs,
some of which are symbolized by words, others capable of being communicated
only through pantomime and non-verbal means, and still others which "have no
language symbols, nor any kinds of signposts whatsoever" (Kelly, 1963, p. 130). These
are channels which crisscross the psychological space in all its multiple dimensions.
This space might be multidimensional and yet one might have limited degrees of
freedom to move within it. The proposition that each of these pathways is two-
dimensional enforces this restriction and reveals the power of Kelly’s model of our
decision-making system. Although it is essentially a deterministic model, it accounts for the chaotic nature of human behaviour.

Given the power of this metaphor, it is not surprising that some scholars throw themselves into the elicitation of personal constructs. The possibility of offering people a complete map of the rival hypotheses of their psychological space is very alluring, even for scholars who assert that predictability of behaviour is unviable. The possession of such a map would correspond to making explicit the grooves of one's personality and thus give the person control over the way he/she moves within it. This is already a bonus, given the impossibility of stepping out of the pipe-like grooves of personality. As Kelly has put it,

just as the experimental scientist designs his experiments around rival hypotheses, so each person designs his daily explorations of life around the rival hypotheses which are suggested by the contrasts in his construction system. Moreover, just as the scientist can not foresee possibilities that he has not somehow conceptualized in terms of hypotheses, so any individual can prove or disprove only that which his construction system tells him are the possible alternatives (Kelly, 1963, p. 129).

Since the construction system sets the limits beyond which it is impossible for one to perceive what is feasible, in the case of science teacher education the implications of Kelly's propositions are genuinely profound. Teachers' constructs concerning pupils, the nature of science, the value of learning science and learning about science, and many other issues, are bound to determine the way they teach this subject. Hence, the elicitation of these constructs could provide teachers with invaluable resources for them to make explicit rival hypotheses which intervene in their teaching. In possession of this knowledge, teachers could revise and improve their teaching of science.

Experience, learning and interpersonal construing

A number of Kelly's corollaries contribute to debates concerning experience, learning and interpersonal construing: individuality, organization, experience, modulation, fragmentation, commonality and sociality. Essentially, what is under discussion is whether or not a system of constructs evolves and how or when does this takes place.

It is through his Experience Corollary (Kelly, 1963, p. 72) that Kelly begins to talk about the grouping or system of constructs. This is where he makes explicit his view that it is not the succession of events lived by a person which denotes his/her
experience; "it is the successive construing and reconstruing of what happens, as it happens, that enriches the experience of their life" (Idem p. 73). Not surprisingly, the topic of learning is also discussed within this corollary.

The question of whether or not [learning] takes place, or what is learned and what is not learned, is no longer a topic for debate within the system we have proposed. Learning is not a special class of psychological processes; it is synonymous with any and all psychological processes. It is not something that happens to a person on occasion; it is what makes him a person in the first place (Kelly, 1963, p. 75).

It is by so describing learning that Kelly removes the topic from subsequent discourse, leaving others to infer from his general propositions particular implications for the understanding of learning processes. Kelly does give a cue for those interested in making these inferences, though. He reminds us that "construing is a way of seeing events that makes them look regular" (Kelly, 1963, p. 76). A system of constructs is constituted of a number of rival hypotheses tested on events experienced by a person. As established in Kelly's Fundamental Postulate, the anticipation of events is the objective of psychological processes. This is where Freire and Kelly coincide: on their ideas about challenges. As Kelly says:

The successive revelation of events invites the person to place new constructions upon them whenever something unexpected happens. As one's anticipations or hypotheses are successively revised in the light of the unfolding sequence of events, the construction system undergoes a progressive evolution (Kelly, 1963, p. 72).

Returning to primary teachers and the elicitation of their constructs about the teaching of science, the question is: would they necessarily revise their system of constructs in view of its revelation? According to Kelly the answer is: it depends. In the passage above it becomes unambiguous that, for Kelly, it is the emergence of the unexpected - not the knowledge of one's own system of rival hypotheses - that enables one to change. On the other hand, the challenging nature of emerging events may escape a person if this person does not attempt to discover their recurrent themes.

The person who merely stands agog at each emerging event may experience a series of interesting surprises, but if he makes no attempt to discover the recurrent themes, his experience does not amount to much. It is when man begins to see the orderliness in a sequence of events that he begins to experience them (Kelly, 1963, p. 74).
Freire would say it in another way: one needs to problematize what was once interesting surprises, challenging the person who has lived them in order to discover the recurrent themes in those events. Kelly himself recognizes in the Sociality Corollary (p. 95) that the basis for social interaction is the subsuming of other people’s construing efforts. So, for example, for me, the reason to elicit teachers’ constructs concerning the teaching of science is to be able to challenge these teachers, not just to make them aware of their own system of constructs. Kelly corroborates this view by saying:

In order to play a constructive role in relation to another person one must not only, in some measure, look eye to eye with him but must, in some measure, have an acceptance of him and of his way of seeing things. We say it in another way: the person who is to play a constructive role in a social process with another person need not so much construe things as the other person does as he must effectively construe the other person’s outlook (Kelly, 1963, p. 95).

Besides, Kelly’s approach to culture and group behaviour is through a study of the similarities and contrasts in people’s anticipations of life events and the channels they construct for making their predictions.

People belong to the same cultural group, not merely because they behave alike, nor because they expect the same things of others, but especially because they construe their experience in the same way. It is on this last similarity that the psychology of personal constructs throws its emphasis (Kelly, 1963, p. 94). This is where the focus of convenience of Kelly’s theory shows its promise for the present work. This promise is further explored below, where I compare Freire’s methodological strategy and Kelly’s methodological approach.

2. Repertory Test

The technique Kelly devised to help the elicitation of personal constructs is known as the ‘Repertory Grid Technique’, ‘Repertory Test’ or even ‘Rep Test’, for short. The use of the Repertory Test Technique to approach primary teachers’ culture, as it were, requires some adjustments. The changes I have made do not de-characterize the process, as this is described in classic references (for example Bannister et al, 1971; Pope et al, 1981; Fransella et al, 1988). Later in this chapter, the way this approach was implemented in the present research is described. This section provides a brief outline, showing how this approach fits with Thematic Investigation. Stated broadly, the Repertory Test consists of offering the interviewee an opportunity to compare elements of his/her reality. The way this
comparison is accomplished varies and depends on the objectives of the study. First, the elements most appropriate for the test are defined and the way they are going to be appointed is decided. Second, comes the comparison of these elements together with a verbalization by the volunteer of criteria adopted in that process. Third, there is an analysis of the consistency with which these criteria are used in the comparison of elements, together with an analysis of the similarities between elements according to the way they were classified. This analysis is accompanied by a discussion of the outcomes of the previous stages with the volunteer.

Perhaps it should be mentioned that due to the Rep Test being an unusual research method, an implementation is usually preceded by an explanation to those who undergo the process. In this study, I found it helpful to use a set of pencils, pens, crayons and marker-pens of different colours. In this description of the Repertory Test I use the same.

The choice of elements (filling of cards)

The Repertory Test consists of a structured discussion about the ways an individual sees particular elements of their life. These elements can be people of one’s acquaintance, public figures, places, objects, feelings... virtually anything. They can also be provided by the investigator, as when I produced my set of pencils and pens, or elicited by him/her from the volunteer’s own private world. In this latter case, after the process is explained, the interviewee receives a series of numbered cards.

In each card the interviewee has to write the name of a person, a place or any other reference to elements of his/her domain of knowledge and experience; this need only make sense to him/her. For the interviewer, each reference is an exemplar of what he/she sees as a class of elements. In other words, these references are answers to questions like: what is the name of… your father? mother? brother/sister? husband/wife? best friend?; questions like: Where do you… work? go to relax? meet people? feel uncomfortable?; or any question of this sort. The figures, places etc presented by the interviewee are the ‘elements’, with which he/she must deal. In fact, the questions which elicit these elements each bear a descriptor of the class of elements to be provided. In recent research in the realm of teacher thinking (Diamond, 1988), for instance, the investigator’s list of descriptors contained figures such as ‘self’, ‘teacher I would like to be’, ‘teacher I fear to be’, ‘mother’, ‘father’, ‘siblings’, ‘spouse/steady’, ‘friends’, ‘pupils’, ‘principal/deputy’ etc. In another study (Corporaal, 1991), about prospective primary teachers’ perceptions of ‘good teaching’, the elements were provided by the researcher and
were statements about good teaching. By and large, providing elements is preferable when the sample is quite large. In that latter study, 117 student-teachers were approached.

Whether the elements are people, places or statements, whether they are elicited or provided, they ought to be significant elements for the interviewee in his/her domain of knowledge and experience. In the case of elicited people, for instance, only the interviewee notes the names written on the cards; they refer to people who are part of his/her relationships. The researcher only knows the ‘role title’ that corresponds to each name; hence the number on each card and a list of titles. It is worth noting, though, that usually the way the volunteer ‘understands the role title’ or ‘responds to the question which prompts the provision of an element’ is not as relevant in a Repertory Test as the way such elements are compared by the volunteers.

Criteria of comparison (the triadic form)

There are many ways the interviewee can relate the elements of his/her reality. To explore these ways, the researcher presents the elements according to his/her quests and interests. The pencils and pens of my set, for instance, can be all presented at once or in the ‘triadic’ or ‘minimum context’ form. In the triadic form, the interviewee is presented with three elements of the set at a time. Each time, he/she is asked to give some criterion which would justify placing two elements as similar and, at the same time, characterizing the third as a sort of counter-example of the two. As a practice run, I used different triads from my stationary set, and, to differentiate the pens, volunteers used criteria such as: ‘pencil as opposed to non-pencil’, ‘cylindric as opposed to hexagonal’, ‘black as opposed to coloured’, ‘expensive as opposed to ordinary’, ‘attractive as opposed to poorly designed’.

Grading similarities and differences

Both similarities and contrasts are written down and a scale is set up; each element is to be graded with a score. For this study, the scores were whole numbers from 1 to 5. Although the range of grades is arbitrary, the users of this technique normally ask interviewees to attribute grade ‘1’ to elements that are well defined by the similarity (or ‘explicit’) pole of the criterion, and the highest grade to those defined by the contrast (or ‘implicit’) pole. Once the interviewee has graded the elements of the triad then the other elements are presented to him/her. He/she has to grade these according to the criterion that initially applied only to the first triad.
The scores for each element are then marked on a grid. A new triad is presented to the interviewee and the process is repeated. This process continues for as many different triads as one can possibly have with the given elements; or, more commonly, until either the interviewee cannot find new criteria to classify the elements, or the interview time elapses.

**Analysis of patterns**

After the filling-in, sorting-out of card triads and grading stages have been completed, the process continues with the analysis of the interviewee’s grading patterns. In this study, the computer based FOCUS algorithm was used (Thomas, 1976). With the aid of computer software (Mancuso et al, 1988) or without it, the analysis measures the consistency with which the interviewee grades pairs of elements under different criteria and the consistency with which pairs of criteria are used to grade different elements. The degrees of consistency can be calculated by comparing the mean values of score differences for each pair of elements, or of criteria. A coefficient of similarity can, consequently, be attributed to each pair.

Figure 5 was generated by RepGrid (1991), the software I used in this study. It shows the results of one analysis. The bipolar criteria are on the grid (or matrix) lines; on its columns are the elements (listed at the bottom). Each cell of the matrix shows how the element was graded under one criterion. For instance, the element 11 (Prism work), when graded under the criteria ‘Skills vs. Knowledge’ was scored ‘1’ meaning that it fits well as a ‘Skills’ sort of element, which is the similarity pole of this criterion. If we look at how elements 2 and 4 are graded we can see why, at the right hand side, the diagram (or ‘tree’) shows ‘100’ on the scale: these elements were graded consistently the same under each and all criteria.

![Figure 5: Output of RepGrid Computer Program](image)
criteria.

Discussion of the analysis of grading patterns

One cannot say that each bipolar criterion is definitely one of the interviewee's constructs in the domain of experience and knowledge to which the elements belong. The most that can be said is either that it is possibly a construct or that it is a proto-construct. In most studies, therefore, the process does not end with the analysis of grading consistency. In fact, it should not stop, but indeed start, there. The discussion of grading patterns (shown by the RepGrid generated trees, figure 5) gives the interviewee a unique opportunity to appreciate the structure of his/her own pathways of freedom of movement. Indeed, his/her psychological space is virtually open to public appreciation in that one particular realm. Thus, the dialogue that accompanies the discussion of coefficients of similarity is usually profound and quite distinct from conventional interviews.

3. Kelly in association with Freire

In previous sections, it has been possible to note points of contact between Kelly and Freire. Kelly's approach to the study of personality is being considered as the means to conduct a Thematic Investigation in this study. Thematic Investigation is the strategy Freire adopted to establish the programme content for literacy classes. However, here it is used as a strategy to establish the points of conflict between theory and practice - the teachers' own and those between teachers and teacher educators - in the realm of science teaching. Therefore, in view of my decision to adopt Rep Test as the methodological approach to this topic, I must consider whether Kelly's Repertory Test fulfils a number of criteria required by Thematic Investigation. I will need to compare Kelly's and Freire's ideas in order to evaluate if they are actually complementary as far as methodological matters are concerned.

As mentioned before, Freire devised a 'technique' to attain the balance of tensions involved in a dialogicity-based education (figure 3, page 73). This technique is the problematization of situations or subjects by the teacher in order that students consider such elements reflectively. This problematization is aimed at conscientização and aided by the previous conduct of a Thematic Investigation of the students' praxis: their actions in relation to their reality and the theories and interpretations concerning all these. So, the pivotal element of Freire's education is what he calls generative themes; themes which:

* are representative of the discourse of the collective of students,
suggest some degree of significance for them, and
potentially have the power to trigger critical reflection on issues of
general, technical, ideological or philosophical importance in society
according to teachers' judgement.

Kelly, in turn, devised a technique to help the elicitation of personal constructs.
This technique has the potential to problematize people's construction of events;
for instance, forcing the person to:
  * classify triads of elements;
  * express the criteria in bipolar form;
  * apply this criteria to other elements;
  * discuss the consistency of grading patterns.

Repertory Tests, too, balance tensions such as experimenter-centred versus
subject-centred research and determinism versus randomness of enquiry. The
cards used when elements are elicited have labels given by the inquirer, but this is
to give the volunteer opportunities to provide elements of his/her choice, and not
to provide exemplars for particular labels. Besides, in the sorting-out stage the
triads of cards can be taken at random from the whole set, leading to challenges
for the volunteer which were unplanned by the inquirer.

In comparing personal constructs and meaningful thematics one notices the fact
that Kelly and Freire conceive culture as constructed. Kelly's basic premise is that
people construe their experience in similar ways because they belong to the same
cultural group (Kelly, 1963, p. 94). Freire's emphasis is on the fact that people's
constructions eventually consolidate into a culture. So, although approaching the
issue from opposite directions, the two authors end up portraying culture in much
the same way. While Kelly describes culture as the subliminal unity in the variety
of individual personal-constructions, Freire portrays it as a social and historical
construction.

For Kelly, construing means 'placing an interpretation' and the distinctive feature
of Kellyan 'constructs' is that they are dialectical, or dichotomous. Likewise, as
Freire sets up the bedrock of his dialogical pedagogy, he depicts 'meaningful
thematics' ('thematic universe') as dialectic concepts. He proposes that, because
meaningful themes are associated with contradictory forces present at a particular
historical moment, they usually represent dialectical tensions experienced by those
living in that period.
An epoch is characterized by a complex of ideas, concepts, hopes, doubts, values, and challenges in dialectical interaction with their opposites, striving towards plenitude. The concrete representation of many of these ideas, values, concepts, and hopes, as well as the obstacles which impede man’s full humanization, constitute the themes of that epoch. These themes imply others which are opposing or even antithetical; they also indicate tasks to be carried out and fulfilled. Thus, historical themes are never isolated, independent, disconnected, or static; they are always interacting dialectically with their opposites. Nor can these themes be found anywhere except in the men-world relationship. The complex of interacting themes of an epoch constitutes its ‘thematic universe’ (Freire, 1972, p. 91).

Both authors talk about the various levels of cognitive awareness which people have, either of their constructs or rival hypotheses (Kelly, 1963, p. 16), or instead of the rival forces intervening in the themes of an epoch. Freire coined the term conscientização to refer to this act of becoming aware of such tensions. Using Kellyan approaches, it is usual to refer to the importance of ‘making the tacit explicit’ (Pope, 1993, p. 16). Nevertheless, both authors contend that one can be unaware of one’s own pathways of freedom of movement - psychologically or sociologically speaking - and yet be constrained in one’s movements by these pathways. Kelly makes this point, as we have seen, when he considers the existence of constructs which cannot be expressed, even by pantomime (Kelly, 1963, p. 130). Freire, to explain what he considers to be ‘authentic reflection’, discusses the notion of consciousness propounded by Sartre (1947) when this author, in turn, discusses Husserl’s concept of ‘background awareness’ (Husserl, 1969, pp. 105-106). It is in this context that Freire clearly expresses his critical realism in the following terms:

Although the dialectical relations of men with the world exist independently of how these relations are perceived (or whether or not they are perceived at all), it is also true that the form of action men adopt is to a large extent a function of how they perceive themselves in the world (Freire, 1972, p. 71).

Constructs elicitation and thematic investigation

Starting with Kelly’s Repertory Test, I am able to induce the emergence of each teacher’s structure of anecdotes, allegories, values and propositions. Then, I can see how, within the framework of individual structures, primary science teaching takes shape or assumes meaning (Cf. Kelly, 1963, p. 50). Once I understand the structural conditions in which the thought and language of the teachers are
dialectically framed, I can find the themes that enable me to communicate effectively with them (Freire, 1972, p. 69), particularly in relation to their professional development. However, for the transference from constructs to themes to be possible, some further developments are necessary. Rep Test has to conform to certain conditions in order to be used in a Thematic Investigation. The following list describes the conditions which I considered relevant and, in parenthesis, explains the way Rep Test can be modified. To serve in a Thematic Investigation, a research method should:

a) probe teachers' theories and practices in equal proportions

   (the elements of the grid must be episodes or events of teachers' practice, rather than people or statements about teaching - given that the criteria to compare these actions would necessarily be indicative of teachers' theories, principles of practice, beliefs, assumptions etc, then both practice and theory can be brought to light);

b) allow the investigation to be focused without the investigator being the only person to define that focus

   (the decisions about what is relevant concerning primary science education, and why, should be shared - they can be arrived at by a careful choice of the element role titles on the Rep Test cards and by the volunteers being given the chance to fill in these cards as and how they wish);

c) be dialectic, that is, it should begin to find in the volunteer the concept that this person has in himself/herself of himself/herself

   (an effort should be made to challengingly question teachers' choices and decisions - this could be achieved by contradicting their opinions when these show strong indication of important subliminal customs, traditions, ideas rising from the background);

d) exploit the role frustrations and difficulties have in one's thinking

   (an effort must be made to elicit elements associated with these features of the volunteers' lives, for use in the Rep Test; also, the triadic form of the test should be maintained since it creates contrasts and difficulties);

e) challenge the volunteers to focus on highly relevant aspects of their praxis

   (first the elements should be related to liberating actions and teachers' strategic knowledge for teaching; second, the discussion of the grading
patterns analysis should maintain a problematizing tone and the balance between the volunteers' propositional and case knowledge, probing both in the same manner).

Used in this way, Kelly's Repertory Test is a very appropriate means of approaching primary teachers, inquiring about their personal constructs and, in a sense, identifying meaningful themes related to the science education of primary school pupils. In order to obtain these results, teachers' individual contributions to the discussion need to be considered in perspective, so that the idiosyncratic component of their rag-bag of experiences, parables, hypotheses, intuitions, values, rules, and so on is left aside, and the societal component of these same features of their discourse can be highlighted.

In short, I am assuming that personal constructs are for the individual teacher what meaningful thematics are for sets of teachers from the same grouping. But in order to obtain generative themes out of a batch of meaningful themes, even more needs to be done. Generative themes are the result of the educator's selection of the learner's meaningful themes. The themes shown to be meaningful for the volunteers' must now be studied. These themes are essentially points of an emotional nature which, when pressed, indicate imbalances in the living organism constituted of the complex teachers' practice--teachers' theory + science educators' practice--science educators' theory (see figure 4, page 124). It is these imbalances which, I believe, impair the professional development of those individuals for enhanced science education praxis.

The following section discusses the selection of themes emerging from this methodological approach. It explains how meaningful themes related to primary science education as viewed by primary teachers are transformed into generative themes for a problematizing and dialogical primary science teacher education programme.

D. THE ANALYSIS

As far as the research design is concerned, I come last to the analysis of data yielded by the investigation of themes in the realm of science teaching. This is an investigation of teachers' discourse through dialectical dialogues with them. The main source of data for this study, therefore, is the discussion of results of the computer analysis of Rep Test. These computer outputs, as I have said, show grading patterns for the elements; grades which were attributed according to the teachers' own criteria for the comparison of such elements. Freire's methodological
strategy - Thematic Investigation - serves as a good guide to the features and procedures to be observed. In following these guidelines I have adopted the result of a previous work of mine as a framework for the exercise. A Tetrahedron of Principles (Vaz, 1989), as I will explain, sets up parameters for the analysis of the dialogues. The characteristics of this device are discussed below, together with a brief description of the study in the course of which it was devised and first used. These observations close my discussion of the research design and, in a new section, I consider the actual implementation of the research.

1. Descriptive Analysis

The use of Rep Test that I am proposing should allow one to recognize the existence and characteristics of imbalances in the relationship between theory and practice in teachers’ approach to the teaching of science. It follows from the previous argument that there is a great deal of worth on a descriptive analysis of such imbalances. It is reasonable to assume that there are, on the one hand, gaps between a teacher’s theory and his/her practice and, on the other hand, differences between teachers and teacher educators regarding each others’ knowledge and experience. All these issues concern abstract relationships between abstract entities. Moreover, these complexes of relationships and entities relate to one another. They are essentially complexes of complexes of complex entities, these repeating patterns of complex entities resembling the structure of a fractal (figure 4, page 124).

Because this object of study concerns abstract and complex relationships and entities, it seems very important to be able to describe it. Those involved in or with teaching will certainly benefit from the rationalization of such an object. Its description can give practitioners and educationists a clearer picture of the obstacles to the improvement of school teaching. Such a picture can, in turn, encourage those involved to rally their own ‘resources’ to fight off the root cause for the aforementioned gaps. I propose that, knowing the existence of these gaps and differences, science educators should study their characteristics and compare them with discussions that occur in science education circles. From specialized literature, for example, science teacher educators can draw on particular topics which may be useful to counteract such imbalances.

The result of this analysis, then, is a sketch of themes to be taken on to the next stage of this programme: that of a problematizing teacher education; i.e. its actual course or counselling sessions. So, during the analysis, teachers’ anecdotes and allegories are clustered and ranked according to the potential they have to
eventually generate teachers' authentic and dialectic reflection. In fact, anecdotes and allegories have not been differentiated from propositions. As I have said earlier in this chapter (part I, section C), it is assumed that anecdotes and allegories may be references to principles (practical or theoretical) and values, while propositions are basically the articulation and expression of these.

Hence, this possible future use of the outcomes of the investigation constrains the number of clusters in the analysis. This corresponds to making the clustering with a particular concern in view. The themes chosen should generate insights into topics found in the broad debate in which the community of science educators is engaged. My role in the process is of teachers' interlocutor. At the same time, I have in mind the design of the eventual 'problematising science teacher education' which will benefit from the analysis of such dialogues. Therefore, the clustering of teachers' anecdotes, allegories and propositions inevitably results from a personal interpretation of what science educators consider science teachers should reflect upon to succeed in their job. Naturally, such an interpretation builds on one's breadth of knowledge of science education research, one's range of experience as a practising science teacher, and expertise as a science teacher education practitioner. Some years ago, I attempted to summarize propositions within science education, and devised a heuristic model, the Tetrahedron of Principles (Vaz, 1989), which I will describe shortly (subheading 5 below). As I intend to draw on this model as a pre-established frame of reference for the codification of themes coming out of teachers' discourse, I shall describe how this integrates with the overall Freirean strategy.

2. The Place of a Fixed Framework in Freire's Thematic Investigation

At this point, it is important to recapitulate the main features of the research design and compare them to Freire's literacy method in order to discuss how my analytic framework integrates with my adaptation of Freire's method.

While undergoing the Rep Test and, later, discussing Rep-Grid outputs, teachers are going to be challenged to reveal anecdotes, allegories, parables and propositions concerning science teaching which are most meaningful for them. Their response to these challenges needs then to be analysed. This analysis has three objectives:

* first, to single out those themes which were shown by teachers to be emotionally significant for them;

* second, to prepare these themes to be re-presented to teachers for
further consideration;

* third, to eventually conduct a problematizing teacher education whose programme content outline sketch consists of these generative themes above.

This moment when teachers face the representations prepared here, is not part of the present study. The present investigation is only the beginning of a teacher education programme to take place in the manner of Freire’s literacy method. The phases of Freire’s literacy programme which correspond to the two main objectives sought here are:

**Phase 1** Research of the vocabulary of the groups with which one is working.

**Phase 2** Selection of the generative words from the vocabulary which was studied.

**Phase 3** Creation of the “codifications”: the representation of typical existential situation (Freire, 1974, pp. 49-51).

The first and second phases in Freire’s method correspond roughly to my, first, application of Repertory Grid Technique and, second, evaluation of this application - which is part of the analysis being discussed here. It happens, though, that this analysis comprises also the beginning of the codification Freire places in the third phase of his method. This is, in a sense, a result of the fact that, where Freire talks about generative words, I am referring to generative themes. Here, it is important to note, a teacher education programme, not a literacy course, is envisaged. Our uses of these terms, generative words and generative themes, should not be confounded. It is worth noting, though, that when it comes to the next phase of the process, we both have to have basically the same sort of material on hand.

The three initial phases of Freire’s method elaborate the programme content of a problematizing education. These phases aim to produce what is necessary to promote students’ ‘authentic reflection’: in the present case, a set of themes to problematize teachers’ constructions in their domain of knowledge and experience in science education. As Freire puts it, for literacy courses:

These representations function as challenges, as coded situation-problems containing elements to be decoded by the groups with the collaboration of the co-ordinator. Discussion of these codifications will lead the groups toward a more critical consciousness at the same time that they begin to learn to read and write. The codifications represent familiar local situations - which,
however, open perspectives for the analysis of regional and national problems. The generative words are set into the codifications, graduated according to their phonetic difficulty. One generative word may embody the entire situation, or it may refer to only one of the elements of the situation (Freire, 1974, pp. 51-2).

The set of themes to problematize teachers’ constructions need, likewise, to be situation-problems. Here too, the codifications should represent familiar situations for teachers. Nevertheless, these situations must open perspectives for the analysis of general problems of science education instead of being constrained to local, personal difficulties. In sum, teachers’ discussion of these themes - with the collaboration of science teacher educators - should lead towards a more critical consciousness of matters concerning the teaching of science.

To obtain such a set of themes liable to promote such ‘authentic reflection’, a particular strategy is necessary. Freire provides a very clear indication of how ‘generative words’ should be chosen for literacy programmes. As we have seen earlier (chapter 2, section B), Phase 2 of Freire’s ‘method’ describes precisely the use of semiology for that end. The same way that for Freire semiology constitutes a representation of the culture of the lettered, the culture of the literacy programme co-ordinator, the Tetrahedron of Principles (page 151 ff.) corresponds to my codification of the culture which I represent: that of science education.

The tetrahedron model fulfils - at least within the realm of this work - the need for a general ‘theory’ for all aspects of science education. The prospect of such a ‘theory’ becoming established among science education practitioners is unrealistic. Even so, there is a need to represent the elements involved in the teaching of science, if only to provide non-specialist teachers with a sort of travel guide or road map of the domain. Indeed, the tetrahedral model of science teaching can be the strike of a balance on an educational and research programme which urges the importance of dialogue, engagement and equality. In the same way that, in a problematizing teacher education, teachers are requested to codify their praxis, they have the right to ask for a codification of science educators’ praxis, and this model provides that. Explicit in this thesis is the recognition that it is as necessary to know and understand the culture of science educators and the social relations and material relations which inform it as it is to know and understand the culture of the teacher (Cf. Gaudiano et al, 1994, p. 137).
3. Analysis of Dialogues

Representing the culture of science educators to teachers, particularly primary teachers, is a very challenging task. To meet Freire's call for cultural contact in the realm of science education, one needs to escape notions of opposition oppressor/oppressed both in teacher education programmes and in the present research, too. At the same time that this research aims to prepare an opportunity for cultural contact, it does itself consist of a cultural contact Therefore, the concrete and lived dialogues taking place here must not be substituted with 'simulacra and pastiche' (Gaudiano et al, 1994, p. 137). It is importance to make clear how the analysis of dialogues between people described as so very dissimilar does not reproduce the usual discriminatory opposition.

The dialogues central to this study are teachers' discussions of the Rep-Grid output with the interviewer. They have been audio-recorded and transcribed, by and large, by a third person, not involved with the process. The transcriptions have then been annotated by the interviewer-analyst, alongside other material (interview notes, interviewee's schemes of work, supplementary comments). The next stage is for the reactions to particular events, or the ideas generated in each person, to be grouped (Cf. Freire, 1974, p. 51). This procedure reproduces Freire's process of selecting generative words from a vocabulary. Maciel (1963) maintains that a semiological principle should be adopted for this task. He draws attention to the importance of "the greater or lesser tenor of conscientização which words potentially carry" (cited in Freire, 1974, p. 51), which, as Maciel points out, stems from the area of linguistics known as pragmatics (Davis, 1991; Mey, 1993).

The object of investigation of pragmatics is the meanings that persons receiving a message attribute to the signs it contains. This, as Maciel has already signalled, corresponds to investigating generative words among illiterate adults. A similar analysis would be helpful in an investigation of themes of science education to generate reflection among primary teachers. As discussed earlier, there is a case for an investigation of non-specialists' interpretation of science educators' terminology applied to the learning and teaching of science. Moreover, there is also a case for an investigation of science educators' interpretation of non-specialists' practice in teaching science. Since these parties have to communicate with each other, rules describing how they may enter into meaningful dialogue would be invaluable. Science teacher educators, in particular, need to know how to sequence topics within their courses and how to anticipate the information needed by teachers. There is something to be learned here from the rules of pragmatics.
The anecdotes and allegories provided by teachers in the Rep Test are - presumably - situations they lived through for themselves or experienced vicariously. In other words, the themes to come out of the present research will be situation-problems and situation-problems will be familiar to teachers if they relate to teachers' case knowledge; the combination of cases Shulman classifies as:

a) prototypes,
b) precedents, and
c) parables.

As I have said, teachers are being challenged to provide these sorts of cases, so the present analysis is likely to portray teachers' case knowledge. However, one must not lose sight of the importance of such prototypes, precedents and parables. For teachers, these cases are examples or representations of teachers' own propositions. In other words, they are teachers' own codification of their propositional knowledge. As Shulman puts it (Shulman, 1986b, p. 10-2), each of the three types of cases correspond to one type of proposition, since they, respectively:

a) exemplify theoretical principles,
b) capture principles of practice or maxims, and
c) convey norms or values.

Incidentally, the three types of propositions, as seen before, are principles, maxims, and norms (Shulman, 1986b, p. 10), respectively.

Whilst for teachers their own anecdotes, allegories and associated propositions can be seen as elements of a fairly consistent and structured representation of reality, these elements may be considered to be 'signs' which these teachers use to communicate their professional praxis. The study or analysis of these 'signs', as they relate to teachers, can be characterized as being concerned with a kind of large-scale pragmatics. It looks at more than teachers' speech, recognizing the local, contradictory, and fragmented character of this discourse of teachers. It takes this communication between teachers and science education expert as productive of experience and constitutive of the reality in which they live and the truths with which they work within professional development and support programmes. This communication is seen as distinct from that teachers establish between themselves; here there are serious cultural and ideological differences between the interlocutors. Teachers' anecdotes and allegories might find no
correspondence in science educators' case knowledge. The former's principles, maxims and norms and the propositional knowledge of the latter might not match one another either.

If the objective here were to study the communication between primary teachers, I could act as an ethnographer and learn the 'vocabulary', the 'semantics' and the 'syntax', in sum, the language of this other 'culture'. In that case, the study would probably follow the pattern of interpreting teachers' anecdotes and allegories in order to infer their own practical, conceptual, emotional or ideological frameworks. But since the communication to be studied is that between my equals and the equals of the present volunteers, a different analysis seems necessary. Instead of interpreting those anecdotes and allegories, or finding out why they were chosen by teachers, in the first place, I will look forward and try to foresee which of those 'signs' used by them are likely to be a source of misunderstandings when other people of similar background to me and them try to communicate as we did. Moreover, I will also try to foresee which of those 'signs' used by them offer me the opportunity to introduce practical and theoretical propositions for them to consider. These propositions, I would draw from my experience teaching and my knowledge of the literature. In other words, instead of attempting an understanding of teachers' syntactics or 'semantics', I am trying to establish ways in which we can have a harmonious and productive conviviality. I am, in short, trying to determine the basis on which rules of pragmatics for science teacher education can be established.

4. Investigation Questions

Repertory Tests can trigger dialogues that are indeed very wide in scope. Nevertheless, they do provide a research method which helps to contain the subject of conversation within manageable proportions. In our case, it helped to guide the conversation to subjects of interest to the investigator. Then, in the process of analysing these conversations, the teachers' discourse could be examined in a search for:

* prototypes to exemplify theoretical principles of, for instance, learning psychology or linguistics;
* precedents which clarify principles of practice, or maxims, for example, about children's alternative conceptions or curriculum planning;
* parables which convey norms or values stemming perhaps from studies on the history, philosophy and/or sociology of science.
Clearly, the aim is to take the situations presented by teachers and re-present them as examples of science educators' propositions. So, the questions asked in the course of the analysis are:

* What type of proposition is the teacher trying to convey through this situation?

* Does this proposition conflict with propositions science educators, in turn, would associate with the same situation?

* Is this type of situation really meaningful for these teachers?

* Are the propositions of science educators that are liable to be associated with this situation relevant in debates of on this subject?

* If conflict seems likely between primary teachers and science educators, is this situation the best available of its kind?

As outlined earlier (part II, section B above), the focus of interest of this study fits into what Shulman calls 'content knowledge in teaching' - domain which he divides into three categories: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge (Shulman, 1986b, p. 9a). The framework for this analysis, described below (subheading 5), comprises elements of teachers' knowledge which fall in these categories of Shulman.

In a sense, the anecdotes, allegories and propositions which volunteer teachers have used are 'signs' or 'codes' which convey 'messages' to me about the way they think about science education, about the primary school ethos, about young pupils, about their (teachers') own sentiments towards all that, and so on. Those signs are teachers' forms of representing categories of knowledge (Shulman, 1986b, p. 10c) - the three categories above, as well as others in additional domains of their knowledge. Consequently, some situations brought by teachers to be discussed are not catalogued as 'themes' during the analysis; even if they comply with what the questions above stipulate. For example: in my earlier definition of the present study's focus of interest, I pointed out that teachers' knowledge of scientific facts, described as 'plain' content knowledge, was an area of friction between primary teachers and science educators. Despite this, and despite the fact that this issue is very relevant for primary teachers in England and Wales - despite, too, my own personal belief that some intimacy with such knowledge can and should be acquired by these teachers - primary teachers' current knowledge of the subject matter of science falls outside the field of the present study, as it falls outside Shulman's categories listed above. I would just like to call attention to the fact that,
in category ‘subject matter content knowledge’, Shulman refers to content knowledge in teaching, not content knowledge per se.

Teachers' knowledge of the facts and theories of science have been discussed by teachers, nonetheless, I do not focus on this topic in this study. The same applies to curriculum and educational authorities demands, availability of material, and other administrative matters. All these topics are relevant to the formation of teachers' beliefs, assumptions and practices. Indeed, they are topics that have been widely researched (Shavelson et al, 1981; Berliner, 1987; Aguirre et al, 1990; Calderhead et al, 1991; Aubusson et al, 1992). However, they are beyond the scope of this study.

5. Tetrahedron of Principles

In a previous work (Vaz, 1989), I employed one model to sum up the apparently implicit principles which guide authors of science teaching proposals. I have since referred to this model as the Tetrahedron of Principles. Here, it is important to explain the main aspects of that work in order to discuss how this model acts as my framework for analysis in the present study.

That work focused on the role played by practical activities - like school experiments, classroom demonstrations and problem-solving sessions of the 'egg-race' or 'open-laboratory' types - in the teaching of physics; especially in schools for post-fourteen education. The objective of that study was to identify underpinning principles for this form of teaching. This objective was sought through a disciplined enquiry into propositions in the literature for the adoption of such pedagogical practice. Having carried out content analyses of articles where the adoption of practical school activity was advocated, I identified four classes of such principles; classes I chose to describe as:

a) epistemology of learning;

b) nature of science;

c) educational aims;

d) theory of communication and semiology.

It is important to note that only aspects of teaching which were within teachers' own control were considered in the analysis. Laws, principles and ‘facts' (phenomena) of physics, availability of teaching material, curriculum demands, and similar external constraints to practical school activities were outside the scope of the analysis, for the same reasons as those discussed in the previous section.
Starting with the analytical approach which identified those four classes of principles, the content analysis continued to a second, holistic approach. The intermeshing of the four classes of principles was then evident. The geometric figure of a tetrahedron presented itself as a good way of representing the links each class of principles has with the other three classes. To impart the idea that each class of principles can be considered on its own while at the same time being ‘linked’ to or influenced by principles of other classes, a hollow tetrahedral structure was chosen in preference to a solid tetrahedron (figure 6). The rods along the edges, linking the spheres on the vertices, represent the tendency of prototypes or precedents of practical activities to be associated with two classes of principles. When it comes to science teaching, a prototype of practical activity can exemplify theoretical principles stemming from areas as diverse as, for instance, learning psychology and semiology. By the same token, practical principles of practice stemming from the history of science can also convey norms or values, in other words, educational principles. So each rod acts as an axis on which prototypes and precedents of practical activities, or even abstract propositions regarding teaching, can be plotted according to the degree of association they have with the areas of knowledge or thought at its extremes. The Tetrahedron of Principles consists, in a sense, of six overarching bipolar constructs to tentatively represent the universe of science education.

Once I had devised the model, I tested its credibility by using it as a rational principle for a third approach to the literature. I also expanded the corpus analysed to include three physics teaching projects: Projeto de Ensino de Física from Brazil (PEF, 1974, 1980), Nuffield Physics from Britain (Nuffield Foundation, 1966) and Physical Science Study Committee from the United States (PSSC, 1960). This expansion of the model’s scope provided an opportunity to verify its transferability and evaluate its stability. Since the Tetrahedron of Principles performed well in this rational approach to the analysis of such projects I can assert its value as a heuristic device. This model can act as a representation of the elements involved in the teaching of science and, additionally, as a codification of the culture of science educators. In this way, it fulfils the need for a ‘theory’ about
the relevant aspects of science education, even if only to serve non-initiates, as is envisaged in the present study.

The six axes linking the four vertices of the model are therefore seen as dimensions of a frame of reference. If the analysis is conducted according to a rational principle of enquiry (Schwab, 1964b), the subjects corresponding to the vertices act as parameters for the analysis. Anecdotes, allegories and propositions which can be associated with each area are clustered accordingly, and can eventually be classified within the cluster. Teachers' values, beliefs and assumptions have a degree of similarity with propositions found in the associated areas of knowledge, though these do not take the form of well defined tenets.

Whether or not there is any explicit intention to convey a principle on the part of teachers, I cluster excerpts of their speech under the headings 'principles about learning', 'principles about the nature of science' etc. The word 'principles' is used in these headings because propositions made in theories of learning, in philosophical accounts of science, etc can be connected to what teachers say. For instance, under 'principles about learning' there will be references to teachers' ideas about how their students learn best. Rather pragmatic by nature, none of the interviewees in the present study, ventured a model or explanation for learning itself. For that reason, few propositions can be considered original; there is usually some degree of correspondence with established ideas. My efforts, however, are not concentrated on making a direct link between what a teacher is saying and assertions made by Piaget, Kuhn, Dewey or any other author. I am interested in pointing out the nature of a generalization or assumption being made by teachers. In some cases, the resemblance might seem to reinforce my argument, leading me to quote one such author; but otherwise no direct reference will be made. I will basically present certain excerpts from interviewees as evidence of ideas related to learning, to the nature of science, to the aims of education or to how best one can communicate something to pupils. A brief explanation of each of these sets of principles will help to clarify the nature of that task. For this, in the pages that follow, I draw on passages from the dialogues that have taken place (the codes within brackets identify the teacher and the passage from which the excerpt has been taken). The explanation of the four components of the tetrahedron is accompanied by references to Shulman's theoretical framework of teachers' knowledge for teaching as these help to explain what I consider to be pertinent to the subject in question.
a) Principles about learning

It is reasonable to consider learning as a component of teaching. The theories of, for example, Piaget or Skinner and even proposals such as those of Bruner or Ausubel, have been very influential. Therefore, one would expect teachers to have had contact with those formalized ideas and to have their own thoughts about how learning takes place. As Shapiro says, "most educators have ideas about how their students learn best, and strive to build this thinking into the instruction which they offer" (Shapiro, 1988, p. 97). However, such thoughts are not always structured and cases such as this illustrated by the passage below are really rare.

Teacher: You don’t know anything about something, unless you do it yourself. You can learn more from doing than from watching.

A.V.: Why is that?

Teacher: That’s the way we are! [laughs]

A.V.: Is that a general rule? Is everything like that?

Teacher: Yes. We learn by doing. Froebel said that. I’m a Froebel student [sound laughs]. (AW2.254-8)

A passage where a teacher declares an affiliation to a school of thought or an admiration for a particular personality is not common. However, teachers usually have their own ideas about the nature of students and how they learn. Besides, it is not uncommon for them to use terms current among educationists, such as ‘cognitive development’, ‘conceptual change’, ‘constructivism’ and so on. These are themes that are placed under the label ‘Principles about Learning’.

It is interesting to note that what I place under this label coincides with what Shulman (1986b, p. 9c) would place in one of his categories within content knowledge in teaching: pedagogical content knowledge. That category includes other principles apart from the ones about learning, as will be seen shortly. With respect to learning, Shulman literally says:

Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (Shulman, 1986b, p. 9c).

Like Shulman, I consider the growing body of knowledge about students’ ‘alternative conceptions’ in science (Gilbert et al, 1983; Carmichael et al, 1990;
Pfundt et al, 1994) and about the instructional conditions necessary to overcome and transform their initial conceptions (Minstrell, 1992; Scott et al, 1992) to be an important reference here. I therefore agree with Shulman when he proposes that such research-based knowledge should be included at the heart of our definition of pedagogical knowledge (Shulman, 1986b, p. 10a), as well as to my definition of principles about learning.

b) Principles about the nature of science

Even though teachers do not always have scientific training they develop views about the nature of science; a simple example would be along the lines of this passage:

Teacher: The thing about science is that it is really a set of right answers, isn’t it?

A.V.: More than Geography or History?

Teacher: Well, with history there are arguments both sides and there are things as bias. I know there probably is in science; but not at the level I’m doing it. (AW3.175-82)

Under this component of the Tetrahedron of Principles I place views about science and scientists, especially with regard to physics: its characteristics, methods and role in western culture as well as in our way of life. It is under this label that I place opinions about the role which teachers think physics should play in pupils’ education. In the case of primary teachers, these views and opinions parallel in importance a science teacher’s knowledge of the history and philosophy of science. As it has been recognized elsewhere:

While it is unlikely that elementary teachers will have knowledge of the history and philosophy of science, they often do have strong beliefs about what science is, how scientific knowledge becomes established and how it ought to be taught and learned (Smith, 1989, p. 4).

In the realm of higher levels of school education, the notion of what science is, how scientific knowledge becomes established and how it ought to be taught and learned is what Shulman categorizes as ‘subject matter content knowledge in teaching’ (Shulman, 1986b, p. 9a-b). As I have said, he draws upon Schwab’s substantive and syntactic structures of disciplines (Schwab, 1964a,b) to characterize this category of teachers’ knowledge. Substantive structure refers to the conceptual structure which guides the formulation of questions, planning of
inquiries and interpretation of emerging data within that field of knowledge (Schwab, 1964a, p. 12). Syntactic structure, on the other hand, is related to the way in which discoveries take place or the proof of assertions is sought (Schwab, 1964a, p. 14).

As with theories of learning and their correlated principles, in the course of my analysis of teachers' discourse I have looked out for signals of the above-mentioned characteristics of teachers' views and opinions. Sometimes, when pointing out these views and opinions, I make reference to historians, philosophers and sociologists of science, as certain passages in the interviews seem to relate to the arguments of some scholars in those fields. I refer to those authors if I think it helps to track the line of reasoning followed by interviewees. Indeed, the argument that propositions put forward in debates about the nature of science can be found in lay people's reflections might follow from these comparisons, but this is not the central objective here.

c) Principles about education

I use this term to refer to the way teachers define their role in the educational process - or rather, the student's role, and the part content matter and the teaching activities play in such process; as in this excerpt, for instance:

My role as teacher is to see those children develop as young children, so they develop socially, they develop emotionally, they develop intellectually. So, by giving a consistent response they can ask me academic questions, social questions... or emotional things. So there is a trust there. My role is not simply to pass on a body of knowledge to those children. It's to get them to develop self disciplines, self-esteem, self-awareness, awareness of others. So in doing that I cannot divide things up. My approach is the same so that they can respond to me in the same way. (MK2.142)

Principles about education may also be taken to imply long-term goals of education, the role of school in society etc; ideals and attitudes about education in general, in accordance with particular moral, ethical and political stances; and the means (processes and techniques) that are thought to implement those ideals. This is yet another point touched on by Shulman in his categorization of teachers' knowledge (Shulman, 1986b); he, however, considers what I refer to as principles about education as a form for representing that knowledge, rather than a category of it. Shulman suggests that some teachers' propositions reflect the norms, values, ideological or philosophical commitments teachers should - if they do not already -
incorporate and employ.

The admonitions to provide each student with equal opportunity for turn taking, or not to embarrass a child in front of peers, are examples of normative knowledge (Shulman, 1986b, p. 11b).

Because this set of principles is bound to be deeply rooted in teachers’ moral and ethical values, as well as ideological or philosophical commitments, I decided not to challenge teachers’ assertions in this area. During our conversations, however, some norms or other propositions related to this area surfaced. In one case, especially, a dilemma experienced by the teacher came to the fore during the course of our conversation in a fairly dramatic way. This dilemma is proposed as a generative theme. It is also used to illustrate the fact that, even in sensitive areas such as these, it is possible to problematize teachers’ personal choices - without confrontation or conflict - in order to create conditions for meaningful reflections to take place.

d) Principles about communication

It seems essential to me that this component should be carefully considered when analysing physics teaching, and indeed any teaching. The educational process is a process of communication; information is been transmitted, ideas are been discussed... Whichever principles one adopts about learning, about education or about the nature of science, there will always be decisions to be made which do not relate to those areas.

Teacher: There were two points being considered. The actual practical aspect of them experimenting with actual physical moving of the mirrors to see if they could actually do that. Then, I also tried to use the analogy of the snooker ball. I used it because I felt that was something they might had encountered; so, I tried to place that in their own learning. If they had a real understanding of that, I thought, that might help them to actually put that into practice.

A.V.: Fine. Let’s take the snooker ball. What was your aim? Why use something different to light at that time?

Teacher: Because I felt that... Because they can’t actually see; because we couldn’t get into a complete dark room; because I couldn’t show them a beam of red light or something. Because they couldn’t actually see it, I needed to give them a closest an example as I could to try and make sure that they had a good understanding of that reflection of light. (MK2.14-6)
As with the other three components of teaching, decisions with respect to communication are not necessarily based on conscious criteria, nor are they simply made in view of resources available as in the example above. Precepts of semiology and communication theory, when used as analytical tools, can help to reveal what teachers intended to communicate and to elicit their own explanations for their successes and failures. In very simple terms, within this component of the analysis I looked for three basic elements: object of communication, language and interlocutors. 'Language' was the element at which I looked most carefully, questioning how the 'object of communication' is represented, which are the 'signs' one finds appropriate to pass the 'message' on, and how one articulates those 'signs' or 'codes'.

This element of the Tetrahedron of Principles also finds counterparts in Shulman's framework of teachers' knowledge for teaching. These counterparts, however, are scattered around what this author calls domains and categories of teacher knowledge, as well as around what he describes as the forms of representing this knowledge. For instance, within the category of pedagogical content knowledge Shulman includes the most useful forms of representation of the most regularly taught topics in one's subject area. Very specific about representations being "the most powerful analogies, illustrations, examples, explanations, and demonstrations", Shulman explains:

> Since there are no single most powerful forms of representing and formulating the subject that make it comprehensible to others, the teacher must have at hand a veritable armamentarium of alternative forms of representation (Shulman, 1986b, p. 9c).

In another category, Curricular Knowledge, Shulman comes back to the same issue again. He says that the curriculum is represented by, first, programmes designed for the teaching of particular subjects and topics at a given level, second, the variety of instructional materials available in relation to those programmes, and, third, the set of characteristics that serve as both indications and counter indications for the use of particular curriculum or programme materials in particular circumstances (Shulman, 1986b, p. 10a). Shulman then suggests that teachers should be like physicians who understand the full range of treatments available to ameliorate a given disorder.

> Individuals whom we prepare for teaching biology, for example, should understand well the materials for that instruction, the alternative texts, software, programs, visual materials, single concept films, laboratory
demonstrations, and "invitations to inquiry" (Shulman, 1986b, p. 10b).

Moreover, Shulman suggests teachers should understand how to adapt the range of alternatives for particular circumstances of sensitivity, cost, interaction with other interventions, convenience, safety, or comfort (Shulman, 1986b, p. 10a). This type of understanding would pertain to the field of pragmatics, if the issue was language usage. This correspondence reinforces my argument for the value of semiology and theory of communication in the realm of teacher education. Shulman himself, however, is rather vague about how teachers would actually choose among the armamentarium of alternative forms of representation should they have that armamentarium at hand. Likewise, he does not specify how teachers' knowledge of curricular alternatives available for teaching would entail their understanding of these. The most Shulman says about this is that such understanding derives from the wisdom of practice. I would endorse that, but nonetheless add:

We can empower teachers in the making of these choices, pointing where, in their wisdom, they currently choose forms of representation or curricular alternatives much as semiology:

* distinguishes between essential, therefore social, aspects of communication and its accidental or accessory, therefore individual, aspects (Coelho, 1980, p. 18; Barthes, 1984, p. 82);
* uses the opposition code/message, to help improving communication between equals or otherwise (Coelho, 1980, p. 19);
* shows that messages are articulated by the source of communication from a selection of a repertory of signs (Coelho, 1980, p. 20); and
* uses the concepts of signified and signifier in the analysis and choice of signs-codes in particular circumstances (Idem).

As a consequence, in the present analysis, teachers' references to their choice of representations are pinned down and discussed.

6. The Framework of Interview Analysis and Generative Theme Labels

When looking at primary teachers' discourse about their practice, in a search for generative themes of science teaching, it is teachers' beliefs and assumptions which are likely to help determine which themes will be generative of reflection. Most of these beliefs and assumptions are bound to be implicit in teachers' anecdotes, allegories and propositions, which are themselves all intertwined in a mesh of apparently twisted thoughts. Using the Tetrahedron of Principles, some of these
lines of reasoning can start to be unravelled - precisely those lines which I have already seen followed by fellow physics educators elsewhere. The parallel with Phase 3 (the creation of the 'codifications') of Freire's method is clear. According to Freire, educators ought to analyse students' reality furnished with their own knowledge and experience. With the aid of the heuristic model I have previously devised, I de-code primary teachers' teaching of science to find points of friction between what each of us regard as fundamental themes associated with such practice. Because the intention is that these themes become foci of discussion on a teacher education programme, the choice of labels for them is guided by topics in the literature concerned with the teaching of science in general and the four elements of the tetrahedron model, in particular. Some labels will convey this clearly, whilst others, inspired by expressions used by teachers, might not be so explicit. Overall, these are just provisional labels I have used my own discretion in choosing. It is through the discussion of the themes these labels designate that this study contributes to the debate on science teacher education.

E. Summary: Language and the Politics of Emotion

By looking at primary teachers' emotions, it is possible to gain access to some of the most important differences between, on the one hand (a) allegories these teachers employ to depict their interpretation of science teaching and (b) the nature of their content knowledge for teaching, and on the other hand, (a) images and (b) knowledge employed by science educators. In other words, in this study it is thought that the emotive can allow the cognitive (knowledge) and the conative (experience) to be socialized through dialogue (Kelly, 1963, p. 130). Teachers' feelings, however, are not being considered as the essence of their emotion; that is, there is no assumption of universality in the meaning of distinct emotions (e.g. as far as science teaching is concerned, shame for primary teachers does not necessarily feel/mean the same as shame for expert science teachers) (Cf. Abu-Lughod et al, 1990, p. 3).

In a like manner those interested in the politics of emotion (Lutz et al, 1990), this study focuses on teachers' language and not on their introspective reports. People's vocabulary is been considered as something bound up with power relations, cultural biases and ideologies. Language, therefore, is taken as more than a medium for the communication of inner thoughts or experiences. The assumption, shared with the scholars I have mentioned, is that in dealing with teachers' language one is dealing with precisely that instrument which makes one capable of socially constructing and contesting realities. In other words, construing language
as that instrument, one asserts that "things which are social, political, historically contingent, emergent, or constructed are both real and can have force in the world" (Abu-Lughod et al, 1990, p. 13).

Here I make a sort of cross-cultural analysis, for I am suspicious of the certainties and unexamined assumptions implicit in assertions about science education most of us in this field take for granted. This analysis, as Lutz and Abu-Lughod suggest, could adopt one of three alternative strategies: anthropological, historical or socio-linguistic.

The third strategy is to focus on social discourse, building less on anthropology’s comparative bent or the broad historical framing of the problem than on a commitment to careful analysis of the richness of specific social situations (Abu-Lughod et al, 1990, p. 6).

It is this strategy, focus on social discourse, the one I follow here. I have discussed its core term (discourse or dialogue) to assess the nature and value of such a strategy. Adopting Freire’s Thematic Investigation, I suggest that, if the concern of this study were linguistic, rules of pragmatics would be employed in such an analysis. However, like those interested in emotion, discourse and politics of everyday life (Lutz et al, 1990), I have moved beyond the pragmatic use of the word ‘discourse’. Here, I adopt it in an effort to refigure two terms that it replaces: culture and ideology (Idem p. 9). As a result, there will be no distinction between the realm of ideas and that of material realities and social practices; this is contrary to common practice in studies of ‘a culture’ or, alternatively, in Marxist analyses of historically specific social groups engaged in struggles of domination and resistance (Idem Ibid).

Kelly’s Repertory Grid Technique allows this investigator and his volunteers to communicate. These interlocutors have couched their discourse about the teaching of science, each in his/her own way. In the event, understanding of teachers’ discourse by the investigator has been possible thanks to the employment of a ‘special language’, originally required by the adoption of a rational principle of enquiry (Schwab, 1964b, p. 48). This ‘special language’ has consisted of a blend of:

1. focus on teachers’ ‘content knowledge in teaching’ (Shulman, 1986b, p. 9a) with reference only to their experience teaching the subject of the investigator’s expertise;

2. recall of ‘liberating actions’ (Freire, 1972, p. 89) to gain access to teachers’ ‘strategic knowledge’ (Shulman, 1986b, p. 13a); that is, emotive
recall of episodes or cases related to that teaching experience intended to focus on ‘something unexpected which invited the person to place new constructions upon events’ (Kelly, 1963, p. 72);

3. Rep Test challenges:
   a) sorting out of elements in Triadic Form with
   b) assignment of bipolar criteria for this comparison and
   b) grading of similarities and differences between each of the other elements;

4. computer analysis of grading patterns, Rep Test way to a quantifiable description of individual uniqueness (Jahoba, 1986, p. 4);

5. dialogical discussion of grading patterns with problematization of teachers’ propositions and the aid of practical precedents, prototypes and parables to illustrate these propositions based on the investigators’ use to his own propositional knowledge, represented by the Tetrahedron of Principles (Vaz, 1989).

As a result, the many abstract systems of relationships involved in this situation (between practice and its interpretation, either the teacher’s or the investigator’s; between each one’s propositions; between each one’s interpretation of the other’s propositions or set of practical precedents, prototypes and parables) might not have been understood. However, with the present design, this research yields a powerful picture of a specific social situation. Since this situation has been carefully analysed in all its richness, this study is bound to achieve its purpose: to bridge the gap between primary teachers’ and science educators’ strategic knowledge of science education.

The analysis of this situation, in which a science teacher and primary teachers meet to discuss primary science teaching, focuses on teachers’ discourse. To frame this, the analysis draws on the investigator’s own codification of science education, represented here by a heuristic device: the Tetrahedron of Principles (Vaz, 1989). The aim is to select prototypes which exemplify theoretical principles, as precedents which communicate practical maxims, and parables which convey norms and values, from a repertoire meaningful to primary teachers. Although the emerging themes are tied to the historical and social context of the respondents’ lives, the research design is not. It is therefore thought that the repetition of this research in other contexts will be equally fruitful, though emerging themes will not necessarily be the same. The investigator’s framework of analysis is a constant variable, albeit evolving, which guarantees that whatever the themes emerging out
of the analysis, they will be generative of teachers' critical and dialectical reflection about propositions related to those areas of knowledge and practice represented in that framework.

1. Synoptic Chart

The following synoptic chart (table 1) relates the contributions of the main authors influencing this study to the main features of its research design. Each row of the chart correspond to one stage of the process.

The first stage of the research can be considered as a sort of research of vocabulary. As the first row of table 1 shows, the aim of this stage is to elicit emotional episodes from teachers. Teachers provide these elements by filling the Rep Test cards. Such elements are in the form of propositions and cases which represent teachers' 'content knowledge in teaching' in the realm of primary science. By identifying these emotional episodes, I believe I am accessing certain liberating actions of teachers.

In the next stage of the research, the second row of the chart, the use of 'vocabulary' just researched is problematized for the first time. To probe the

<table>
<thead>
<tr>
<th>Freire's strategy</th>
<th>Shulman's framework</th>
<th>Kelly's Rep Test</th>
<th>Thematic Investigation of Teachers' Thinking and Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liberating Actions</td>
<td>Propositions and Cases</td>
<td>Elements (statements on cards)</td>
<td>Emotional Episodes</td>
</tr>
<tr>
<td>Meaningful Theematics</td>
<td>Strategic Knowledge (Propositional + Case Knowledge)</td>
<td>Complex of Constructs</td>
<td>Criteria to compare episodes</td>
</tr>
<tr>
<td>Selection of Generative Words</td>
<td>Translation of Propositional Knowledge (teachers' and experts')</td>
<td>Analysis of Complex of Constructs (Focus Analysis)</td>
<td>Challenge teacher to account for gaps between own discourse and practice</td>
</tr>
<tr>
<td>Creation of Codifications</td>
<td>Election of prototypes, precedents &amp; parables</td>
<td>Analysis of Focus Analysis</td>
<td>Framing teachers' discourse</td>
</tr>
</tbody>
</table>

(Representation of typical existential situations - based on Semiology)

(Representation of 'cultural differences' - teachers' vs. investigators' - based on Tetrahedron of Principles)

Table 1: Main features of research design and associated contributions from authors influencing this study
relationship between elements which emerged in the first stage, teachers are asked to compare them. The Rep Test forces teachers to make use of their strategic knowledge, since it asks them to compare the different cases provided earlier. Teachers' rival hypotheses used as criteria of comparison of elements in the Rep Test denote meaningful themes related to science content knowledge in teaching.

In the next row of table 1 is the third stage of the research: the dialogues between investigator and teachers. At this stage, a confrontation of views take place: those of the investigator and the teachers. Teachers' analysis of the Focus Grid is problematized by the investigator in view of his own analysis of it. The translation of teachers' and investigator's propositional knowledge starts with areas of friction between these being mapped. Generative themes begin to be identified.

The final stage of the process consists on the analysis of dialogues with emphasis on teachers' discourse. The parameter adopted by the investigator for this analysis is the Tetrahedron of Principles. According to Shulman, this corresponds to electing cases to exemplify propositions, the former being from teachers' experience, the latter corresponding to the three major sources of knowledge about teaching held by science educators: disciplined empirical or philosophical enquiry, practical experience, and ethical reasoning (Shulman, 1986b, p. 11a). In Freire's terms this bridge between one and the other corresponds with the representation of teachers' typical existential situations. In the realm of Personal Construct Psychology, this kind of analysis can be compared to that aimed at eliciting socio-constructs.

III. RESEARCH IMPLEMENTATION

Having discussed the purpose of the present research and its design, I will devote this part of the chapter to dealing with its implementation. The description and further considerations of the task actually carried out in this research have been divided into two parts. First, I focus on the interaction investigator-respondent; then I turn to the analysis of transcripts of our dialogues. Section A, 'The sample of Interlocutors', starts by describing the research volunteers and the circumstances in which they were enlisted. This is followed by section B, 'Repertory Test Approach', where features of the test's application are described; a special emphasis is given to the way in which, by evoking episodes through associated feelings, the elements to be compared by teachers were elicited. In section C, 'Challenges and Dialogues', the interviews that followed the application of the
Repertory Test are examined. A word about the analysis of these dialogues follows in section D, ‘Discourse Analysis and Other Investigations’. Section E provides a diagram and an outline of the research implementation and ends the chapter.

A. THE SAMPLE OF INTERLOCUTORS

The inspiration to develop this study in the form of a Thematic Investigation results from my wish to design a teacher education programme in the style of Freire’s problematizing literacy programme. Earlier in this chapter (part II, section A), I spoke about the most convenient universe sample from where to seek volunteers seemed that of primary school teachers. Within this sample, primary teachers from England and Wales were considered particularly suitable for the study. That was more or less all the discretion I was able to use in this process. A number of factors, which I discuss shortly, made it impossible to avoid the volunteers forming an ‘opportunity sample’.

Table 2 introduces the volunteers for this research, giving their gender and a brief note about their experience. They all were working in south-west London at the time of the interviews. I met each teacher three times, usually within a period of three to four weeks. Each interview lasted at least one hour. The order shown in table 2 is that I interviewed teachers. To preserve their anonymity, this study bears only their initials throughout; in interview excerpts where they mention their own names or that of their spouse, I have changed these for fictitious names.

<table>
<thead>
<tr>
<th>Experience</th>
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<tbody>
<tr>
<td>TC</td>
</tr>
<tr>
<td>TC Year 1 to Year 5 (5-10 year olds): 12 years. Female.</td>
</tr>
<tr>
<td>GR</td>
</tr>
<tr>
<td>GR Year 1 to Year 4 (5-9 year olds): 8 years. Female.</td>
</tr>
<tr>
<td>AW</td>
</tr>
<tr>
<td>AW Year 3 (7-8 year olds): 3 years. MA (Sci Educ). Female.</td>
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<tr>
<td>SS</td>
</tr>
<tr>
<td>SS Reception (4-5 year olds): 4 years. Degree in Biology. Female.</td>
</tr>
<tr>
<td>MK</td>
</tr>
<tr>
<td>MK Year 3 to Year 5 (7-10 year olds): 4 years. Male.</td>
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<tr>
<td>LP</td>
</tr>
<tr>
<td>LP Reception and Year 1 (4-6 year olds): 15+ years. Deputy Head Teacher. Female.</td>
</tr>
<tr>
<td>JC</td>
</tr>
<tr>
<td>JC Reception to Year 4 (4-9 year olds): 10 years. Female.</td>
</tr>
<tr>
<td>DH</td>
</tr>
<tr>
<td>DH Reception to Year 5 (4-10 year olds): 10 years. Female.</td>
</tr>
<tr>
<td>CP</td>
</tr>
<tr>
<td>CP Reception to Year 5 (4-10 year olds): 5 years (1 yr reading for MA-Sci Educ). Female.</td>
</tr>
</tbody>
</table>

Table 2: Synopsis of Volunteers’ Experience
1. Effects of Teachers' Industrial Action on Volunteer Enlistment

There was a hindrance to the enlistment of volunteers that deserves a comment. The introduction of the National Curriculum (DES, 1989) was not as smooth as I naively thought it would be. At the same time as I was conducting the first pilot studies in May 1991, the new version of the science curriculum (DES, 1991) was being sent to schools. So, by the time the main core of interviews was due to happen, the row between the government and the main teaching unions was at its peak. In the Summer term (April-July) of 1992 teachers were boycotting national tests planned by the Department of Education. This led to a situation where, on the one hand, teachers could not feel comfortable committing themselves to research while arguing they could not take on extra work; and on the other hand, head teachers could not possibly ask teachers to contribute to research. This was either because they would not then be able to sustain teachers' arguments when responding to their superiors, or because among staff, the divisions and tension were so great that no request for volunteering could be easily met.

This state of affairs compromised this study to a considerable extent. To start with, there was a gap in the data collection for quite a long time; the last batch of interviews was conducted in the Autumn of 1993. The extended period of data collection was inevitable given the events of 1992 and my own sentiment that more teachers needed to be studied. My concern with the number of volunteers stems from my wish to avoid accounts solely at the level of the individual, as I mentioned earlier. I went on trying to enlist teachers but, being an outsider, I lacked contacts and could only count on institutional connections with schools to succeed. Unfortunately, despite the good will of those responsible, the latter networks did not prove so effective, either.

The institutional connections established at the time were mostly on a teacher training basis. Although heads and teachers of schools with which the Faculty of Education - Roehampton Institute - liaised would happily welcome an ethnographic sort of research, they continued to draw on arguments related to the tensions of 1992, staff shortage and the like to refuse allocation of teachers' time to research. As far as institutional intermediation was concerned, it became clear that, given the political and economic - that is, external - factors at work, co-operation would result only if one of two measures were taken. One of these measures would be a better marketing of educational research to overcome its stigma as wholly useless (Fenstermarcher et al, 1993, p. 101; Goodson, 1994). The other measure which might obtain more co-operation from schools would be
payment for the time required. There was no time left to pursue the former alternative, nor moneys to pursue the latter.

In the end, most teachers who agreed to collaborate did so on the basis of their contact with people of my acquaintance. Given the philosophical framework I adopted, the hope was that volunteers would be co-investigators, that they would be as interested to reflect upon their constructions of science teaching as myself. Naturally, not all nine teachers interviewed were equally motivated by this.

A small number of respondents, an extended period of data collection and a confluence of data from volunteers with different approaches to the research, are all factors which influence the outcomes. To judge by accounts of primary teaching used as instruments of authentication of this study’s findings (CACE, 1967; Galton et al, 1980; OFSTED, 1995), the themes that are being proposed here seem quite likely to generate teachers’ reflection and action. In that sense, the present outcomes give a good account of Thematic Investigation, as it has been used in this study. It did engage volunteers in meaningful reflection. It is therefore imperative that the employment of the Repertory Test approach is detailed.

B. Repertory Test Approach

As I have discussed in the research design section, in choosing as elements for the Repertory Test episodes that have affected teachers personally, it is not possible to provide these for them; it is only the person himself/herself who knows what is significant for himself/herself. On the other hand, in an effort to avoid providing these elements, there is a risk of laissez-faire; trying too hard not to interfere with the process, the researcher fails to encourage the volunteer to genuinely reflect on his/her actions and thoughts, and does not allow him/her to act upon them, either.

So, for the purposes of this study, it does not seem appropriate just to ask teachers to list a set of events with respect to which they feel any emotions. Given that memory is selective, they might then recall only those episodes they have, even if unconsciously, chosen to remember. It seems necessary to offer volunteers some promptings that help them to look somewhat deeper into their memory for personal episodes to analyse.

1. The Questions to Prompt Meaningful Recollections

I decided that in this case the prompting would consist of a question written at the top of each card. Such questions would ask the volunteer to recall an event marked by a particular emotion; an emotion to which there is an explicit reference in the
With respect to physics teaching what do you remember as something DISAPPOINTING?

Figure 7: Specimen of Question-Card.

The set of cards initially presented to the volunteers had twenty-three numbered cards. Figure 7 shows a specimen of the cards used. The full set of questions written on the actual cards is found in Appendix 1. The formulation of these questions was based on my own teaching experience in post-fourteen school education. I searched my own memory for episodes that have been meaningful in one form or another and tried to identify the feelings I associate with them. I then made the questions, balancing three types of feeling. Some questions, thus, are meant to prompt episodes associated with 'positive feelings'. These ask teachers to recall, for instance, 'something that gave them personal satisfaction' or something which they found 'funny'. Other questions are intended to prompt teachers to recall episodes associated with 'negative feelings'. One of these questions, for instance, reads: 'What do you remember as something disappointing?'. The rest are questions supposedly liable to be interpreted from either a positive or a negative or, indeed, neither of these points of view. These questions refer to something 'surprising' or 'reasonable', for instance. Since table 3 (page 185) has all these feelings noted, I shall leave the discrimination of which type of feeling each question bears to my discussion of teachers' response to these questions.

2. Sorting out and Grading the Recollections

Although answering the questions was not really problematic, in this study the Repertory Test proved to be disconcerting at first. During the initial interviews, the volunteers were asked to fill in all the twenty-three cards bearing questions (this is henceforth going to be referred to as Filling-in Stage). The printed questions were then cut off the cards, leaving them only with the teacher's handwriting and a printed number for identification. This lower portion containing a reference to episodes, anecdotes or allegories was re-presented to teachers. Once the 'triadic' or 'minimum context' form of sorting out was adopted, all these responses to the questions were compared in sets of three (Triadic Stage). The comparison of all responses proved inefficient: teachers became bored and the number of criteria used to classify and grade the triads (Grading Stage) was not enough to generate significant discussion in the following stage - the dialogue between teacher and
investigator. After teacher G.R., running out of time, did not do much in her test, it became clear that it was necessary to change the form in which the Rep Test was being implemented. In the search for a better form, the alternative adopted partially broke with the principle of rejecting *laissez-faire*. Teacher M.K., who was approached this way, was allowed to provide episodes more or less at his own choice.

This teacher was asked to list three episodes or cases about which he feels positive, three which he feels were negative and three to which he feels indifferent. Although this approach triggered a rich dialogue, the FOCUS analysis showed little discrimination between elements (figure 8); there was no cluster which allowed one set of elements to be distinguished from another and the coefficients of similarity were relatively low compared with other trees of grids in Appendix 2. This proved a disadvantage once the volunteer himself suspected the technique was not good enough; it did not expose the differences he himself saw between different episodes. The attitude of *laissez-faire* had to be entirely rejected.

Now that, ideally, the atmosphere should be one of trust and solidarity, the research procedures could not seem awkward to teachers. The research design had to evolve. The form then adopted flowed better once it allowed teachers more freedom. It also gave volunteers more confidence in the process, discriminating as it did between elements (this will be further discussed in section B, part I of the following chapter).

In this final form, teachers did not have to make the effort to answer all questions on the cards provided. They were asked to respond to them only if an answer came straight to mind. As I have said, this strategy is meant to numb any control mechanisms which teachers might have. Teachers were also given extra cards with just a number to identify them. The purpose of these blank cards was to allow teachers to introduce episodes they themselves consider important to contemplate in the process but for which there was no question to prompt their inclusion. The introduction of cards

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**Figure 8: Example of Little Discriminatory Rep Grid**

- **Elements:** 9
- **Constructs:** 8
- **Range:** 1 to 5

<table>
<thead>
<tr>
<th>Description</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning for its own sake or for a purpose?</td>
<td>100</td>
</tr>
<tr>
<td>Anecdotal stories help my relationship w/ class</td>
<td>90</td>
</tr>
<tr>
<td>Don't focus question on chdn who lack confidence</td>
<td>80</td>
</tr>
<tr>
<td>Hope chdn felt successful tackling sci work</td>
<td>70</td>
</tr>
<tr>
<td>Appraisal: hope to improve through help w/ rsch</td>
<td>60</td>
</tr>
<tr>
<td>Informal chat w/ small groups: back up learning</td>
<td>N</td>
</tr>
<tr>
<td>Talk back: chdn reflect on what they've learned</td>
<td>+</td>
</tr>
<tr>
<td>How to apply knowledge gained</td>
<td>-</td>
</tr>
<tr>
<td>Felt familiar to teaching practice</td>
<td>-</td>
</tr>
</tbody>
</table>

---

**CHAPTER 3 - Part III**

**RESEARCH IMPLEMENTATION**
without questions was felt necessary by the first volunteers. The number of cards introduced within the triadic stage also changed. The use of an elective procedure seems to work better.

In the elective procedure, after the filling-in stage, cards without response or which have only 'yes' or 'no' answers to the printed question are left aside. The question-heads of the remaining set are equally cut off the cards. Looking only at their responses hand-written on the set of numbered cards, teachers are asked to choose the nine most significant episodes for them: those teachers believe are representative of themselves, particularly as related to their teaching of physics. The number, nine, is chosen purely for convenience. By writing the printed numbers of the chosen cards on a 3 x 3 matrix, it is easy to tell the teacher which cards to choose for each new triad. This procedure avoids repetition; which can lead to loss of time and irritating waits. The sorting out and grading proceeds in the 'triadic' or 'minimum context' format, as explained.

C. Challenges and Dialogues

The second and the third one-hour meetings with each teacher were devoted to conversations about their experience as well as their beliefs and assumptions related to the teaching of physics. Starting with a discussion of the Focus Grid, an output of the RepGrid program with an analysis of the response to triadic stage, a dialogue with a clear problematizing tone emerges.

Teachers' discussions were audio-recorded and transcribed. What the Repertory Test offered the researcher was the possibility to get the interviewees to relate very specific elements of their spheres of knowledge and experience. After just one meeting, teachers provided some elements of their experience teaching science in primary school and talked about these in different forms. In a word, interviewees presented the researcher with fragments of their reality and started to show how - in their opinion - these relate. Thanks to the repeated requirement of the Repertory Test to classify each and every element under different criteria, teachers ended up connecting fragments of understanding and experience in ways they probably would not had done consciously. As for the investigator, he made no attempt to connect the fragments and infer the existence of implicit theories or conceptual framework in the minds of teachers. Because the approach adopted is 'critical', not 'interpretive', the task of the investigator was to challenge teachers to produce anecdotes and allegories to illustrate the propositions these teachers presented.
Thus, the second meeting started with a general discussion about what happened at the first meeting. The time span between the second and the first encounters was usually one week, and this introductory talk returned the teacher to the context of the study. Soon, the very connections between elements shown by the RepGrid elements-tree were posed as problems to the volunteer. Usually, he or she still had to think for a moment about what they had originally written on the card. They had to recall what the note written by themselves actually meant or to what were they referring. After this brief consideration of each element in isolation, typically a line of reasoning began to unravel and, through constantly comparing the elements in question, a series of different and apparently disconnected issues started to emerge. At this early stage, most of the discourse was based on what could be described as ‘educational jargon’. The use of ‘buzz words’ from National Curriculum documents, for instance, was very common among teachers in this study. The initial intention possibly was to explain me, who they looked upon as outsider, exactly how the system functions. Nevertheless, the use of some terms persisted for longer than necessary for that purpose; in Chapter 4, I analyse this pattern further.

On the assumption that we belong to different cultures, I cannot take it for granted that the words used by primary teachers convey the same meaning science educators attribute to them. So, when a teacher stated, for instance, that this and that card were clustered together because they refer to activities where, instead of imparting knowledge, the teacher gets the knowledge from children, I had to ask what does she mean by ‘to get it from pupils’. I had to ask when it is not like that and imparting knowledge is appropriate; I asked how she proceeds in each case; I asked for examples, and so on, and so forth. My purpose was to reveal what teachers associate with the issues emerging in the discussion. This involved checking which kind of activities the teacher used in order to exemplify some principle or value expressed. By the same token, the investigator could make a statement about one of these factual examples, ask the teacher to comment on it and hence get him/her to express a principle or value.

The importance of RepGrid results in this study is, therefore, relative. The analysis of similarities and differences between elements and criteria of comparison provides a good starting point for the enquiry since it allows me as interviewer to pose questions about the teacher’s grading pattern. My questions might touch on what, at first, might seem only a foible, but can, in fact, reveal inconsistencies between the teacher’s practice and his/her intentions, or between practice and interpretation of this practice. That is, the questions might expose gaps in teacher’s
praxis, gaps between knowledge and experience. This is very valuable. These gaps might consist of generative themes; their identification therefore is one of the objectives of this study. In this sense, if a question led the line of enquiry to progress from one topic to another, always revolving around new ideas at different and ever deeper levels, then the RepGrid output could be left aside. On the other hand, if the opened vein of reasoning had dried up by going back to the RepGrid output it was possible to start exploring in other directions. At one stage the enquiry could begin by questioning the possible reasons why the interviewee had graded two elements consistently, a fact which is shown by a high coefficient of similarity. At another stage, the interviewee might be invited to explain why he or she thought the set of criteria which differentiate the elements were so clearly split in two clusters. One element might be graded only with a score of ‘3’. A particular criterion might have just one element on its contrasting pole, all others being on the similarity pole.

Indeed, in this approach the possible starting points for new enquiries are endless, and yet their aim is not pre-determined by the researcher. If teachers are really eager to learn more about themselves, then these patterns in their classification will always be relevant for them. Therefore, since the initial question refers to a pattern in the teacher’s own grading of elements (elements provided by himself/herself), it is not usually ignored or perfunctorily treated by the teacher. The evidence that, for instance, two elements of teacher’s repertoire resemble each other, or that two criteria were used the same way, challenges the teacher without paralysing him/her. Initially, the question is about the pattern shown in the Rep Test, it is not about something embarrassing for the teacher to answer or offensive for the investigator to ask. Each pattern shown on the RepGrid output is therefore potentially problematizing; each can be posed as a catchy problem teachers probably would not face had they not volunteered. Besides, the historical and cultural context in the background inevitably comes to the fore; which is important given the purposes of this research.

If questions can lead the conversation to sensitive areas of a teacher’s values, then, I consider that special care is needed. For instance, although it was my intention to be challenging and provocative, it seemed I could only be so provided I stopped short of actual conflict; otherwise volunteer teachers would not become co-investigators in the process. As mentioned before, I felt this situation could arise from my ‘problematizing’ teachers’ propositions in relation to particular issues; so, I decided not to probe directly into their propositional knowledge on matters concerning their moral, religious or political values. Considering that these values
would probably come out in a discussion of teachers' principles about education, I chose not to probe this area to start with, even if anecdotes or allegories relating to it were presented. It so happened that, in a few instances, this issue emerged without an apparent risk of conflict or confrontation; where these led to apparently meaningful themes, such themes are given in the next chapter.

Because of the potential the Rep Test had for problematizing teachers' knowledge and experience, the dialogues which were established were seldom narrow in focus. These dialogues represented a rich source of themes that may stimulate reflection and insight in other teachers - teachers whose knowledge, experience and interests are similar to those of the volunteers in this investigation. An analysis of the dialogues has been carefully conducted with a view to revealing these themes.

**D. DISCOURSE ANALYSIS AND OTHER INVESTIGATIONS**

Data input in this research depends on three factors:

* the questions about emotive elements of teachers' experience teaching science;
* the adoption of Repertory Grid Technique to force the comparison of these episodes; and
* the dialogue triggered by discussion of the outcomes of the two features above.

I will refer to data resulting from the first two features as teachers' emotive reactions. I consider this to be a source of preliminary data. The source of main data is the transcripts of teachers' discourse - transcripts of our dialogue about the pattern of scores teachers attributed to their own responses to the emotive questions written on Rep Test cards. This section describes the way each of these sources of data are analysed.

**1. Teachers' Emotive Reactions**

The first source of data to be analysed consisted of teachers' answers to the questions concerning episodes they associate with different feelings. In chapter 4 (part I, section A) I consider all the answers teachers wrote on the cards provided. The purpose of this analysis is twofold. Firstly, to evaluate whether the assumptions and theoretical considerations on which this study is based are empirically tenable.
One of the assumptions evaluated is that the Science National Curriculum in England and Wales represents a limit-situation for primary teachers. There should be some evidence of this on the cards. References to the curriculum are sought and their nature considered.

With this analysis, it should also be possible to judge the premise that reference to emotive episodes prompts teachers to express their thoughts and actions, giving access to both their knowledge and experience.

There is also to be considered the proposition that teachers develop a strategic knowledge when principles contradict one another, or when the precedents of particular cases are incompatible (Shulman, 1986b, p. 13a).

The second purpose of this analysis is to estimate the potential which the response to the questions concerning emotive episodes has to represent the domains and categories of teacher knowledge.

In order to estimate the potential which responses to 'emotive questions' have in representing teacher knowledge, different domains or categories of teacher knowledge should be organized in the 'forms' mentioned: propositions and cases. So, examples from both subject matter knowledge and pedagogical knowledge, but especially from the categories Shulman (1986b) devised for 'content knowledge in teaching', have been sought here.

Teachers' patterns of comparison of emotive elements of their experience in teaching science also consist of emotive reactions. These patterns are revealed by a factor analysis of grades attributed to the cards where those elements are written. These grades were attributed according to bipolar criteria teachers themselves established. The grades attributed to each pair of elements are compared, and elements graded similarly are then clustered together. The same kind of comparison is made for pairs of criteria, and these are themselves then clustered according to the way they were used to classify different elements. These calculations, although involving simple differences of squares, are laborious and time-consuming; thus, after doing them myself for one teacher's responses, I have resorted to a computer to speed up the calculations for the other teachers. Therefore, despite the expression 'FOCUS analysis' being used, the RepGrid software calculation of grading consistency is not itself an analysis. The interpretation of such calculation, however, is very important. It was by considering the patterns of scores shown on the FOCUS analysis that I could challenge teachers and thus get them to talk about issues that are meaningful and relevant.
for them.

In chapter 4, part I, section B I analyse these patterns of scores. Thus I reassure that, having recourse to Repertory Grid technique, the attention is not turned away from relevant points raised by the elicitation of emotive elements of teachers' experience. In fact, the attention is focused on these points.

2. Teachers' Discourse

The emotive reactions of each teacher is re-presented to him/her for discussion. This way teachers can comment on what, in particular, led them to select the specific elements of their experience which they produced when answering the emotive questions on the cards. They can explain the bases in which they have chosen the criteria to compare these elements. Also, they have the opportunity to make some sense of the patterns they are shown to have followed while classifying those elements with these criteria. During the course of discussing all of this, the teachers' descriptions are questioned and their assertions problematized - a process which leads them to illustrate in yet more detail their experience and knowledge. The thematic investigation of all this discussion is referred to here as analysis of teachers' discourse. Earlier in this chapter, I have devoted section D (part II) to the purpose and rationale of this analysis. I will now detail the execution of those plans.

The general idea underlying this analysis is to assign labels to propositions or cases provided by teachers in their responses to the challenges and problematizing questions to which they were subjected - labels which indicate points of friction between the science teaching praxes of primary teachers and experts. They can act as descriptors of themes which are meaningful for teachers, find correspondence with the experts' construction of science education, and will therefore generate reflection and debate between these two parties. This study in part parallels work on alternative frameworks in school science, in the sense that generative themes do not pertain to an individual, but rather to the investigator's interpretation of statements at a general, functional, level (Watts, 1983, p. 4.18). I will therefore draw on a diagram used by Watts (1983, p. 4.22) to illustrate the steps which have been taken during the analysis of teachers' discourse, from the raw transcripts of interviews to the assignment of labels to generative themes.
This analysis moves from 'gross' excerpts from transcripts of my dialogue with teachers, towards more 'delicate' excerpts; that is, from fairly long passages, where the subject may not be so narrow, to shorter and focused ones. At the same time, it searches for points where accounts of science teaching provided, on the one hand, by the investigator and, on the other, by teachers seem to clash. First, transcripts of the dialogues are read with the intent of grouping passages according to the four areas represented on the vertices of the Tetrahedron of Principles: learning, nature of science, education, communication. Although very far removed from primary teachers' own frameworks of cases and propositions, these categories are intended to reduce the data base and put it into a manageable form. Instead of whole interviews arranged chronologically by teacher, their discourse now assumes the form of sets of passages from several teachers and of variable length. In organizing the excerpts of dialogues into these four general categories, no attempt is made to include every passage transcribed; the parameters for determining what enters depend on the investigator's sphere of interest, discussed in part II, section B. Moreover, there is no restriction to particular passages fitting more than one category; the tetrahedron model accommodates these hybrid elements which might, should the need arise, be discussed in more than one component of analysis.

The four sets of excerpts are analysed one at a time. During the application of the Rep Test and subsequent dialogues, insight is gained into the various weight attached to the teachers' anecdotes, allegories and propositions concerning science teaching. Having come to the surface, though, such themes do need to be selected and organized. For this to be done according to a Freirean strategy, it is necessary that a well-defined set of criteria on the part of the investigator is adopted. The prototypes, precedents and parables which arise from teachers' discourse are selected by the investigator according to criteria set by the Tetrahedron of Principles.
Principles. These criteria are used just as ‘phonemic richness’, ‘phonetic difficulty’ and ‘pragmatic tone’ are used to select generative words for literacy programmes (Freire, 1974, p. 49). The investigation questions (part II, section D, subheading 4) are applied and excerpts, thus, clustered accordingly.

The clusters of excerpts are then organized. They have to be, since only a few cases can be re-presented to teachers. According to Freire’s method, the best generative theme is that which combines the greatest possible ‘percentage’ of the criteria set in the investigation questions (Freire, 1967, p. 114; Freire, 1974, pp. 51-2). A particularly important criterion to be observed here is the greater or lesser tenor of conscientização which a theme potentially carries. The tenor of conscientização which a theme carries can be judged, as previously explained, by the socio-cultural reactions which the theme generates in the teacher or group of teachers referring to it. These reactions correspond, for the individual, to those feelings which the discussion of such a theme arouses. Analyses of this kind, in the realm of language and speech, pertain to the domain of pragmatics. Here, the greater or lesser tenor of conscientização which a theme potentially carries is an important criterion for choosing generative themes, as well.

Themes that cause emotive reactions in primary teachers can be assumed to be meaningful for them. Among these themes, some must relate to the disciplined empirical and philosophical enquiries of science educators, as well as to the practical experience and moral or ethical reasoning of these experts. So, the criteria for selecting generative themes from a choice of meaningful themes follows from the parallel with pragmatics. Those themes believed to be meaningful can be associated with primary teachers’ strategic knowledge, and therefore with their propositional and case knowledge (Shulman, 1986b, p. 13). In turn, the set of generative themes stems from the propositional knowledge in teaching of science educators. Therefore, it is the responsibility of science educators to point out which of those themes, shown to be meaningful for teachers, can generate reflection and an enhanced awareness about science and its teaching.

What is sought in the present analysis are themes that relate to primary teachers’ knowledge and experience (with particular regard to their emotions) and which, at the same time, relate to issues considered by science educators to be worth teachers to reflect on with a view to enhancing their teaching practice. These themes, it is assumed, might have the potential to raise the awareness of those teachers about what these experts put forward for consideration in their research papers and other works. However, it is reasonable to argue that primary teachers
might not accept the suggestion to discuss these themes. They can justly argue that some topics raised by science educators in their research are irrelevant to primary science teaching. Though this argument might be justified with regard to some topics, it is not necessarily so for all the topics which primary teachers might at first be tempted to dismiss out of hand. A Thematic Investigation such as this might successfully point out topics which are relevant for primary science teaching and yet have failed to attract the attention of primary teachers enough for any meaningful reflection. Assuming that the themes resulting from the investigation are in fact really relevant, the failure to motivate teachers to reflect on these themes might, therefore, be due to the form in which these themes are presented to teachers. For this reason the investigation does not stop at the identification of generative themes; it goes on to codify them.

The codification of themes consists in selecting emotive episodes drawn from primary teachers' strategic knowledge which relate to themes considered by science educators to be worthy of reflection. The purpose of this is to bring about dialogue between primary teachers and science education experts. It is, therefore, particularly important that misunderstandings and mild frictions between them are represented by these codifications. I must emphasize, the rationale for this research effort is a collaboration, in the field of primary science teaching, between primary teachers and science education experts. It has been primarily this criterion that has inspired the labels designated to the different codifications of a particular generative theme. Each label is designed either to impart the significance that teachers attribute to a particular principle, maxim or norm, or to highlight the importance of one of these propositions in relation to the major sources of knowledge informing science education researchers: disciplined empirical or philosophical enquiry, practical experience and ethical reasoning (Shulman, 1986b, p. 11a).

E. Summary

The investigation of primary teachers' praxis in the teaching of physics in this study has been conducted according to the flow chart below. I will recapitulate its main features.

The sample has been chosen from primary teachers in the UK because these have been challenged with the instruction to introduce science to school-children within the core of their curriculum. Nine teachers volunteered and seven of these were asked to audio-record an activity in which a topic related to physics was being
taught by them. Teacher D.H. did not do this because she was on maternity leave at the time. Teachers S.S. and J.C. provided records of activities they had made in the past for other purposes. The other teachers developed activities on ‘Gravity and Free-fall’ (AW), ‘Reflection and Refraction of Light’ (MK), ‘Forces: Pushes and Pulls’ (LP), and ‘Electric Circuits’ (CP). When they volunteered, all agreed to meet me on three different occasions, for one hour each time. For personal reasons, teacher D.H. only met me twice, while A.W. met me four times. Most of them have allowed me extra time in one or two of the meetings.

**Filling-in stage**

Stage when twenty-three questions, each written on a card, were presented to teachers. They had to answer one question at a time, writing in a designated space on the card. The twenty-three questions are listed in Appendix 1. Apart from answering the questions on those cards, they were also allowed to provide extra material for discussion by writing a reference to meaningful experiences on blank cards. Teacher M.K. did not answer the question-cards. He was allowed to write down nine experiences he associated with different feelings of his own choice.

**Selection stage**

Stage when teachers were asked to choose nine answers out of the whole set. Each of these answers is considered as an ‘element’ of teachers’ experience. Exceptionally, teachers T.C., G.R. and S.S. worked with all the answers they provided.
Triadic stage

Stage when the teacher was presented to a set of three cards and asked to suggest a criterion to join two of those elements of his/her experience, at the same time placing them in contrast with the third element. This criterion had to express the point of similarity between the first two cards, as well as their point of contrast with the third one.

Grading stage

This is the stage when teachers used the criterion established in the Triadic Stage to attribute scores from '1' to '5' to each element chosen in the Selection Stage. All teachers, with the exception of teacher G.R., attributed grades to each card of the selected set according to each criterion provided.

Focus analysis

This is the factor analysis of scores attributed to elements in the Grading Stage. This analysis was performed by a computer program (RepGrid, 1991) between the first and the second meeting and is called FOCUS analysis. The results of such calculations are in Appendix 2.

Dialogues

In the last two meetings I had with each teacher, I produced evidence to him/her that his/her scoring in the Grading Stage followed some sort of pattern. By doing that and by challenging teachers to justify such patterns, I was able to make them think further on the criteria they had established in the Triadic Stage. By thus problematizing teachers' propositions, I had opportunity to accompany them as they voiced their reflections on previous or vicarious experiences they had, together with values and principles they drew on to as they did so. These reflections were tape-recorded and transcribed.

Analysis of dialogues

Discourse analysis of the verbatim transcripts followed and was performed on all the interviews at once. This analysis was conducted according to the 'Tetrahedron of Principles' model, designed to represent implicit principles which might have guided authors of science teaching projects.
CHAPTER 4
DATA ANALYSIS

I. ANALYSIS OF TEACHERS' EMOTIVE REACTIONS

A. EMOTIONAL RECALL: RESPONSES TO QUESTION-CARDS
   General matters which emerged as elements for discussion
   The dichotomy: knowledge of subject matter versus knowledge of teaching
   The National Curriculum as a limit-situation
   Reasonably emotional

B. CRITERIA TO FRAME RECOLLECTIONS: GRADING PATTERNS ON REP TEST
   Reflection on similarities and differences

C. EVERYTHING BUT CONTENT MATTER

II. ANALYSIS OF TEACHERS' DISCOURSE

AN EXAMPLE: THE THEMATIC INVESTIGATION OF A.W.'S DISCOURSE
   Generative themes and their presentation

THEME 1: DISCOVERY LEARNING
   1. 'Hands-off' Teaching for 'Hands-on' Learning
   2. Making and Taking Excitement
   3. Motivation and Relevance
   4. Challenge is a Motivational Tool
   5. Cognitive Abilities Ought To Be Respected

THEME 2: RECEPTION LEARNING
   1. Different Abilities, Similar Goals
   2. Piecemeal Teaching for Hierarchical Learning
   3. Staging for Meaningful Reception Learning

THEME 3: SCIENTIFIC KNOWLEDGE
   1. Truths or Theories?
   2. Whose ideas are these, anyway?
   3. Autonomy from the 'Canons' of Science

THEME 4: SCIENTIFIC ENTERPRISE
   1. Science or Technology?
   2. Content and Process

THEME 5: THRUST OF TEACHING
   1. Understanding?

THEME 6: CHILDREN'S DIVERSITY
   1. Fairness, Equity and Justice

THEME 7: ELEMENTS OF COMMUNICATION IN A TEACHING PROCESS
   1. Objects of Communication in the Teaching of Science
   2. Processes of Science as Object of Communication
   3. Sources of Information in the Teaching of Science
THEME 8: SCHEMES FOR THE ARTICULATION OF MESSAGES
1. Obvious and yet not Trivial to Communicate
2. The Scientific Ways to Represent the World
3. The Use of Analogies
4. Follow in Scientists' Footsteps

SUMMARY OF ANALYSIS OF TEACHERS' DISCOURSE
The introduction by the National Curriculum for England and Wales of science as a core subject for all pupils from the age of five has, in many ways, seriously challenged primary teachers. With the research designed for this study I set out to challenge a group of these teachers yet more. This chapter discusses in detail the results of this intervention.

This investigation can be seen to be parallel to Freire's Method of Education (see chapter 3, part II, section D). In its first phase, I have used question-cards and the Rep Test to research the range of ideas and experiences non-specialist teachers of science draw on when they talk about science teaching. In its second phase, the teachers themselves have selected ideas and experiences from their own repertory and then used and discussed them. In its third phase, I have begun to codify the strategic knowledge of these teachers and create representations of situations they recognize as typical. These representations may eventually be used to stimulate reflection on issues that pertain to science teaching and hence promote professional development.

In this chapter, I describe the outcomes of this investigation. In the next chapter, I consider whether those outcomes can in fact stimulate reflection that promotes teachers' professional development. Since this stimulus to reflection seems possible, I also discuss how a programme to promote professional development could be organized.

There are two sources of data in this study: the teachers' emotive reactions to Rep Test early intervention; and, the teachers' discourse in response to my challenges to their emotive reactions. This chapter is organized according to these sources of data. Part I, called the 'Analysis of Teachers' Emotive Reactions', presents an analysis of the teachers' responses to emotive questions on Rep Test cards. It also discusses the trend that the various FOCUS analyses of the teachers' Rep Test results show as we compare them. Part II, entitled 'Analysis of Teachers' Discourse', illustrates how I have scrutinized the verbatim transcripts of conversations triggered by the Rep Test. In order to illustrate the process involved, I analyse the transcript of one interview with one teacher in the manner employed throughout all the transcripts. The same process was undertaken with transcripts of interviews with all the teachers. The result is a set of eight generative themes. Part II brings these themes to life by discussing them from the point of view of their relevance for teachers and teaching.
I. ANALYSIS OF TEACHERS' EMOTIVE REACTIONS

Once I had adopted Freire's ideas as a philosophical framework, a series of premises were adopted for the present study. In the first part of this chapter, I discuss the practical results of adopting two such premises to study primary teachers' thinking and practice in relation to the teaching of science.

The first of these premises is that 'turning points' in an individual's professional life are marked by emotions. So, by asking an individual to list emotive events one has the opportunity to generate a sample of good elements for discussion with that individual. In section A, 'Emotional Recall: Responses to Question-Cards', I discuss the outcome of the card-filling exercise, the feature of this research which is explicitly based on that premise.

The other premise concerns normally unexpressed beliefs, assumptions and constructions associated with the professional activity of people. The premise is that these aspects can become explicit when one recalls the thoughts and emotions related to an event; and when one recalls and compares these with emotions related to other events, thus labelling their similarities and differences. In other words, as stated in Chapter 3, I have assumed that Kelly's method for the elicitation of personal constructs, the Repertory Test, is a useful tool to attain the purposes I aim for in this study. In section B, 'Criteria to Frame Recollections: Grading Patterns on Rep Test', I discuss what resulted from the built-in analysis of this methodology, the FOCUS Analysis of Repertory Grids (RepGrid, 1991).

A. EMOTIONAL RECALL: RESPONSES TO QUESTION-CARDS

In the first of a series of three meetings each volunteer was asked to provide a list of events they associated with particular feelings and sensations with regard to their teaching of science. They were all asked to complete a set of cards noting past episodes where they were involved in the teaching of science, particularly some aspect of physics. At the top of each card a question was intended to prompt the recall of episodes associated with a particular emotion. The volunteers were given the opportunity to skip those cards with labels that led to no particularly memorable episodes. They also had cards without labels in case they wanted to mention particularly significant events which did not fit the labels provided.

Here, I gather together the results of this exercise. Table 3 shows the cards filled by the eight teachers who took part; teacher M.K., as I have already mentioned,
<table>
<thead>
<tr>
<th>TC</th>
<th>Floating boat (using different materials)</th>
<th>Figure</th>
<th>X</th>
<th>SAT</th>
<th>Names Club (a few)</th>
<th>When the stick breaks sound</th>
<th>Work on magnets</th>
<th>Quiet children making hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR</td>
<td>Doing science with nursery children - their capability</td>
<td>When 2 children planned their own investigation, without help</td>
<td>Group of children testing the grip of shoes</td>
<td>X</td>
<td>RE - Religious Education</td>
<td>Copying from reading books</td>
<td>Class discussion</td>
<td>Children behaving appropriately</td>
</tr>
<tr>
<td>AW</td>
<td>Rymy's egg mix</td>
<td>National Curriculum imposed breadth but not depth, Time restrictions which this creates</td>
<td>Flight - making paper kites where the children experimented with different weights</td>
<td>X</td>
<td>Flattening and bending - the incredible thought that went into the bridge building activity</td>
<td>When the children designed different materials according to their properties but only really looked at size, clarity and the function of the object</td>
<td>Design &amp; Technology practical problem solving when it demonstrates into chaos</td>
<td>Children through their own investigation and not that intentions make strong structures for bridges</td>
</tr>
<tr>
<td>SS</td>
<td>SS - The incredible thought that went into the bridge building activity</td>
<td>SS - How many children are quite happy to hypothesise</td>
<td>SS - How many children are quite happy to hypothesise</td>
<td>X</td>
<td>SS - The incredible thought that went into the bridge building activity</td>
<td>National Curriculum imposed breadth but not depth, Time restrictions which this creates</td>
<td>Design &amp; Technology practical problem solving when it demonstrates into chaos</td>
<td>Children through their own investigation and not that intentions make strong structures for bridges</td>
</tr>
<tr>
<td>LP</td>
<td>The children were motivated, A - The exploration in their learning, B - I was encouraged by the ability to intervene</td>
<td>Observing children's independence in learning</td>
<td>Children not always on task but the different activities sometimes inhibits the discussions</td>
<td>When we take the temperature each day and the children are pleased if its right!</td>
<td>N.C. The prescriptive &amp; 'straight jacket' nature of the curriculum</td>
<td>How much some children already know from their experiences</td>
<td>The ability of some children to read quite difficult texts</td>
<td>Joy when an activity goes well</td>
</tr>
<tr>
<td>BC</td>
<td>Putting electricity into the younger children's house</td>
<td>Something going really well and children enjoying it</td>
<td>Electricity work - manage to get something to work.</td>
<td>Echoes</td>
<td>Shadows</td>
<td>Musical instruments</td>
<td>Gravity</td>
<td>Hook &amp; I, for moving.</td>
</tr>
<tr>
<td>CH</td>
<td>The success of my first electricity session with 3 yr olds</td>
<td>Setting up - clips, museum, with 3 yr olds coming own guides &amp; information leaflet</td>
<td>My own lack of understanding of Space &amp; 3. 3 inability to teach appropriately or inspire the children</td>
<td>Electricity - model working</td>
<td>Having to do it all</td>
<td>The group of the concept of electricity by very young pupils Work previously taught at secondary level</td>
<td>Teacher still felt uncomfortable &amp; A co-ordinator asked to support.</td>
<td>The places &amp; space - How do I know?</td>
</tr>
<tr>
<td>CF</td>
<td>Problem skills, developed finding faulty bulbs and battery</td>
<td>When children get excited not to cover and having fork</td>
<td>Need small groups not class too difficult to manage (children)</td>
<td>4 yr old mixing paint - magic. Her face.</td>
<td>Whole class teaching.</td>
<td>Classroom management with new equipment</td>
<td>The questions, plain work. I'm not telling it to the children &quot;exactly&quot;</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3: Responses to Question-Cards**

**CHAPTER 4 - Part 1 DATA ANALYSIS**

- Card selected for triadic stage
- Card left blank
- X Card not given to teacher
| Table 3: Responses to Question Cards |

**CHAPTER 4 - Part I: DATA ANALYSIS**

| T.C. | No been grow at all | group discussion on identity (autobiography) | Science in Prin. N.C. | Impotence | Keeping animals in class | Descriptions (bim) | model broken | nature talk | chalk and talk | misuse of sanctions | ch. working together | an outing to the park on a sunny day |

| S.R. | Child of fire, candle and jae | Children working independently, without needing help/intervention | Science N.C. | Attempt teaching about stars (repertoire and dialogue) | More time for doing things on the spur of the moment | Imperator and the butterflies | Work on Earth and Space | Disturbed, difficult children | Promote autonomy/independent learning | From disturbed children | Most of the children on task, some doing fully unexpected work, some doing more stimulating activities in science | Beginning chess | Restaurant |

| A.W. | Creativity experiment when I expected all the kids to do the game. Necessity but they didn't! | Small class investigation with all children working together | Children demanding to do certain topics | Morning & meeting choke hold as a wide class demonstration – children were bored + resistive | Children doing unexpected things in with taps. Were the consequences were unacceptable | Corse of children running around the room | Clock * Talk | Teaching the HC with no resources = very little training inadequate knowledge | Children's level of participation is usually good | Doing electricity – making circuits. They had achieved success in the lab and I felt that the desired learning had taken place |

| S.S. | When something happens that I couldn't explain | I would like to teach (but haven't done so) ocean and light | That all areas of 'wonder' need to be covered. Then hopefully the children will have had a broader experience than my generation | Feeling blobby by my own lack of expertise | I miss having a wide range of practical things to do in the classroom | Some of the children's perceptions they already have at 5 yrs | X | X | X | X | X | X |

| L.P. | I don't actually look forward to teaching AT4. I look forward to the completion of the lesson. | I'm pleased that the N.C. has given a framework for science. A given emphasis to the importance of the lesson. | I've never been taught the subject. | Being allowed to be in control, or able to respond to unplanned for situations. e.g. when children bring in things – building a topic around the children's interest | Some of their concepts are always explained. One child always responded to that God did everything. | The amount of knowledge (or facts) are expected to be taught. | Some of the ideas proposed by inspectors | AT4 (past should be able to describe the apparent movement of the Sun across the sky) | These children are usually inquisitive and physical lean towards experimentation for young children | Working together + finding out |

| J.C. | Sound making during homework, after orchestra visit | Making a switch | Following up a child's interest – not the time. | Mimes. | What magnets can do? Tell the children! | Working model making | Not at all – the opposite is true. | It is now a 'normal' part of the curriculum & is planned into people's weekly curriculum |

| C.P. | C.P. How science is approach. AT4s. How I go about it. | Lack of knowledge: People ask me what knowledge they should be teaching. | Very young introduction science | Staged to be acceptable | AT4 21 fixture Studies. T expanding experience out of the lab of AT4 | That people think you can do science with nursery children |
did not fill in these cards but provided nine events of his own choice. The shaded cards are the ones the teachers selected for the triadic stage; only five teachers did so. Some interesting points arise from the analysis of this tabulation of their answers to the questions asked. The premise that lead to the formulation of these questions, I want to argue, seems reinforced by the overall results obtained.

The responses at this stage of the process show its value from the variety of responses provided by each individual. Some cards could be said to refer to 'positive feelings', as they ask the teachers to recall something exciting, remarkable or funny (there are ten such cards: 1, 2, 4, 9, 10, 13, 14, 16, 17 and 23). Nine cards (3, 5, 7, 11, 15, 18, 19, 20, 21) refer to 'negative feelings', since they request something disappointing or awkward, for example. Finally, four cards (6, 8, 12, 22) could be classified as 'neutral': card 6, for example, refers to something surprising and card 8 to something reasonable. All the teachers managed to name episodes for cards labelled with 'positive', 'negative' as well as 'neutral' feelings.

General matters which emerged as elements for discussion

How did the teachers respond to the questions at the top of the cards? What is noticeable is that a number of their responses are not direct answers: many of them do not describe episodes as such. They do not make reference to a particular event that could, so to speak, be located in time and space, but refer to a kind of situation that happened or, indeed, might happen. Take for instance, teacher L.P.'s card 16 (LP16 for ease of reference). This teacher writes that she misses "being allowed to be innovative, or being able to respond to situations for which there have been no plans"; another teacher also gives a response of this sort, writing that she finds it normal "to wait for children to experience and to discover" (JC22). The fact that these notes make no explicit reference to any aspect of science teaching could be worrying; a nuisance which - at first sight - seems not to fit in the research. Perhaps, to the same questions, it would be better to have only responses like "I miss keeping animals in classroom" (TC16) and "Children working [in an exploration] together is normal" (TC22). However, that is not the case. From a Freirean point of view this lack of focus, as one might call it, does not prove to be so daunting, indeed it is a rather positive sign.

In Freirean terms I am researching the frameworks of this group of teachers. I am trying to select the frames of reference most weighted with existential meaning and thus the greatest emotional content. This involves typical thoughts as well as words and expressions linked to their specific experiences. In the same mode as Freire, I suggest that "these interviews reveal longings, frustrations, disbeliefs, hopes, and an
impetus to participate" (Freire, 1974, p. 49). The generative themes for which I am searching should therefore emerge from the reflections registered on these cards, the grid analyses and the interviews that follow. The teaching of science is not the sole outcome of this early stage in the process.

As I have said, the design of this research is intended to reveal cases, that is events or episodes, but not necessarily those lived by volunteers; vicarious experiences are also its target, especially those which represent the teachers' propositions and/or knowledge. This is the case with the examples above. When teacher L.P. says she misses being allowed to be innovative and respond to unplanned situations, she conveys a norm or value regarding teaching, namely that teachers ought to be creative and capable of making decisions for themselves. In that sense, her response is a parable, which according to Shulman (1986b, p. 11c) is one type of teachers' case knowledge. By the same token, teacher J.C.'s response communicates a principle of practice or maxim: if you wait, children will discover. That is, her response can be regarded as a precedent - another type of case knowledge. In sum, challenging these teachers to recall emotive episodes, and, later, problematizing the propositions they say are associated with these cases, gave rise to a range of valuable but unexpected correlations with the central theme of discussion. The richness of the teachers' discourse in the course of this research is considered in part II.

The dichotomy: knowledge of subject matter versus knowledge of teaching

It is interesting to note that the pattern of response to the cards confirms, to some extent, my initial premise about the dichotomy between subject matter knowledge and teachers' expertise. Even though I was asking for examples of their experience when teaching topics in physics, they took the request in a much broader sense. They did not centre their reasoning on issues of content matter and this, as I show later, eased the analysis of their thematic universe. The implicit consistency observed in their reflections is not produced by the internal logic of the subject matter, which I believe would have been manifest if they were expert teachers.

It is evident from some cards how much interviewees resent their lack of content knowledge; take, for example, the card on which a teacher writes that she finds it awkward "to be asked questions she can not answer or for which she can not find out anything about" (AW11); cards SS5,12,15; LP15; DH3,11; CP11,15 have similar remarks. These confirm what each one of these teachers voiced at the time they agreed to be interviewed: mastering subject matter might not be sufficient for 'successful' primary school teaching of science; however, an understanding of the
subject does help in teaching it.

**The National Curriculum as a limit-situation**

I stress, my attempt here is to establish with the teachers as authentic a communication as possible. The card labels, which make explicit reference to feelings and sensations, were meant to prompt the teachers to provide topics about which they would eventually talk emotionally. The strategy, as I have said, was to numb any control mechanisms which the teachers might have to systematize their thinking. To debate one’s practice and thoughts without personal commitment would be of little use or relevance. One can elaborate a calculated discourse, arguing that ‘the facts speak for themselves’ (Taylor, 1993, p. 96). In my opinion, however, facts do not do so; at least not in the realm in which I am now working.

Consider, for instance, the introduction of the National Curriculum. The present enquiry reveals that behind teachers’ ‘professional approach’ to it lay a series of emotional issues that need to be interpreted in some detail. The short notes made by the teachers on the cards give some indication of their viewpoints on this matter. This is an example of how their explicitly expressed fears - as well as hopes and other feelings - conceal particular characteristics, qualities or tendencies which teachers do not recognize themselves as having. In a word, the cards acted as triggers to bring these issues to light; and did not do so by tapping into the teachers’ reasoning, but rather their emotions.

The questions at the top of the cards ask for what the teachers remember ‘with respect to the teaching of physics’. They could have answered these questions by focusing solely on topic work, classroom activities, procedures etc. Instead, to some questions, they gave answers that pointed in the opposite direction. They turned to overarching contexts in which the teaching of physics itself is now inserted - to the curriculum that forces on them certain topics, activities, procedures etc. An emotional, rather than rational, link seems to have been established.

Given the recent changes which the National Curriculum has imposed on the teachers' routine, some reference to it was expected. However, it is the kind of reference made that shows the significance of the imposition. Some of the teachers made it very clear that the National Curriculum does represent for them what Freire described as a ‘limit-situation’. One teacher, for example, mentioned the National Curriculum on three separate cards. On the basis of these it is possible to infer that this teacher sees the National Curriculum both as a "straight-jacket" (LP5) that makes her feel uneasy with the teaching of physics topics (which she
would rather avoid) (LP13), and as a welcome initiative that provides a framework for the teaching of these subjects (LP14). Another teacher puts it in similar terms: "being expected to teach something otherwise avoided" is "uncomfortable, but professionally challenging" (DH14). These are two good descriptions of what Freire meant by the expression 'limit-situation'. Similar references to the National Curriculum can be found on the following cards (see table 3, page 185): TC5,14; GR14,16; AW5,21; SS14; LP5,13,14,18; DH5,6,14,22; CP13,20.

These are examples which show that the National Curriculum prevents teachers from being what they want to be, and from doing what they want to do in the classroom. This is because, first of all, the National Curriculum is imposed; so, it is an obstacle to teachers' self-determination: metaphorically, it is a 'straight-jacket'. Second, it requires primary teachers to teach topics which relate to concepts they do not understand; and, in doing so, it creates a climate of hopelessness, hence, leading to their avoiding those topics. However, over and above that, these examples show what is corroborated by the analysis of the teachers' discourse discussed below: the National Curriculum does not merely represent an impassable obstacle. Once it has challenged teachers - at least these mentioned - to bring forth ideas, actions and teaching solutions not thought possible before, the National Curriculum has teased out the awareness of teachers' own limitations together with a consciousness of their own potential. In other words, it has opened up an 'untested feasibility' for teachers in terms of their teaching of science. This, as we have seen in Chapter 2, is as good a definition of the concept of 'limit-situation' as can be made.

Reasonably emotional

The answers to the questions on the Rep Test cards confirm the initial assumption about the limiting nature of the National Curriculum. This confirmation, however, would be rendered irrelevant if the methodology adopted in this enquiry had not also allowed the teachers' to 'name their world'; that is, if it had not elicited topic work, usual classroom activities, procedures etc. I am not interested in an inventory of the teachers' actions. However, according to the precepts discussed in chapter 2, the study of their thinking would not provide a picture of their praxis if the actions that inspired their reflections - as well as resulted from them - were not present.

The Repertory Test cards also show the hallmark of National Curriculum (DES, 1991) science attainment targets. Even a superficial look at the responses to question-cards suggests which topics must be approached according to the new
curriculum. An analysis of the card labels associated with each topic indicates which topics teachers can work with more or less comfortably. Indeed, since some of the teachers' responses shown in table 3 (page 185) refer to instructional materials in relation to those topics, as well as alluding to indications and contraindications for using these, it seems possible to infer from this their 'curricular knowledge', one of the three categories of Shulman's 'content knowledge in teaching' (Shulman, 1986b, p. 10a). Electricity, for instance, is the topic which appears most (AW23; CP1; DH1,4,9; JC1,4,13; SS5; TC13). Only teacher S.S., on card 5, expressed anguish about her lack of understanding in this area. For the others, electrical concepts and aspects of its teaching were placed under positive labels. Whether this means that they are all more confident than S.S. about concepts of electricity is hard to tell.

Some topics can be easily seen as associated with success in the classroom. From table 3, I would place 'Sound' (AW2; CP2,26; JC12), ‘Weather/temperature record’ (AW10; LP4), ‘Building Structures’ (AW8; SS1) and ‘Magnets’ (DH17; TC8) in that category. On the other hand, topics such as ‘The Earth’s place in the Universe’ (DH3,11; GR18; JC24; LP21), ‘Energy to make things work’ (DH19; SS7; TC3) and ‘Gravity’ (AW12; JC8) were all placed under labels expressing negative feeling. One exception here is J.C. who describes a ‘Remarkable’ experience when a particular child seemed to blossom when she made her car move. The other topics mentioned - like ‘Light’ (CP11; JC6,17; SS13) and ‘Floating and Sinking’ (AW3; SS2; TC1) - show mixed emotions.

Given that the curriculum implementation constrains the teachers’ freedom, it is not surprising that these topics are all to be covered under the National Curriculum; these are amongst the most meaningful elements of reality for primary teachers from England and Wales at the moment. But, from the patterns of response observed, little can be said about the teachers’ content knowledge. What is possible, is to identify areas of discomfort. Some topics lend themselves better to National Curriculum’s Attainment Target One (AT 1): Scientific Investigation; others are more ‘content driven’ and come under AT 4: Physical Processes. It is interesting to note that the topics placed under negative labels in table 3 come exclusively from AT 4, while the other two groups contain topics from both AT 1 and AT 4.

B. CRITERIA TO FRAME RECOLLECTIONS: GRADING PATTERNS ON REP TEST

As described earlier, in this research the first meeting with the teachers comprises
three other stages apart from card-filling: selection, triadic and grading. After choosing nine episodes among the set of completed cards (now without a question at the top), in the triadic stage the teachers are presented with three cards at a time. Each time they are asked to provide a different criterion which highlights one similarity between two of the cards and which contrasts these with the third one. This criterion is then used to score each one of the nine cards with a whole number from 1 to 5 inclusive.

The outcome of this exercise is a matrix of grading scores. By taking episodes in pairs and comparing scores given to them, one is able to cluster together episodes which show similar score patterns. These similarity measures are known as FOCUS Analysis, which is a built-in feature of the software RepGrid (1991) used in this study (see FOCUS grids of all volunteers in Appendix 2).

Reflection on similarities and differences

With regard to positive and negative labels, another interesting trend may be observed in the next step of the process. As mentioned earlier, not all volunteers were initially approached in exactly the same way. The majority were asked to complete the cards shown in table 3 (page 185). Among these, most were asked to choose a sample of nine out of all the cards they had filled. Three teachers were not asked to do this, being asked instead to classify all cards they had filled in the first place. These cards had their labels cut off so that the interviewee would deal only with what he/she had actually written on it, not with what was initially printed there. It was only then that the triadic elicitation process was introduced to generate the Repertory Grids.

There is an interesting pattern to be noticed in comparing FOCUS grids, the graphs generated by the RepGrid software (see Appendix 2). The teachers tended to cluster cards which, prior to the triadic process, had either positive or negative labels. The example in figure 11 shows this; the original labels of the cards in the bottom cluster could be said to refer to ‘positive sensations’ (‘Joyful for you and pupils’, ‘Gave you personal satisfaction’) or, although ‘neutral’, were interpreted from a positive point of view (‘Reasonable’, ‘Surprising’) (see Appendix 1 for cards full labels). The five cards at the top, on the other hand, refer to negative feelings and sensations. This pattern of responses seems a reasonably good validation of the card-filling exercise and the triadic process.
Another trend observed was the generally higher level of similarity within one of these clusters, as is the case in the bottom cluster in figure 11. There seems to be more in common between those episodes originally placed under positive feelings than between those under negative feelings. The tendency suggests that a successful course of action results from a much clearer set of beliefs, assumptions and constructions about the elements associated with teaching. In other words, the reason for one’s pedagogical success, if it is not a unique instance, tends to rest on fairly limited grounds. The reasons for lack of success, on the other hand, tend to be many.

C. EVERYTHING BUT CONTENT MATTER

So far I have argued that the different card clusters listed above are basically signals of how much the National Curriculum is a limit-situation for these teachers and I have given some evidence of the degree to which their professional reflections can be emotional. Both arguments serve to make the point that my initial premise is tenable; in asking individuals to recall emotive events, one has the opportunity to elicit cases and propositions which can be used to generate meaningful dialogues with those individuals. Now I would like to initiate a separate line of argument.

Within the same chart (table 3, page 185) there are two reasonably large sets of cards which I have not yet analysed. Both deal with aspects of teaching at a superficial level but they already contain hints of what later, in the analysis of the teachers’ discourse, I call generative themes for dialogical teacher education in science.

The largest of these clusters brings together references to different classroom organizations. Few classroom procedures seem to be missing. The teachers mentioned ‘Chalk and Talk’ (AW20; TC20), ‘Group Discussion’ (GR3; JC10;
TC13), ‘Autonomous Learning’ (GR10,13,21; LP1,2); ‘Demonstrations’ (AW10,15; CP26), ‘Science Circuses’ (AW19), ‘Workshops’ (DH13), ‘Class Museums’ (DH2), ‘Vivaria’ (TC16), ‘Practical Experiments and Investigations’ (AW13; GR2; SS10) and ‘Field Studies’ (TC23). They also made reference to ‘Class Size’ (CP3,5) and the ‘Efficiency of some Teaching Processes’ (CP18,24; JC22,23; LP16,23).

The other cluster is comprised of different reactions to acts, or responses by the children in relation to science activities. Most came under "(9) Remarkable" (DH, JC, LP, SS, TC) and "(17) Funny" (DH, JC, LP, SS), and there were two under "(6) Surprising" (LP, SS). Teacher L.P., the most experienced of the teachers interviewed, proved to be the most amazed by children's reactions. She made five such references (LP1, 2, 6, 9, 17). As a matter of fact, in the interview, she declared that in the past she had avoided teaching science. This is partly due to her impoverished scientific background and other particular circumstances, for example the influence of her husband on her propositions about the nature of science. I will deal with this later in this chapter (Theme 3).

While the first categories of the teachers' answers referred, in one way or another, to the introduction of science in the National Curriculum, the latter two point to issues usually classified as ‘pedagogical’; thus, how versed one has to be in a particular concept or topic is not at stake here. Nor is accountability to external boards or standard examinations. In fact, the largest set of answers above - which refer to generic principles of classroom organization, management and the like - would be described by Shulman as ‘pedagogic knowledge in teaching’ (Shulman, 1986b, p. 14b). This domain of teachers’ knowledge, as I have said, is outside the scope of this study. On the other hand, the latter set of answers are about those in charge of the act of teaching (teachers themselves), their immediate public (the pupils) and their main stage-set (their classes): the lessons one gives or would ideally like to give. Although the variables of subject matter and external professional control do enter into the equation, they might be seen here as separate variables which refer to external conditions. To draw on Shulman’s framework again, this set of responses to the questions about emotions falls squarely in the category of ‘content knowledge in teaching’ which he calls ‘pedagogical content knowledge’ (Shulman, 1986b, p. 9c). The pedagogical content knowledge variables can be taken as, so to speak, independent of variables in the more obvious domains of teacher knowledge: knowledge of subject matter and general pedagogic knowledge. The analysis of interviews that follows is focused primarily on ‘pedagogical content knowledge’ variables, though attention is also
given to aspects of the other two categories in the domain of content knowledge in teaching: subject matter content knowledge and curricular knowledge.

II. ANALYSIS OF TEACHERS’ DISCOURSE

I have assumed all along that primary and specialist teachers belong to different cultures. My research protocol, then, was designed and conducted so that it would help to overcome possible linguistic - and indeed cultural - barriers between the two parties. Interviews followed the card-filling exercise, sorting-out of card triads and grading of similarities and differences between cards. These interviews were intended to be more like conversations. The initial questions I asked concerned consistencies and inconsistencies which showed up in the second level of analysis: the triadic and grading processes. As I have explained, scores attributed by the teacher to different personal experiences - according to criteria they had chosen themselves - were used to generate the graphs in Appendix 2. Such graphs cluster together experiences the teachers classified the same way.

Since the questions during the conversations referred to patterns in their own responses, the teachers tended to show a sense of identification with the process. This could be noticed in some passages. Here is an example of a quite spontaneous manifestation in this respect:

A.V.: Alright, let’s have a look... Those two [cards, numbers 11 and 14], you said are different, they are linked to these two [3 and 12]. How do you interpret that? Do you think they should cluster together?

Teacher: Oh... I think that forms ah... a strong link. Those two [3 and 12] link strongly and these two [11 and 14]... I’m not sure about those.

A.V.: Yes. And without noticing, you’ve graded 11 and 14 with similar grades to these two [3 and 12]. Do you think it’s just a coincidence?

Teacher: No... It’s... It’s... That’s me [laughs]. (AW2.167-78)

In general, after the first meeting, once the volunteers knew exactly what to expect, their attitude towards the enquiry became more favourable. At the start, some had shown uneasiness and a sense of being under scrutiny, whilst now they were more collaborative and interested in the process. One or two volunteers, though, did not change very much in their attitude, and remained hesitant. More could be made of interviews where the conversation flowed. All in all, one might conclude that Freire’s strategy does not always break the defence mechanisms particular
individuals use to conceal their thoughts. For those volunteers who entered the process with a favourable disposition to collaborate, Thematic Investigation helped barriers - cultural, or otherwise - to be overcome. For those volunteers who were not whole-heartedly acquiescent, Thematic Investigation has not proved to be such a good ‘ice-breaker’.

For the sake of clarity, the order of presentation here is not dictated by the sequence of interviews or that of the conversation in them. As I mentioned in the previous chapter, the raw transcriptions of interviews, together with notes and commentaries, were cut into passages according to criteria set by the Tetrahedron of Principles. This framework’s four components helped me to ‘pigeonhole’ passages of the interview and sections from different interviews under the following headings:

* Learning as a Component of Teaching
* The Nature of Primary Teachers’ Science
* Primary Teachers’ Educational Propositions
* Teaching as a Process of Communication

A great variety of themes were still embedded in each of these headings, requiring yet another clustering. Still inspired by parameters stemming from my previous work (Vaz, 1989), I began to identify, within each heading, anecdotes and allegories denoting propositions. I did this with a view to acquiring a better picture of what such groups of teachers seemed most concerned about. So, the categorization used here is a refinement of that 1989 work. By revealing the teachers’ propositions (principles, maxims and norms), as well as precedents, parables and prototype cases (Shulman, 1986, p. 11), the themes these interviewees associate with the teaching of science can be studied and ‘Generative Themes’ can be described.

Because of the complexity of this analysis, I present it in stages. First, it is necessary to describe:

* which sorts of events and assertions were isolated in my Thematic Investigation;
* what resulted when an event, anecdote or allegory was elevated to the status of ‘a case’ or when an assertion was elevated to the status of ‘a proposition’.

Thus, I initially consider the discourse of only one teacher. In this example of
analysis, I study the transcript of the interview when the Repertory Test FOCUS analysis was discussed. I then extract particular events mentioned and assertions made by the teacher in the order they appeared in the dialogue. Once these events and assertions are seen as revealing of gaps within that teacher's praxis or exemplary of differences between the stances of primary teachers and science educators, such gaps or differences are discussed. At the end of this exercise, I produce a summary of themes identified as meaningful for this and other teachers and likely to be generative of authentic reflection. This will serve as an example of the procedure followed with the other interviews conducted in this study.

The second stage in this presentation is my analysis in full, which consists of a discussion of the themes identified when transcripts of all the teachers had been considered. Short accounts of the generative themes resulting from this investigation are given, and the eight themes which were identified have their various distinct aspects labelled and discussed. The conclusion that such issues are 'generative themes of science education among primary teachers' is drawn from the data obtained.

AN EXAMPLE: THE THEMATIC INVESTIGATION OF A.W.'S DISCOURSE

Teacher A.W. was the first to undertake the Repertory Test as it stood in its final form. She chose to work with nine cards, out of all question-cards she answered. Then, she compared these cards three by three, stating, for each triad, a bipolar criterion to distinguish one card as opposed to the others. These criteria, each of which was also applied to the remaining six cards left aside, were used as parameters for the teacher to grade each element-card with a score from 1 to 5. On the basis of these scores, elements graded similarly and criteria applied in the same manner were clustered.

The output of RepGrid FOCUS analysis of teacher A.W.'s test is shown in figure 12. As can be seen, both teacher A.W.'s elements (listed at the bottom) and bipolar criteria (at the top) mix different kinds of things. The elements, for instance, are all episodes from her experience; most refer to topics she taught, or worked on with pupils, while numbers 11 and 14 are particular situations in which she found herself at times.

Without showing A.W. the tree which groups, at the top of figure 12, the bipolar criteria she devised and used, I asked her to comment on the pattern of the tree at the bottom. The latter tree, as can be seen in figure 12, has three distinct branches: one branch at the top, with three elements (15, 11, 14); one branch in the middle
and the lowest branch, in which, according to the scores given to cards 2, 6, 8 and 23, one sees the highest level of congruity between elements. In her remarks, A.W. returned to the idea of success and gave me the chance to provide her with some sort of validation of the clustering process. I referred to the bipolar criteria, which she had devised herself, but did so about a week before this interview. She had then used, not only (1) Successful, but also (7) High-Personal Motivation, and (4) Unexpected Phenomena, to describe the four activities closely connected at the bottom (23, 8, 2 and 6). Dwelling on that, I could initially only obtain the statement: "If I am motivated to do something, generally it is successful. But when you are teaching, you try to teach everything with equal motivation; although, obviously, I am more motivated in certain areas" (AW2.14-16). This seems a truism to me. I would not, therefore, take this assertion as a proposition likely to generate reflection.

Interestingly, it was by calling A.W.'s attention to similarities on the grading of subsets of elements, rather than to the general pattern of their whole tree, that it became possible to obtain more promising statements from her. Here is the first of them:

2 and 8 are both examples of times when things have come from the children. They are both very investigative and they are times when I tried to hold back the teacher and observe the children rather than doing a more teacher directed thing which is important to me. I am happy if the children are discovering for themselves. (AW2.32)

We find in this statement something that can be regarded as a theoretical principle; namely, where A.W. says: it is important to hold back the teacher and
observe the children. The two activities (2 and 8) which brought this principle alive are recalled as very successful. The scores attributed to these particular activities on sound and structures show other criteria A.W. used to describe them. Among these descriptors is 'discovery'.

The term ‘discovery’ used there refers to ‘discovery learning’ - as eventually became clear. A number of issues related to this theme emerged in the subsequent discussion and returned time and again in this and in our next meeting. Here are some examples of these issues in the form of propositions:

* the preparation of ‘discovery’ activities involve the ordering of concepts (AW2.36);
* the recourse to ‘discovery’ activities aims to motivate pupils, as motivation is essential for one to understand new ideas and concepts (AW2.40);
* the teaching strategy to promote pupils’ ‘discovery’ is enquiry teaching accompanied by practical activities (AW2.44).

These ideas show up in the array of anecdotes, allegories and events A.W. used to exemplify her own assertions. Her examples can be considered idiosyncratic prototypes for theoretical principles in favour of ‘enquiry teaching’ and ‘discovery learning’. On the other hand, later, A.W. herself contrasted to these principles - the pillars of her ‘philosophy’ (her term) - ideas that can best be described by the expressions: ‘didactic teaching’ and ‘rote learning’. These contrasts resemble those of a debate widespread among educationists (see for example Novak, 1979); many remarks made by A.W., therefore, look like those of this wider debate. Such resemblances help to reveal part of what goes unsaid in this teacher’s discourse, or else, they simply help to express what she said in a more concise manner.

As soon as the discussion threatened to become circular, I shifted A.W.’s attention to the other elements clustered with 2 and 8 on figure 12. Element 6 (Paper airplanes. Experimenting with different weights) happened to be an activity very similar to the Bridge (2) and the Ear Muff (8) activities and did not render any new comment. On the other hand, Electric Circuits (23) gave A.W. the opportunity to touch briefly on a new point on the subject of learning. She had said that Electric Circuits was a slightly different sort of activity. I asked what was particular about electrical circuits and, apart from saying that the nature of the subject was different, she answered:

I think it’s the concepts children have already got in their heads about
electricity. They already know what it does. They know it’s a power source and there is energy in there. They know there are travels around the wires. They know a lot about it already and some of them might know things that aren’t necessarily right. They don’t know it has to travel in a circuit maybe. So that’s slightly different, because you’re working with quite a lot of knowledge they already might have got. Some of which might not be right. (AW2.68-70)

This passage shows that among A.W.’s concerns there are also questions regarding the way students come to understand the products of science; it is not only questions that deal with the teaching of the science process that interest her. A.W. did provide more statements on the issue, but only later; here, there is just a hint of that: "they know a lot of things that aren’t necessarily right".

In the stretch of conversation before the theme 'science concepts' was clarified, a number of different topics were touched on. Among these, one particular statement stands out, since it conveys one of A.W.’s values as well as a proposition I myself make in this study regarding emotive episodes, liberating actions and teachers’ strategic knowledge. It is the following:

Teacher: Elements 11 (Being asked questions I can’t answer) and 14 (Children demanding to do certain topics) are things that are out of my control. Things that haven’t occurred to me. Surprises. Shocks.

A.V.: And does it puzzle you, them being out of your control?

Teacher: First of all it makes me think I should had thought of that. Then I feel obliged to carry out. Ah... maybe I don’t know how to do that. (AW2.96-KX)

Just after this passage, A.W. went on to detail what - I would contend - is a value of hers. "As a teacher, I should respond to pupils" (AW2.102), she said, going on to affirm that it is her obligation, when children want to find out about something, to help them to do so. In a sense, she is saying that a teacher should be a resource person, a facilitator. Consistent though this might be with the earlier issue concerning discovery learning and enquiry teaching, the concern she now expresses hints at a worry about her competence to fulfil the job she has been given. More about this issue shortly.

I would just briefly like to make a parenthetical comment. The thesis I defend about emotive episodes and teachers’ strategic knowledge, which this case illustrates, is that many dilemmas and professional conflicts which teachers experience begin when they are surprised by something unexpected - in this case, certain questions or demands from children. This point has a bearing on different
ideas discussed in detail earlier. Among these are the concepts of 'limit-situation' and 'liberating action', both developed by Freire (1972, p. 89). Moreover, it brings forward Shulman's proposition that "strategic knowledge comes into play as the teacher confronts situations or problems where principles collide, or the precedents of particular cases are incompatible" (Shulman, 1986b, p. 13a).

The theme 'science concepts', briefly touched on earlier by A.W., began to be clarified following a further shift of focus made possible by the RepGrid's output. Moving down the scale of grading congruity, we focused our attention on elements 3 (Floating and Sinking) and 12 (Gravity Experiments). These elements showed the lowest level of similarity in A.W.'s Rep Test (see figure 12, page 198). The conversation which immediately followed this is noteworthy:

A.V.: Let's see how it follows. The next link is here. Do you really feel that these elements are similar?

Teacher: In terms of success, yes. They are out of my own capabilities. They are, both, dodgy areas. I'm not convinced that I know what's right or what's scientifically accepted. So they are subjects that I will teach but I'll be worried while I was doing.

A.V.: Why do you worry?

Teacher: In case I'm giving the wrong ideas. And in that case I'll try not to give any ideas [laughs] in case they are wrong. I know what I think, but I don't know if it's right; about Forces and all the rest of that.

A.V.: And do you think it's important to have it right?

Teacher: I think it is important to know how to get it right. It doesn't have to be right at the start but you have to know, to see if you can get the answer. Because otherwise you're teaching them one thing they will have to unlearn and learn again later on. (AW2.147-52)

Here, I would like to point out what can be argued to be propositions articulated by A.W.. One of these can be read as follows: In case I am giving wrong ideas, I will not try to give any idea. This proposition sounds more like a norm - something observed because it is morally or ethically right - than a principle deriving from research or from accumulated wisdom of practice. If this was read as a theoretical principle, it could be interpreted as yet another reference to discovery learning and, by extension, inductive teaching. Read together with the passage immediately before, however, this proposition arguably sheds light in other directions.
Out of nine cards selected for the Rep Test by A.W., only three bear topics related to concepts of physics - as conventionally described in post-fourteen education. Looking at how these topics were graded during the Rep Test, one can already tell that A.W. makes a distinction between them. ‘Electric circuits’ was not classified in the same way as ‘Gravity’ and ‘Floating & Sinking’, but very much the same way as other activities; namely the ones she used to epitomize ‘discovery’: bridges, ear muffs and airplanes. Hence, A.W.’s attitude towards the two ‘dodgy areas’, as she described ‘Gravity’ and ‘Floating & Sinking’, seem to show the importance that knowing and understanding the concepts of science has for A.W.. This could all be simply a matter of having the right answers at hand, but that does not seem to be the question here. Let me illustrate this.

At the time of the interviews, A.W. had been teaching for about three years, and was working with eight-year-old children. Perhaps because of her lack of experience, her possession of subject knowledge was an important issue. This kept coming back into the conversation and gave her the chance to express what others would have just hinted at.

I had asked A.W. to record some classroom activity before we talked. She chose ‘Gravity’. Eventually she explained that she had done so because she has difficulties with this topic. She approached the subject through the phenomenon of ‘free fall’ and, as a specialist might imagine, faced the predictable problems of an empirical approach to it. Using balls of different size and weight, she tried to reproduce the ‘Tower of Pisa’ experiment, in which two objects - one light, another heavy - are dropped at the same time from a certain height. Before conducting the experiment, though, A.W. undertook a ‘brain storming’ session with her pupils, asking them to predict "which ball would hit the ground first" in various situations. These predictions were mostly confirmed when, eventually, teacher and children carried out the experiment together. However, A.W. did not consider that the children’s predictions were proved correct. She was disappointed because the balls did not hit the ground at the same time. In other words, A.W. insisted that the experiment had gone wrong. When I asked how she planned to overcome these difficulties in the future, her answer was:

Well with the Floating and Sinking activity, [laughs] I avoid it, I won’t do it again for a while. With the Gravity I’ll do that again but, having done it once, I think I would talk to my colleagues more and see what they think of that. And I will look through all the packs that we’ve got, and see if I can understand it. But even then, even when my own understanding is clear, the results may not confirm the accepted theories. So then, I’m left thinking one
thing and the children are left thinking something else. And that's not the way I want it to be. (AW2.196)

What is striking about this declaration is the different attitude A.W. has towards each of her two areas of difficulty. I did not notice this ambiguity during the interview so I did not probe her to understand it. In any case, my intention has never been to draw conclusions, but to identify contradictions between anchors of teaching which are explicitly stated and those which teachers illustrate as they make reference to actions, allegories and anecdotes. Let me discuss the tension implicit in the extract above.

As I said, A.W. declared she would not give any answers in case they were wrong answers. She admitted to having difficulties with both 'Gravity' and 'Floating and Sinking'. When it comes to 'Floating and Sinking', however, it is not only that she would rather not give any answers. When it comes to this topic, A.W. does not believe there are right answers. She looked for them, but could not find any as straightforward as 'big objects sink' or 'light objects float'. So, she gave up teaching such topic. On the other hand, when she sought right answers about free-fall, she believed she had found a 'straightforward' answer, exactly as she expected. She repeated such answer several times, to me and to children:

When you drop the balls the weight of them is irrelevant. Because in space, it doesn’t matter how heavy things are. That’s my understanding, and I hope that that’s right. (AW2.204)

Reciting the right words, however, did not grant A.W. understanding of the concepts involved. It is pointless to speculate about the differences it would make if this teacher had a better understanding of the free fall phenomenon, in particular, or better knowledge of the theories of Galileo, Newton or anyone else for that matter. There will always be a phenomenon, concept or theory about which the teacher is ignorant. It is much more important that we attend to A.W.'s attitude towards the phenomenon of free-fall, which she studied together with her pupils, as well as her attitude towards the relevant laws of physics which she had studied on her own beforehand. The children's almost complete unanimity, and a considerable amount of experimental evidence, could not persuade her to question what she regarded as 'accepted theory'. She persistently maintained that "when you drop the balls the weight of them is irrelevant". I tried to challenge her thinking, asking her whether the facts did not rebut these statements. She denied it and said that the balls "weren't being dropped simultaneously", suggesting that the resources available were to blame.
In my view, teachers should have a better understanding of science in order to teach it. But is it not a fact that the teacher here failed precisely because she held too tightly to the theory concerned? With all the factual contrary evidence, could she not conceive the possibility of such theory being wrong - or, as happened, that she was applying it in a wrong context? Maybe this is too much to expect because, as she declared, she regards science as "a set of right answers". Seeing science in this way, she could not conceive of any bias - such as her own - interfering with her explanation of phenomena - at least not at the level of simply letting two balls fall.

It is interesting that the attempt to encourage A.W. to continue expressing her ideas led her to come out with something that has the tone of a maxim and, indeed, provides a key to the problem in question. It is as if, unknowingly, A.W. bore the wisdom of practice. I asked whether she thought it was important to have the right scientific facts or concepts at one's fingertips. She said she finds it important to know how to get it right. The difference is subtle, but aided by an understanding of the structures of the disciplines, as defined by Schwab (1964a,b), we can see that the problem goes beyond knowledge of the facts or concepts of science.

When one says it is important to know how to get it right, one is, in a sense, saying that it is important to know the ways in which truth or falsehood, validity or invalidity, are established in science. This, essentially, is what Schwab calls syntactic structure of a discipline (Schwab, 1964a, p. 21 ff.; 1964b, p. 31 ff.). So, A.W.'s assertion hints at a proposition about the nature of science. Moreover, it can be classified as an expression of her propositional knowledge in relation to subject matter content knowledge - one of Shulman's categories of content knowledge in teaching (see Shulman, 1986b, p. 9a-b). In any case, the passage quoted seems to suggest that the processes of science, and indeed the nature of the scientific enterprise, is a meaningful theme for this teacher and should be a generative theme for primary science teacher education. Besides, I do not think there would be much doubt about 'nature of science' being an important topic in a science teacher education programme.

There is another aspect of this episode which is noteworthy. The first concerns the 'task' this teacher was given and the way she sees it. This one I see as a matter of principle, principle about education - the dilemma of either giving pupils wrong ideas or not giving them anything at all. This is a dilemma most teachers experience, say, when they admit to lack competence in certain areas within their field of knowledge, for instance.
In the sequence of the passage quoted above, the conversation remained closely tied to the issue of content knowledge. This topic was the last in which the events and assertions mentioned were considered to reveal tensions between A.W.'s theories (thinking) and practice (action), or between her (personal) and science educators' (formalized) pedagogical content knowledge in science teaching.

**Generative themes and their presentation**

The following sections discuss the themes which emerged from the above analysis of teachers' discourse as relevant for teachers and likely to challenge them to reflect on topics of science education in the event of a teacher education programme. The perceptions of various teachers about themes related to the teaching of science are used to illustrate the extent to which they are meaningful to them and likely to be generative of reflection in professional development programmes. This is how I have labelled these themes:

- Theme 1: Discovery Learning
- Theme 2: Reception Learning
- Theme 3: Scientific Knowledge
- Theme 4: Scientific Enterprise
- Theme 5: Thrust of Teaching
- Theme 6: Children's Diversity
- Theme 7: Elements of Communication in a Teaching Process
- Theme 8: Schemes for the Articulation of Messages

These themes emerge from the analysis of teachers' discourse and reveal my perception of what seem to be, either points of friction between primary teachers and science education experts, or else evidence of gaps between teachers' rhetoric and their own praxis. My perception is influenced by the heuristic model of science teaching I adopt - the Tetrahedron of Principles (chapter 3, part II, section D). It is worth noting that the first pair of themes relate to learning, and the others relate to: the nature of science (themes 3 and 4), educational propositions (themes 5 and 6), and communication (themes 7 and 8). The following sections discuss the extent to which these eight themes are meaningful for teachers. In the next chapter I discuss the extent to which, in a teacher development programme, these themes would generate reflection within the four components of science teaching; areas which correspond to the classes of principles of my heuristic model (see figure 6, page 152).
Each theme manifested different facets of itself in the discourses of the teachers. In other words, each theme was perceived by the teachers from different points of view. Thus, one theme runs throughout a section, showing its different forms. To ease the flow of discussion, sub-headings are used to help organize the text. The wording of these headings is the result of one or more different processes. It may consist, for instance, of a reference to an expression frequently used by teachers, side by side with a reference to the idea that contrasts with that of the first expression. So, for example, the heading "'Hands-off' teaching for 'hands-on' learning" incorporates "'hands-on' learning", which is an expression the teachers used quite often, with the opposite, "'hands-off' teaching", which I coined to convey the idea teachers contrasted to the first concept. Therefore, although these headings are simply meant to be sign-posts indicating shifts of perspective in the discussion of generative themes, they may also be useful in the event of those themes being considered when thoughts on science teacher education programmes are sought. In such an event these headings could be presented to teachers as themes for discussion. Just as they have helped in the organization of the text in this study, they may also help in the organization of the discussion of generative themes in that educational situation.

**Theme 1: Discovery Learning**

A reference was made earlier (page 154) to a passage of conversation where the teacher mentions a particular author when expressing ideas about learning. This was not a common occurrence. In my conversations with volunteers, it was more common for them to use educational colloquialisms, talking about ‘discovery’, ‘child centred’ or ‘hands on’ learning. The teachers’ choice of terms gives a signal of the themes about which they are most concerned at the moment. Alternatively, such choice simply signals the sense teachers make of particular expressions, some of which were introduced by curriculum designers, textbook authors or subject experts.

In the course of the interviews which followed the Rep Test, the topic of learning emerged as a theme in different ways. Despite the apparently varied way this topic appeared, however, all its forms of appearance seem to cluster in two main strands of propositions, depending on whether the suggestion is that school knowledge is more efficiently gained through *construction* or through *instruction*. Thus, teachers tended to describe learning as a result of only one of two diametrically opposed practices: ‘heuristic teaching’ and ‘expository teaching’. As we see in this and the sections ahead, though, in practice teachers consider learning through discovery as
well as learning through reception. In this section, the discussion focuses on the first of these modes of learning.

In exploring teachers’ different anecdotes and allegories I have been able to see some of the dilemmas and conflicts experienced by primary teachers, as well as issues that have long being discussed by science educators. The expressions I have chosen for the headings in part reveal these dilemmas. I have organized the discussion of the theme ‘Discovery Learning’ under five headings:

1. ‘Hands-off’ Teaching for ‘Hands-on’ Learning
2. Making and Taking Excitement
3. Motivation and Relevance
4. Challenge is a Motivational Tool
5. Cognitive Abilities Ought To Be Respected

Here is the first of them.

1. ‘Hands-off’ Teaching for ‘Hands-on’ Learning

How do children learn best? It was not necessary to ask this question explicitly for its answer to be given. The teachers invariably expressed their beliefs about this issue with self-assurance. Here is an example:

Teacher: There are demands... in terms of "not doing their thinking for them", allowing to come from their minds. I do sometimes feel that I stepped in, told them.

A.V.: Is it a problem? Do you see it as a problem?

Teacher: I think it's better in a way if [the thought] comes from them because they feel they have achieved that on their own... When it comes from them, they can see the value because they own that work. They have a sense of ownership. If it comes from me, I own it. They still can gain a degree of success, but I don’t think it’s the same. The constraint is for me to hold back. And also, there is a frustration when, perhaps they go in a very different tangent and I want to get them back over here. Then again I must step in, and say too much perhaps. (MK2.188)

Apparently, primary teachers believe that children learn best through discovery. They seem to suggest that pupils acquire a mastery of science content, at least in part, through direct and independent interaction with the materials of science
themselves. This might sound like plain common sense: as the Chinese saying goes, "if you listen, you will forget it; if you see, you will remember; but if you make it yourself, you will know it". However, much as it seems to be common sense, this idea is in some ways controversial. The same saying is quoted by those who - for example, in pre-university courses - argue for mechanical repetition of exercises, such as lists of problems to be solved. Then, the implicit belief is that learning comes from routine repetition, a bit like stimulus-response-reinforcement. Primary teachers in this study argue strongly against any such mechanical reinforcement. Indeed, they associate it with 'being a teacher', a role they seem to want to avoid playing:

I think the seeing for themselves is really important because, I think far too much teaching comes [from the teacher]. I think [the children] think that the source of knowledge is up there [on the blackboard]. I mean, often I am moving around the room, but there are times when I'm standing up there. And I think I need to say that not all knowledge comes from me, a lot comes from them. I direct, you know, because that's... because I perceive there are certain things they need to know. So I direct their learning but a lot comes from them, rather than me saying: "write: light refracts because... write that down, because I told you so." I don't feel that's the best way for them to understand science, just for me to tell them. (MK2.102)

Like the teacher cited above, others said that for learning to take place one must "hold back the teacher" (AW2.32). They make such a proposition apparently to make clear the position they hold on learning. However, as the excerpts above and others below indicate, teachers seem to suggest that at the moment they are working at slightly cross-purposes with their superiors. The latter require that knowledge be imparted to children, and, moreover, they impose time-constraints that render inductive, enquiry teaching almost counter-productive. As a result, faced with a conflict of conscience, teachers try to find a "balance between imparting knowledge and giving them the idea that they can find those things out for themselves" (LP2.148).

2. Making and Taking Excitement

What, then, is the reason for so much 'hands-on' in primary science teaching? One reason is the feedback teachers get from this practice themselves:

I think what I miss about teaching young children science, their first introduction to it, is the excitement they get out of it. Because they’ve got no preconceived ideas. They haven’t been introduced to it before, so the first
time they light their light bulb, it is just... that, sort of, makes me quite excited about the whole thing. (CP2.59-60)

Teacher C.P. considers, like the other volunteers, that young children are curious and eager to learn, besides being very spontaneous. Being so, even the most shy of pupils show their enthusiasm through discovery and success. This proves to be a great stimulus for teachers:

suddenly realising somebody’s got more there than you thought, or more to offer, or... It’s useful then to notice that a [shy] child like that has got the ideas up there. They’re able to do it. So, you suddenly think you can draw out a bit more and be a bit more aware that they’re not the quiet person that they might look. (JC2.74)

This makes me wonder why, in the early stages of the process, I did not use the label ‘exciting’ for any of the cards in the triads. It might well be argued that this is one of the ‘cultural’ differences between specialist teachers, like myself, and primary teachers. I decided to add to the card-set a question about what teachers find exciting (card number 4), after this appeared as a pole of one bipolar criterion used by teacher S.S. (Appendix 2). It is interesting that this term turned out to be generative of distinct associations. From most of the later interviews it can be argued that this is an important component in learning and teaching. It is evident in passages like this:

She was purely excited, so pleased with herself as well. This is it; she could make a car that works, that moves on its own. I think she was totally surprised. You know, it was like... That was something you opened up to them. I suppose that they had never thought they could actually make something like that. (JC2.78)

In this case, teacher J.C. is talking about the behaviour of a particularly shy and introspective child when that child succeeds in doing something. It seems that the simple expression of joy by pupils, as in this instance, is enough for some teachers. Nevertheless, one should not take the significance of this component only in terms of the expressed wish to ‘hold the teacher back’. Despite clearly avoiding an instruction-like approach, teachers do have a sense of being responsible for pupil’s learning:

Would there be another way? Ah... Well there would be, by simply telling them that that’s the theory, by instructing them. But I don’t feel that that kind of instruction is as memorable as them actually finding out for themselves.
So, the point is, I was pointing this hypothesis up that light travels in this way and I was asking them to find out whether that is so or not. (MK2.38)

Teachers look for what pupils will find exciting. They also find it exciting themselves to see children in the process of discovery. But because teachers feel they have to draw out of children what the children have to offer, they end up assuming postures about learning - demonstrating their principles - while uttering what at first sight seem to be just so many 'buzzwords'.

Facilitating, I'm sort of 'facilitating' their learning... You are providing the... resources, and you're guiding them by the way you're speaking to them, what you're talking to them about, aren't you? (LP2.188-90)

I'd see myself perhaps as a facilitator by giving them the situations and things to be able to discover it, and if there's a possibility of science... of them having a discovery-type situation, I would want to use that, yes. And I might with them. As it is, you'll tease that question and your things out, so I would hope in the end they have got the knowledge. (JC3.6)

The term facilitation might, for instance, cover such postures as 'teasing things out', or of 'taking the learning from students', which denote a heuristic attitude that 'facilitation' need not necessarily convey. The teachers seem to try "having an empathy with the children, and their learning" (LP2.234). Learning, however, was never defined with any precision by the participants in this study. The best I could elicit from them were descriptions of the conditions necessary for it to take place. Here is an example:

I think that one of the most important things for children, when they are learning, is that they are motivated. So you have to motivate them, in order that they will want to learn. So, if they are asking the questions themselves, and wanting to discover the answers rather than me asking them questions, then the motivation is from within themselves. So they will be keen to find out the solutions. (AW3.8)

The question, then, is how one speaks to children and how the resources are provided. This is where another reason for so many hands-on activities seems to lie. These activities fit in well with the learning model expressed by the Chinese saying (if you do it yourself, you will know it), in a fashion distinct from the instructional one.

I think that I can teach them all about gravity and weight, all about that, just by writing down on the black board, them copying it down, and they would
recite that to me 50 times. Then they would all 'know' that, all in order to do
that. But they wouldn't understand any of it. They'd know it but wouldn't... it
wouldn't be their own. They wouldn't understand it. (AW2.218)

3. Motivation and Relevance

In analysing the discourse of the teachers, I noticed that it is generally believed
that pupils must be involved with issues, that they have to become motivated.
Motivation is, apparently, another theme around which controversies may arise. I
found that implicit within primary teachers' ideas about motivation are
prerequisites and stimuli distinct from those to which I - and presumably other
science specialists - would have normally given priority. The issue about making
things exciting obviously stems from this same root. As for the other strands, to be
able to guess at them, one has to look at how pupils, their interests and their
learning processes are construed. More often than not it is children's feelings that
are valued by primary teachers:

The children I teach are emotionally, socially deprived. They have very
deprived backgrounds. Which means that they are taught from the beginning,
by their parents, to look after themselves. They are the important thing. They
are selfish, egocentric, they've got very, very short concentration spans. They
can't do anything for very long. Ah... They are very poor on negotiating skills.
Very little support from home. Most of them love coming to school and
they're usually enthusiastic about learning; if they see it as important to
themselves. (AW3.258-60)

The association of children's feelings with their reasoning seems to be the basis for
one working hypothesis of teachers: the idea of relevance.

[The children] go off target and talk about things that aren't actually relevant,
because... what you're trying to do, obviously, is not relevant to them, is it?
You know, it isn't actually always relevant to all children, how the sun passes
across the sky, I don't suppose they could give a tinker's cuss how it passes
across, they... I didn't start thinking about things like that until I was well into
my teens. I was only about fourteen or fifteen, and I didn't really want to
know how a camera worked until then, I'm not very inquisitive about those
sort of things, but now, often, I will suddenly think, 'I wonder...' (LP2.250)

At first sight, relevance could be thought to be simply the extent to which children
are interested in a particular issue. But when teachers elaborate more on these
ideas they allude to issues such as children's cognitive readiness and the
appropriateness of particular communication channels.

I deal with it in a realistic way. I know that if I'm going to do something, like 'the sun's passage across the sky', out of thirty five in the class, myself and perhaps two others will get it. Others will, sort of, begin to think, 'Mm, what's she on about?', or are going to be fiddling with their shoe laces. You can start off, I suppose, with talking, I mean, it's quite nice to have some children who have got a grasp of these things, to initiate the conversation and bring up the level of discussion. But sometimes you just realise that you just cannot get out of them what you want to, and that you're going to have to pitch it lower, and start again, you know? (LP2.256-8)

Clearly, relevance here is still centred on children rather than subject matter, curriculum or remote aims and ideals. This fact points to one area where primary and specialist teachers need to negotiate with each other a compromise. I noticed that the topics which interviewees rate as unsuccessful are those they cannot see as relevant for children.

What's important to them? Well... They are very egocentric. They are important. The fact that the Earth is spinning... You can't see that it's spinning; you can't feel it's spinning... As far as they are concerned it is not spinning. So there is no difference if it is or is not spinning. It is just not relevant. (AW3.248)

The spinning-Earth thing... I am not saying that I wouldn't do that and couldn't do that, but I am saying that I would have to find a way to make them to see it as relevant to find some way of them noticing it or them suggesting it, rather than me asking that question. Just asking that question wouldn't be enough. (AW3.264)

Young children only think of themselves... as being, you know... as being here, they can't, I don't think that they can really see us in the context of the Universe. (LP2.132)

4. Challenge is a Motivational Tool

Participants in this study consistently claimed they are challenging the children; that they are attentive to pupils' will, and want to tease learning out of them. On various occasions, I asked teachers about these propositions, interested to find out how that translates into practice. The particular passage below followed not my own problematization of a proposition of teacher M.K., but one challenge Rep Test set him. In other words, this is his response to the request for a criterion to
cluster meaningful (i.e. emotive) episodes of his experience - episodes laid in front of him on the table, written on cards.

You had to build something to take some weight, or to build something so that it was tall enough to support something else. So in that way, they're making something happen. The experiment often forms part of a task, in that there might be some result that we're looking for. The result might not be made clear to the children at the beginning, so I might not tell them what the result is, even though I have a result in mind, because it might be better for me not to... it might be more exciting and better for them to think about why the result happened, rather than me saying, "If you do this, this will happen". [On the other hand] if I've told them the possible outcome, it's to maintain their motivation. If I think it's an outcome that will interest them, and an outcome that they will enjoy seeing or enjoy experiencing, um, then I might disclose the outcome. (MK3.41-3, 51)

One feature common to the responses of other teachers is noticeable in this excerpt. Asked to provide a proposition about teaching, teacher M.K. has not stated this directly. As it happens, here, 'theoretical', 'practical' and even 'philosophical' principles might not be stated as propositions. Instead they can be expressed in terms of 'cases'; in a sense the term is being used here (Cf. Shulman, 1986b, p. 11). It is possible to infer from the passage above a prototype of practical activity to which teacher M.K. resorts when he plans an activity of this type. He says that a practical activity is often part of a task and goes on to describe features such an activity might have. As he lays bare these characteristics, the following propositions can be inferred:

* the experiment to be chosen has a result that is expected;
* this result is not to be initially made clear to children;
* children become excited thinking why the result happened;
* pupils get no excitement out of empirical confirmation of an expected result.

As can be seen in the passage cited above, while presenting his prototype, teacher M.K. ponders that in practice an experiment might not comply with the characteristics outlined. He does so by drawing on precedents. These are also valuable, for they consist in sources for specific ideas. As this excerpt shows, teacher M.K. admits to having told children the possible outcome of an experiment. He then argues for the adoption of this apparently contradictory
course of action. As he says, it might be worth telling children the outcome of an
experiment since:

* it is possible to maintain children’s motivation this way;
* the outcome itself can be of interest to them;
* the outcome can be such that children will enjoy seeing or experiencing it.

The following passage, taken from my conversation with another teacher, refers to
the same issue.

Teacher: The delight comes into both... I think that both electricity and
magnets... Children can be delighted when they first meet these, because it’s
exciting. They can be equally delighted when they can apply it to something
else. For example, if you make a magnetic model where you move cars or
whatever around a track with a magnet, they can be delighted that they’ve
done that, yes? In the same way that they, using the electricity, can make a
model, they can be delighted to have done that. But that’s an emotion. What
I’m saying with the idea of grasping it, is that they are able to grasp or
understand it and therefore use the knowledge in a, in a different situation.

A.V.: Right. Are these ideas, ideas that come up when you are planning your
activities?

Teacher: What, their delight? To an extent, yes. Not as a rule, though. You’ve
got a curriculum to present, but you certainly want to have some aspects of
delight to capture their imagination and their interest and their desire to
want to continue to find out. So I think delight is definitely part of the
agenda, but not the whole agenda. (DH2.286-94)

The experiments here assume the form of problem-solving activities. In these
instances, pupils’ sheer pleasure at being challenged is exploited as a motivational
tool. Apparently, the main aim is to provide pupils with a stimulus in order to
preserve their interest in the subject; and eventually they will learn established
procedures or concepts. In the following excerpt, teacher M.K. gives further details
of how to challenge pupils to that end:

Teacher: To try and get the children to feel successful is to give an open-ended
element to the task so that there isn’t a right and wrong answer, so that they
can achieve something that they feel is successful. And also, to make sure
that there is an element of extension to the work, so that those children who
can easily achieve the first stage of success have something to go on, and
don't become bored. So there would be an element of extension, I mean a very similar task but you've made it slightly more difficult for them.

A.V.: Do they feel challenged?

Teacher: Yes! I think they feel, once they've been successful once or twice, that "OK, I'm going to make it more difficult now", they enjoy that element of it, and also the fact that they know that they're onto something more difficult, so they slightly enjoy the fact that they're a step or two ahead of other people.

It can be noticed that here teacher M.K. expresses a maxim and a theoretical principle. The maxim reads: give children an open-ended task, making sure there is an element of extension to the work, this way children can achieve something that they feel is successful and those who can easily achieve the first stage of success have something to go on. The principle, in turn, can be thus read: challenges are motivating and an element of competitiveness is subliminal to any challenge. What is interesting, regarding the latter proposition, is that the contest need not be between individuals. For instance, sometimes the challenge is to build or achieve something. Then, the adversaries are you and your own skills and abilities; the scientific laws behind the phenomena involved; or just the availability of resources. For instance, the excerpt below, taken from another teacher who contends that challenge is a motivational tool, reinforces this idea:

All right, they can get a motor working, they got a bulb working, but how might they use it in something. "Now, can you get it working? Can you put it in, let's say, a lighthouse? How are you going to have it on, when you want, and off, when you want, without having to undo wires or something?" Or, "Right, you've made a lovely car, now how are you going to get it moving without having to...?"

Here, the motivation is expected to come from the challenge to apply what has just been learned. The attention given to pupils' 'will' does not imply neglect of their reasoning. During talk-back sessions, teachers do try to stress the key points that have been investigated, so that key principles are assimilated. The carpet talk with children...

it's an opportunity for me to reinforce the key points of the lesson. So I would be perhaps directing, I will be remembering certain responses that I had from the children and bringing out the key elements. "Why was yours successful?", "Because of this", "Why do you think this one didn't work? How could you've made it better?" That kind of thing. It's to reinforce the key principles of that
session about load bearing, or strength, or centre of gravity, or whatever it was. It’s a chance to reinforce that and to try and hope that the children got that. Now, I think sometimes they get it in the small group, they don’t always get it, but it’s another chance for children to reflect on the success of that session. And just to reinforce the key principles. (MK2.204)

5. Cognitive Abilities Ought To Be Respected

Challenge can be a motivational tool, as we have seen in the previous section. However, these attempts of primary teachers to foster children’s reflection intrigue me; rational reflection does not seem to fit with the pragmatic attitude clearly underlying the whole approach shown by such teachers. The issue of challenge raises the question: which kind of challenge? When I questioned some interviewees about this, I realized that these primary teachers are not talking about the same sort of conceptual, abstract reflection that is likely to be found in a science lecture at college. Here is one passage that supports this conclusion:

Teacher: Me giving them examples... Just to provoke their own thought? [pause] Yeah. I could do. I don’t... I don’t know if it will be successful or not. [long pause] I guess it wouldn’t. It wouldn’t be successful.

A.V.: Do you have any reason to think this way?

Teacher: Because it’s created. It’s imagined. And, it’s my perception. Therefore, it is immediately distorted because the idea is that children build their own.

A.V.: But you could work out a way of making them ask you their own questions about something they are not actually seeing, as you usually do!

Teacher: Yes. I could.

A.V.: But even though you think it’s not likely to be successful?

Teacher: No. It’s just not motivating enough; and it is not... It is not tangible enough.

A.V.: Can you give me more clear evidence for why...?

Teacher: Well, because... If I am imagining a situation and I am telling them my imagining situation... already it’s I putting my own perception on it and distorting it. (AW3.230-40)

To judge from what I heard from teachers, in the talk-back sessions, when children usually sit on the carpet in one corner of the classroom, there is no intention to theorize about issues such as the movement of the Earth. Apparently, these are
extravagant speculations for ‘grown-up’ scientists. For these teachers, the ‘child scientist’ has different quests, which apparently remain at the centre of all discussion so as to keep teaching relevant to children - and probably safer for teachers.

A.V.: What sort of questions do you ask then, once they’ve succeeded lighting the bulb?

Teacher: Well we talk about how can we switch it off. We talk about the lights in the classroom. I may ask: "do you think there are any wires for these lights?"

A.V.: Does anybody ask, where is the battery, the power source for such bulbs to light up?

Teacher: I’ve not been asked that question. No, I haven’t.

A.V.: And has anybody asked "why does the bulb light?", in the sense of "what’s going on in there?" or... "what does the battery have?"... ?

Teacher: Well, they know what... Well, it has electricity... I suppose. Doesn’t it? They know that electricity exists, don’t they? children? I wouldn’t have any greater knowledge to offer anyone... (DH2.180-7)

Indeed, the primary teachers’ emphasis on particular questions shows the difference between the enquiry they try to foster and that which a science specialist would do.

A.V.: In this activity, when you ask them to predict, you are asking them why.

You said something like, "Because when they are not really predicting, they are not justifying why".

Teacher: Yes. Because of that I ask them a lot, "Why do they think?". I want to know what sort of ideas they have about something.

A.V.: And what do you accept as a "why" answer?

Teacher: Oh... anything that’s plausible and we can test. Like, "because the wire’s in the wrong place".

A.V.: Is this an answer for a "why?" question.

Teacher: Yes. If you had a smaller group of children, you’d ask them, "Well show me why?" Then, they could point to where it is. Because the bulb’s in the wrong place and they’ve explained this to me, that suits me. I don’t expect them to say, "The bulb’s in the wrong place, it has to be..." (CP2.234-45)

One can ask "why?" for many reasons and with many different purposes in mind.
"Why?" is a question that usually leads to an explanation, and explanations can assume different forms. On the other hand, questions asking 'what?' and 'how?' primarily evoke descriptions. The use of these questions may be seen as more consistent with the aim of making children aware of physical phenomena, as opposed to asking them to make sense of such phenomena. Apparently, some people in primary education would not consider this type of explanation an appropriate objective for the teaching of science at this level.

It would be a kind of "Have you noticed?" question, or "did you see?", rather than "What do you think?". Not... Not asking them questions to which I know the answers. You see what I mean? Not asking them questions when I've got the answers fixed in my head. Just getting them to look and observe things. Not necessarily their eyes, but just observe generally. In order that they can pick up, and what's it I'm trying to get at. I'm asking questions to help them to observe the phenomena I want them to observe. So I'll be directing and focusing their attention onto what is the one key, you know, at that time. And I wouldn't ask questions directly about concepts, because it's not appropriate at that time; it's not fair. Make them ordinary questions and they answer them. (AW2.48-50, 56)

Primary teachers are aware of the difference between observation, analysis and synthesis, as well as of their interdependence. However, when teachers try to make pupils achieve each of these stages, the simple posing of the question 'why' does not prove sufficient:

A.V.: What did you read from their answers?

Teacher: That they had no experience with that. That they were able to observe what happened, but they weren't able to give any real reasons why. When I ask why, they just make an observation. For example... a lot of explanations like "Why does it bend in the water?" "Because it looks as if it's bent..." "Yes, I know that. But Why?" "Because it's moved..." They are just sort of again making the observation not analysing why. (MK2.85-6)

For science specialists, to see and be able to report what was seen does not necessarily mean to make sense of it. Given that primary teachers ought to follow National Curriculum guidelines, they need to find means of taking children further; for instance, from observation to analysis, and from there to synthesis. In order to do that, their heuristic approach apparently gives way to a more instructional approach.
THEME 2: RECEPTION LEARNING

The topic of learning emerges in different ways in teachers' discourse. These seem to cluster in two main strands of propositions, the first of which I discussed in the previous section (Theme 1). The second strand refers to what teachers take into account when they have to teach in a more instructional way, through 'expository teaching'. This is the topic of 'Theme 2: Reception Learning', which has three subheadings:

1. Different Abilities, Similar Goals
2. Piecemeal Teaching for Hierarchical Learning
3. Staging for Meaningful Reception Learning

Given the influence of Piaget, Bruner, Vygotsky and Freire (even if indirectly), as well as of other authors on contemporary educational thought, one would expect teachers to use pedagogical strategies to suit their audiences, instead of simply delivering lessons regardless of local peculiarities. However, it is the way they do this that might provide some insight. This study focuses on primary teachers and their teaching of science, so insights can come from the way those teachers' awareness of their pupils' cognitive abilities manifests itself in relation to the subject matter. There are some examples of these insights in the extracts above. It seems clear that primary teachers adopt learning principles in which the emotions, reasoning and past experience of the pupils are more important than the formulas or pedagogic solutions that science content knowledge would provide.

At times, however, primary teachers' approach to the teaching of science becomes less heuristic and leans slightly more towards instruction. Yet, this shift is conditional upon a series of circumstances. This section focuses on ways in which teachers have represented these circumstances in their discourse. A number of teachers' anecdotes, allegories and propositions show evidence of a great dilemma experienced by these teachers: given that, apart from enjoying school and the activities within it, children must also learn things at school, how can directivity be reconciled with self-determination? Didactic methods may be wholly rejected but instruction is considered seriously. This dilemma can, firstly, reveal a gap between teachers' theory and practice. Secondly, it can lead to a gap between teachers and experts, not least because the latter may not experience such a dilemma themselves. For the experts, learning is acquiring knowledge and understanding. For primary teachers, although learning is also described in these terms, it is understood as being a matter of acquiring confidence and building up curiosity,
ability and the will to learn. The gap between teachers' theories and their practice is evident in the distance between what they express through propositions and what they convey as they draw upon prototypes, precedents and parables from their case knowledge.

1. Different Abilities, Similar Goals

All interviewees stressed the importance of "assessing where pupils are up to", just as strongly as they stressed their intention of "moving children on", of "extending them further". As one teacher puts it, "it's a bit of a philosophy of start-where-they-are-in-their-own-experience and take-it-further" (MK2.20); an aim which suggests the desire to provide pupils with the knowledge and ability they lack.

Naturally, teachers have to know (a) pupils' starting points with regard to knowledge and ability, and (b) their learning pace and (c) potential to progress. This is not to say, however, that primary teachers' appraisal of pupils' current knowledge and abilities follow structured procedures:

[How am I able to find this example?] I think partially by guessing, partially by asking them what experiences they had, partially by drawing on the experiences that I know they've had. For example... There is a computer game that they have played with; a snooker ball that has to do with angles in Maths. So that I knew that lots of them have encountered that game. So, that was a real experience I knew they have. (MK2.25-6)

At some occasions, teachers may be rather pragmatic and, for example, extrapolate vicarious experiences by simply relying on what colleagues have accomplished with similar groups. Here is an example:

I said to the reception teacher, "I'll do pushing and pulling." I knew that the other teacher had done it, I said "What did you do for pushing and pulling?" She said, "You do this, this and this, and you make that", and I said, "Right, I'll do that." But I really needed somebody to say this is how they did it, you know, to present it to me in a practical way. (LP2.110)

These approaches do not seem to match easily with the preceding set of learning principles. If there, under the label of heuristic approach, I listed evidence of an attitude of trust by teachers in children's curiosity, ability and will to learn, here, the propositions all seem to imply a certain scepticism by teachers of children's potential. The contradiction may be evidence of a gap between propositions they articulate and attitudes their actions reveal. The propositions make the teachers
seem more daring than do the situations they draw on. These situations make them seem rather timid, conservative.

Striking a balance between ideals and the reality of the profession forces a constant resort to pragmatic responses. As one teacher says, in a passage quoted on page 212, there are times "you just cannot get out of [children] what you want to" (LP2.256-8). So, despite the ideal of children 'learning by themselves', 'learning by discovery' or whatever, sometimes primary teachers find themselves in a situation in which none of this active learning is possible:

If some [children] really get it quickly, I think often they're the ones that generally like that kind of working things out, doing things for themselves, experimenting. But as I say, you've got the ones that really can't get it and you almost give up. I wouldn't want them to fail, so I give more hints, basically. So... "Have a look now!" You know?! And they probably think they've done it. But they haven't actually, but then... All right! The next time of course you think 'all right, a little help', give it to them again, it's like starting from scratch again. They probably wouldn't remember. (JC2.142)

Obviously, the questions every secondary teacher has to face regarding mixed ability groups are also the concern of primary teachers. Even at primary level there are slow and fast learners, there are those who are more interested and involved than others, and all these factors which differentiate children defy teachers to come up with approaches that will not exacerbate inequalities:

I hope that within the session everybody had a chance perhaps to meet the basic requirement. Let's say that it was to build a structure! Now, some children will perhaps go on to build a more sophisticated one, to take a greater load or a taller one or whatever it was. So it's open ended in a way that I set a basic criteria that I hope every one will meet; knowing that some children will exceed that and hoping that everyone will reach that point. So, the point is really that even though there is a difference of ability, there shouldn't be a failure. Everybody should have succeeded. Some will have succeeded to a greater extent. Some will be able to apply the principle to a wider extent. Some will just learn that in that situation. They can build up and not be able to take any further. (MK2.206)

The solutions primary teachers find may, at times, not be in accordance with their values and principles. However, from the empirical evidence gathered here, it can be argued that, even under pressure of demands for a new curriculum, and other constraints, primary teachers' solutions still show signs of common features, albeit
distinct from teachers at other levels of education. For instance, while some people would probably have discarded attempts to continue with open-ended teaching, primary teachers, apparently stick to their subliminal belief in a degree of self-determination by the learner. Besides, their belief that learning and emotions are linked always seems to slip through eventually. For instance, in the next excerpt the teacher shows that even when he is having to overcome a number of time constraints, when he can no longer afford to challenge students and begins instructing them, even then he does not lose sight of one of his ideals: to foster confidence.

A.V.: What about the others [who are slow learners]? Do they have the same chance of being challenged, and do you try to do it?

Teacher: I think the difficulty with that is, there's a time constraint, so often they don't get beyond the first challenge. Now, it's possible that they would meet the second challenge at the next session. Again, there's a time constraint there. But I have felt that where there has been the correct degree of support, either from their peers or from me, they have felt successful, and they have felt they've achieved what is required of them. (MK3.86-7)

It is interesting to note that a case like this one works as a parable. It conveys certain moral rules. In this example, the value indicated is that it is important to help pupils to acquire self-assurance. Values and principles, however, ought eventually to give place to features of one's pedagogic knowledge that pertain more to a 'strategic' than to a 'propositional' form of knowledge (see chapter 3, part I, section C).

2. Piecemeal Teaching for Hierarchical Learning

One common-sense principle regarding learning is that 'first things come first'. This principle proposes, in general, that one learns best if one starts with what is simple, and progresses bit by bit. It all sounds very logical and there are theories that give substance to it. Gagne (1977), for example, suggests that intellectual development results from the learning of many discrete intellectual skills. For him, learning material has to be broken down into small segments and arranged sequentially; hence his theory of learning, called "hierarchical learning". This idea is one that emerged in the discourse of my volunteers.

It seems logical to me to do it that way, rather than to jump right in, because I want them to have some small snippets of information that they can draw on. I think you have to stage it, so that they come away with something that is
some bit of knowledge. I think about what I want in the long run. And then I try and break it up into little bits... and then from the little bits... (CP2.281-3)

This idea of information being taught bit by bit could be called 'piecemeal teaching'. In the history of ideas in science education, this sort of idea was once common (DeBoer, 1991, p. 205). In their consideration of students' acquisition of science concepts, for example, Bruner (1960) and Schwab (1962) proposed that the teaching of science should move away from the earlier approach of brief reference-book-style descriptions of phenomena. Indeed, the era of science projects - in the late fifties and sixties (chapter 1, section A) - saw a great improvement in science texts inasmuch as science concepts were presented in a more conceptually meaningful way. Some debates of that time seem to be replicated in the discourse of primary teachers. This coincidence makes 'piecemeal teaching' one aspect of 'reception learning' worth considering as a theme for generating teacher's reflection.

Take, for instance, the procedure of breaking down the material to be taught in small items and sequencing them properly. It may be that primary teachers adopt this procedure, taking for granted an important underlying analytical premise of inductive teaching. An inductive approach to teaching assumes that a whole can be broken into its constituent parts and these, when appropriately re-joined, will reconstitute the whole. How well any analysis of science concepts is undertaken by primary teachers in the first place could itself be a matter for investigation. Even if these teachers do not perform such an analysis themselves, the way they enact it through their teaching of children is worth an assessment. This will not be considered here. The point I want to make is this: apart from such academic research, it is crucial that teachers themselves reflect on two questions. First, whether or not they assume that pupils are able to synthesize the parts and thus understand these as parts of a single whole. Second, whether or not teachers consider students' ability to do this dependent on the way the situation is presented to those students.

3. Staging for Meaningful Reception Learning

Once motivation and challenge have lost ground to instructional teaching, the teachers say they have to "pitch it lower" (LP2.258) or "come down a little bit" (MK2.44) in order to reach pupils. It may be that, at this stage, the teachers are not so much concerned with understanding; all they might want is for children to acquire some knowledge:
If they come to a plateau, or come to a stage where it's impossible for them to go any further without your intervention, or your guidance, you're there as a kind of facilitator of learning, aren't you, but then on the other hand there is knowledge, to impart to them. I mean, I think that's what part of the National Curriculum is. There are sets of criteria for imparting some sort of knowledge to the children... I mean, there are facts and things for them to learn, aren't there? I've sort of used scientific words, and said, 'this is called such and such'. You know, given them the actual words, got them to talk through the process just knowing when to intervene to give them the appropriate vocabulary. To move them forward, I suppose. (LP3.22-30)

Their metaphor is that learning is like digesting. Once you begin feeding children, you need to measure your pace, and the size and content of each spoonful, for them to digest the knowledge well. 'Staging' in this case refers to adjusting the size, shape etc of pieces being offered. Here, staging refers to the object to be learned. But the teachers are also concerned with the subject who is learning:

Because I was a reception teacher, I thought, 'These kids aren't ready for this', but I know that, they'll look at my records and see, 'Ah, she hasn't covered pushing and pulling', so therefore they'll think, 'This is an area we've got to develop.' That's where your continuity and progression comes in, that if I think, you're not going to teach the whole of, um, Level One in reception, it's, it's a two year programme, isn't it? So I know there are some things that I don't think is appropriate for a reception teacher to teach children, and I think that you... are fostering an idea and investigating and exploring, and getting [them] interested in the subject is the foundation, because then the other teachers build on... when you're doing things that are perhaps a little bit contextually more difficult. (LP2.282)

The teachers constantly consider whether or not children are ready: ready to perform certain tasks; ready to reason; ready for a particular kind of question, and so on. Implicit here may be the idea that all children pass through similar stages of intellectual development. It would not be surprising if the teachers had assimilated this idea from Piaget's theory about children's stages of intellectual development. Another possibility is that the teachers base their convictions, such as this one about children not being ready to learn something, on a notion of the human mind and how it develops which is similar to that of Ausubel (1968). Ausubel argued that mental development is a process by which new concepts are continuously brought into the conceptual framework of the mind. Old conceptual structures are modified to accept the new concepts as those new concepts are assimilated with
the old. In the excerpt above, the teacher could be suggesting this. In that respect, she says that "these kids are not ready for this" for one of two reasons: either, children have not developed any conceptual structure that would accommodate the information brought in; or, the new information being brought in would require children to undergo a significant change in their conceptual structure, a change impossible in practice.

In any case, if teachers accept these theoretical propositions, they should discuss how much such theories help in practice. Teachers may agree that a particular stage must be achieved for subsequent learning to take place, possibly because they gain a certain feeling about these stages through experience. As mentioned at the introduction, Freire (1994a, p. 43) proposes that intuitions and feelings, such as those that teachers apparently have about children's stages of intellectual development, should not be disregarded. However, as this is something teachers might feel intuitively but cannot set out precisely, they need to submit it to a rigorous consideration, not least because primary teachers, more often than not, rate the present stage of their pupils' development as lower than they must in fact be. Otherwise the teachers would not be so surprised at children's interest in scientific issues, and ability to learn them.

**Theme 3: Scientific Knowledge**

Teachers have touched on many issues relevant to a discussion of the nature of science. However, two themes seem to run below the surface of the main issues in question. They are "Scientific Knowledge" and "Scientific Enterprise". The former is discussed in this section, the latter in the next one. The present section is made up of three subheadings:

1. Truths or Theories?
2. Whose ideas are these, anyway?
3. Autonomy from the 'Canons' of Science

The obvious reason for scientific knowledge to be chosen as a generative theme is primary teachers' great concern with their own limitations in this respect. It is worth emphasizing, though, that their knowledge of subject matter per se is not an issue here (see chapter 3, part II, section B). As I point out in the course of discussing the theme in question, knowledge of subject matter per se is necessary for good teaching, but so is content knowledge in teaching, and this is the focus of the present discussion.
It is possible to identify, in the discourse of the teachers, tensions generated by their lack of command in the two domains of knowledge for teaching. On the one hand, their limited scientific knowledge puts them in conflict with science specialist colleagues and companions. This, in turn, puts them in conflict with themselves, once they fear that their heuristic, inductive form of teaching may deprive pupils of 'correct' knowledge. On the other hand, their limited familiarity with science, let alone with the philosophy and history of it, puts them in conflict with science educators. In this case, the tension appears in different forms. It may be in a kind of reverence for the dictums of science. It may be in a certain degree of scepticism about the achievements of science. It is reasonable to assume that this mix of awe and apparent contempt jeopardizes teachers' efforts to improve their practice. Moreover, it annoys teachers themselves. In any case, this contradictory attitude is accompanied by a certain difficulty in separating two different objectives: that of giving children knowledge about natural phenomena, and that of giving children knowledge about science, human beings' knowledge about nature - certainly an important theme in science teaching.

My discussion of these tensions comes under three headings. The internal conflict is discussed in "Truths or Theories?"; and the cultural conflict, in "Whose ideas are these, anyway". "Autonomy from the 'canons' of science" discusses how the teachers find their way out of such dilemmas.

1. Truths or Theories?

Primary teachers make no secret of their lack of content knowledge. This is a deficit they try to handle as best as they can. Whether it is a matter of finding answers to pupils' questions, trying to understand a concept before introducing it in the classroom, or simply deciding how do introduce it, the teachers say they: look it up in encyclopaedias (AW), talk to peers (LP, MK), consult scientifically educated partners (CP, LP), or seek external help - even from parents who have an appropriate scientific background and are prepared to be called upon. However, this does not prevent primary teachers from being apprehensive, and herein lie some clues on their views about science.

There is an obvious and general concern, particularly among science teachers, about not knowing science and yet having to teach it. This concern reveals some preconceived ideas about the nature of science - ideas which need to be reflected upon and discussed for an enhanced teaching of science.

I find the prediction, the observation, the coming to conclusions, very
important in my science. But also I find important in my science is the fact that I’m not relaying it correctly to the children. I don’t know necessarily how the prism works, so I speak to my partner and he explains it to me. Then I have to relay it down to the children. So by then it gets so distorted, that so-called truth. (CP2.91)

Even a young and open-minded primary teacher such as C.P., who did an MA in science education and is science co-ordinator, is very concerned with the ‘truth’ of the knowledge she imparts to children. Note that she feels the scientific process of enquiry is as important as the knowledge of science. She made herself very clear in that respect as she commented on the clustering of two cards of her set during the Rep Test (card 1: Prediction skill developed and card 11: Prism work - not relaying correctly to children; see FOCUS Grid CP in Appendix 2).

They’re both quite high on my list, that I’m not teaching them the correct thing and the idea that they are doing the prediction, the skill. Because I think that’s different. Card 1 is sort of the process of science and card 11 is the knowledge of science. And both of them I hold in quite high esteem. I can see why they come out pretty similar, though they’re not, they’re not really related. I do think of them as being two different things but they’re both sort of at the same plane of importance. (CP2.93)

Later, teacher C.P. turned back to this issue, now expressing her anxiety in its respect:

I feel that, suddenly, everything becomes so sort of inept, what I’m trying to explain to the children. Because I can’t speak to them on my partner’s level, I can’t speak to them down on my level, I’ve got to make it down an even further level, and I distort it. And that infuriates my partner, the fact that I’m distorting it, because the truth isn’t there. And that’s where the tension starts to grow. What do you do? Because I want them to understand what’s going on. I mean, that might not be a correct physics explanation, but it’s something that they can cope with. I feel that having my partner speaking... children will go away from this classroom not knowing anything more than they did before they even had the discussion. (CP2.339)

However explicit teacher C.P. may be about the equal importance she places on science products and processes, she still shows herself to be in a dilemma common to her peers. In part this is a moral dilemma and is therefore related to her principles about education. However, this dilemma is also related to principles about the nature of science. The idea of scientific truth illustrates that. Through
the shadowy presence of her partner, science appears as an exact discipline where half-truths are not good enough. A half-truth can distort 'reality', which, being an objective, real entity only has room for truth. There was another teacher who had the opportunity to express herself in these terms. Here is an excerpt of our dialogue:

Myself: Do you think that your teaching can overcome your lack of content knowledge?

Teacher: Well... No. I'd like to say yes but... You try to use your professional knowledge to help the children learn. But, the thing about science is that it is really a set of right answers, isn't it?

A.V.: More than Geography or History?

Teacher: [pause] Ah... Yeah... Ah... Well, with history there are arguments for both sides and there is such a thing as bias. I know there probably is in science; but not at the level I'm doing it. (AW3.175-82)

As one can see, these teachers accept that historical events and geographical features are open to interpretation and bias. The human dimension of science, however, sometimes seems beyond them. For some people, science is all coherence and neatness. In fact, a caveat needs to be added to this assertion: people may confuse science, human beings' knowledge about nature, with nature itself. Hence the emergence of statements about the truth of theories of science. This sort of assertion was common in the course of this study. So, when I came across Wolpert (1992) I could recall passages of interviews that would confirm his thesis about "the unnatural nature of science". Wolpert suggests that scientific ideas are, with rare exceptions, counter-intuitive and that many people accept the ideas of science because they have been told that these ideas are true rather than because they understand them (pp. x-xi). In that sense, it is interesting to note what the teacher just cited said later about scientific theories:

I see the theories as 'out there' as opposed to 'in here'. They are created, imagined by some one out there, someone much cleverer than me and I have to take their word for it that that was the truth. (AW3.314)

At the level of discourse she makes a distinction between the human enterprise to understand nature and the natural world itself. Still, as discussed in the first section of part II of this chapter, in her practice this distinction is not so clear. I would like to argue that at least part of teachers' difficulties in the teaching of science results from their seeing science in the way described above. Teacher A.W., for instance,
seems to stand in awe of science. As a consequence, simple phenomena - such as balls falling or objects placed on water - present themselves as full of secrets which, for her, only cleverer people are able to unveil. Teacher L.P., reflecting on the challenge science represents for teaching, compares it with mathematics. She finds science very difficult to teach, because "you're not able to vertically go through it as it jumps from different levels of understanding" (LP2.266).

Another passage from the dialogue with teacher L.P. expresses well what may be at the heart of the matter. She seems to suggest that, in the final analysis, it is science's end results that matter most. She also suggests something along the lines of "science involves a special mode of thought and is unnatural" (Cf. Wolpert, 1992, p. xi). In short, struggling to get pupils to find out everything for themselves can be counter-productive.

You can't expect [children] to keep re-inventing the wheel. If the knowledge is there, and somebody has slaved away for thousands of years to find out about it, you can't expect them to, sort of, go and do a Pythagorus or something. You've got to give them the knowledge. (LP2.146)

To sum up, the discussion on whether science is about asserted truths or critical enquiry emerges from this study as a key generative theme; one which might help to elicit the teachers' implicit principles about the nature of science, however these might have developed. The importance of discussing this theme is even greater once it implies the other kinds of principles which the teachers may hold: educational ones, for instance, which are rather more concerned with which level one is teaching. Depending on the depth of such discussions, it might be worth further raising teachers' awareness of their implicit principles by looking specifically at their teaching.

2. Whose ideas are these, anyway?

As the discussion delves deeper into the topic of scientific knowledge, one notices that some of the 'internal' tensions the teachers experience, as they try to strike a balance between theory and practice, have roots in cultural tensions. Primary teachers, in particular, are likely to pose as literary intellectuals in the scenario portrayed by C.P.Snow:

The whole of western society is increasingly being split into two polar groups. At one pole we have the literary intellectuals, at the other scientists, and as the most representative, the physical scientists. Between the two a gulf of mutual incomprehension - sometimes hostility and dislike, but most of all lack of
understanding. They have a curious distorted image of each other. Their attitudes are so different that, even on the level of emotion, they can't find much common ground (Snow, 1959, p. 3-4).

This Thematic Investigation has given me the opportunity to examine the extent to which such a cultural split is a relevant theme in the professional development of primary teachers in England and Wales. A particularly striking aspect of this issue, which Freire's strategy of enquiry helped to reveal, is the influence that colleagues and partners, as well as public opinion, has on primary teachers themselves. Let me draw on a teacher's own words to illustrate this point:

Teacher: Well, I think the shameful thing is your knowledge. Hopping back to the "awkward" bit [question-card number 11]. When they are giving you questions, you sort of feel you should know some of this. You sit here teaching them about electricity though you don't really know yourself how it really works.

Myself: Do you feel ashamed, then?

Teacher: Well, I do a bit. I tell you what makes me feel shameful about it. It's Johnny, my partner. He did physics you see. And when we talk about things, he sort of says "Well, don't you know?" And I sort of think: "No". (CP1.172-4)

I found this revelation astonishing. I tried to probe this issue further; although conscious it could be very sensitive indeed.

Teacher: I feel ashamed. I should know and I don't know this.

A.V.: But... What your partner knows about...

Teacher: I know... What he knows about teaching reading? He could feel equally shameful. I think it's my knowledge that makes me feel bad. It's my lack of knowledge. And also, being science post holder and seem to have this lack of knowledge when people come around and say to you: "How do you do this?" I can tell them how they can teach it. But if they say: "What is it doing then?", "What are the children learning by it?" It is odd. Specially when we don't have the vocabulary and we talk about the thing, the squiggly bit in the middle. (CP1.175-8)

It could be argued that teacher C.P. feels as she does because the pressures of her post. Her position in the school hierarchy may make her feel she has to have ready answers. As she does not have them, she feels bad about her lack of knowledge. Although this is a reasonable argument, I suspected there was more to this feeling
than just that. I suspected that Snow’s scenario of lack of understanding between
physical scientists and literary intellectuals was a bit bleaker here. Though lack of
knowledge need not make a teacher feel ignorant, it is possible that one feels in a
position of inferiority only because the knowledge in question is related to science
and one is a primary teacher. Being able to ask teacher C.P. more about her
partner’s attitude, I did so at our next meeting. Note that the names used here are
not the real names of these people.

Myself: Let me ask you something about your partner. It seems that when you
talk to him, he kind of asks you, "Don’t you know that?".

Teacher: Yeah I know. He drives me mad. What happens is, I’ll go to him and
I’ll say, "Tell me why this happens." And he’ll say, "Well, don’t you know?" And
I’ll say, "No". He’ll say, "Well you ought to know", and he does it to wind me
up, because he knows I don’t know. Because I’ve never done physics before
or anything, and he plays on it.

Myself: Is it light-hearted?

Teacher: It is light-hearted when it’s happening, but I don’t take it light-hearted
only when it comes to the fact that... You know, here I am, and Johnny says it
to me, "Cathy, I don’t know how they let you loose teaching science to these
children. You haven’t got a clue, have you?" (CP2.326-35)

This passage indicates that her partner may have grown contemptuous of the
whole idea of non-specialist teachers teaching science topics. Such an attitude of
contempt is apparently not uncommon, and teachers sometimes feel inhibited by
it. Teachers A.W. and L.P. also referred to people who had this attitude
(AW3.192; LP2.196).

Teacher L.P., as I have said, was very amazed by children’s reactions when she
developed one activity on ‘pushes and pulls’ at my request. This is not a mere
coincidence. It signals principles which are embedded in her propositions as if they
were her own, but which may in fact conflict with her truly heartfelt principles. As
mentioned on page 194, a series of her propositions seem to be rooted in the views
of her husband. He is a scientist and, from evidence she provided (in a passage
cited below, for instance), it is possible to infer that his views parallel those of
Popper (1968). Her statement that it is nonsense to expect children to keep re-inventing
the wheel, her initial resistance to teaching science and her amazement
with children’s responses during the activity recorded for this study are examples of
this tension. These teachers show themselves to be holding conflicting views about
the nature of science. Their concern to impart correct knowledge contrasts with
their preoccupation with providing pupils with a more open, less isolated image of science. It is also possible that they are themselves growing doubtful about the viability of science teaching in primary school.

In all these cases, the cultural divide is apparent. Indeed, this issue could be explored further. It would be interesting to pursue this investigation, first, because within British society science has never been regarded as a fundamental part of the intellectual culture (Snow, 1959; Jacques, 1993). Second, because all these responses come from female interviewees and they seem less versed in scientific theories than their partners. Would this not be a case for exploring feminist science (Bentley et al, 1986; Watts et al, 1994)? It might well be, since, as will be seen below, these teachers are suspicious of their partners’ principles - a kind of suspicion that can be the seed of critical and creative action in science teaching.

3. Autonomy from the ‘Canons’ of Science

It can be argued that primary teachers sense there is something wrong with the view that science is simply about truth. This may be to happen because they sympathize with children. It may also be because they are in a teaching position while, in fact, having little command of the content of what they teach. Their independence from science as an institution becomes, all of a sudden, a virtue:

I think it's quite good that I'm not particularly sure of [science], because I think I'd be more thorough in the way I'd present it. I think, [the children and I] are learning these things together and therefore I haven't got any preconceptions and I'm not inhibiting them. Now, my husband has a PhD in science and I don’t think he could tolerate teaching children this age, because their naivete would probably irritate him thoroughly and he’d have to get the facts right. You know, he’d have to say, ‘No, you’re wrong’, or, ‘This isn’t how it works’, and go off at a complete tangent. Well, I haven't got the ability to do that so I'm not saying to these children, ‘No, you're wrong.’ I'm saying, ‘This is what you think, let's have another look at that.’ So, I don’t feel I inhibit them in their learning in something like science. I'm not exactly learning with the children, but, um, I feel I'm able to let them go a little bit in their learning, and find out by mistakes, rather than being judgemental.

(LP2.194-6)

Intuitively, primary teachers seem to set their way of teaching science apart from the way they imagine that scientists would go about it. They recognize that the latter's emphasis on truth makes the world look simple, neat and logical but, at the
same time, secluded and ascetic. These teachers apparently feel that they themselves picture the world in a less consistent fashion but at least intertwined with other matters of human concern:

there is a lot of confusion in my own mind about this, because I think my secondary colleagues are too academically minded. They should be focusing more in the processes and looking at things more in a context, rather than saying: 'this is such and such's law and this is this person's rule'; not actually putting the whole scope of things and setting in a world context. It's just science, a little box just of science. I am not sure that we should be doing that and how appropriate is that for anybody to know these things. Isn't it more useful to have it applied? So I am totally in confusion about that. (AW3.192)

This attitude implies a certain relativism. As Chalmers says "a relativist will deny that there is a unique category, 'science', that is intrinsically superior to other forms of knowledge, although it may well be that individuals or communities place a high value on what is usually referred to as science" (Chalmers, 1982, p. 103). At times, these primary teachers exhibit this attitude. They seem to be saying something along these lines: the aim of knowledge-seeking will depend on what is important for or what is valued by the individual or community in question (Idem p. 102). It is inspiring to see how primary teachers overcome the dilemmas resulting from tensions such as those associated with the theme 'scientific knowledge' discussed earlier (headings 1 and 2). Nevertheless, it is important that teachers move on a step further. Raising the issue of relativism in discussions of this theme could have this effect. Do teachers admit to being relativists? How far will their relativism go? It is one thing to propose that science is not about truths and another, altogether, to knowingly set children to pursue investigations that will not lead them towards scientifically accepted theories.

In brief, inconsistencies exist between those principles about the nature of science which teachers explicitly express and those which their practice suggests. One example shown here is that those who took part in this study criticize scientific emphasis on laws and concepts, and a lack of connection between these and reality. Yet in spite of this, they are concerned about their inability to deliver the correct concepts and facts. Another example of inconsistency is when, the teachers complain that children end up with their own ideas, rather than 'scientifically accepted' ones, thus showing that they do not value the procedural component of science as they claim to do. However successful children's investigations may be, teachers can throw a wet blanket on what they consider to be poor achievements where these are different from the 'scientifically correct'.
The next theme, apart from being generative of discussions in its own right, serves to reinforce the point above about relativism. In the excerpt cited above (AW3.192) - as well as in many others - one sees that the teachers would prefer to motivate children to concentrate on the process of enquiry characteristic of science. The knowledge that science produces is somehow less valuable in their eyes. This attitude towards the products of science can be a subliminal statement about the scientific enterprise, suggesting thus that, although the teachers did not refer to these topics as meaningful themes, they are bound to stimulate teachers to reflect on their current ideas and practices.

**THEME 4: SCIENTIFIC ENTERPRISE**

'Scientific Enterprise' is an important theme implicitly connecting issues the teachers have touched on while discussing emotional situations they associate with their professional development. My analysis of the teachers' discourse with regard to this theme is arranged under two subheadings:

1. Science or Technology?

2. Content and Process

The theme 'Scientific Enterprise' is undoubtedly relevant to a discussion about the nature of science in science teacher education. First of all, because science comprises a set of products. Since our standard of living, as human beings, has changed dramatically with the advent of science, it is important to know the principles behind science's offshoots. Besides, as an area of human endeavour, science is continuously subject to critical analysis. To encourage the scientific enterprise to undergo further improvements the new generation has to learn how its products came about - to know what is so peculiar about its processes of enquiry.

In the discourse of primary teachers, one can identify misunderstandings regarding the nature of the scientific enterprise. Of these, some can be argued to generate tensions in their teaching of science. On the one hand, the way science and technology are portrayed in primary school leads at times to their being confused. On the other hand, the difference between content and process as aspects of the scientific enterprise becomes confused with content and process as two possible emphases of teaching itself. This, again, suggests a certain difficulty in separating two different objectives: that of giving children experience in a process of logical enquiry and give children knowledge about the process of scientific enquiry. Logical enquiry is a very important aspect of scientific enquiry, but is by no means
exclusive to the scientific enterprise, which is distinguishable in that it aims to formulate general laws, at least as far as physics is concerned.

I have organized my discussion of these confusions under two headings. "Science or Technology?" discusses the confusion between science and technology. "Content and Process" the distinction between teaching as enquiry and scientific enquiry as a characteristic process of investigation.

1. Science or Technology?

The teachers participating in this study seem positively in favour of introducing science early to children. They regret the way they themselves were taught and praise the challenge set by the National Curriculum. Evidence of this is shown in the response to card 14 ("What do you remember as something welcome, although imposed?") on the part of many teachers in the first stage of the study. They said the introduction of science early in the school curriculum was an interesting initiative (table 3, page 185). Their criticisms of their own education is well expressed in statements such as the following:

I was turned off science, obviously. I’m fascinated by lots of aspects, but I wouldn’t do ‘O’ Level or anything. I wasn’t even taught science at school. Ahm, so it’s obviously been presented to me as a thoroughly boring subject, which I know it’s not... so I don’t want to turn children off. I would rather give them the experience of finding out things, at this level, and just opening up the horizons: ‘Ooh, I wonder what happened there?’, ‘I wonder why...’ As a child I was always asking, ‘I wonder how a camera works?’ and everything, but... we didn’t do that in school! It was all a rotten old Bunsen Burner, and boiling up a few chemicals or something that the teacher did, and you’re at the back of the class and you don’t know what the heck’s going on. That was about the amount of science work, I suppose, that I did. I don’t want that to happen to children, I’d rather have them have hands-on experience, and know that they’re capable of finding things out for themselves. So it’s a balance, isn’t it, between imparting knowledge and giving them the idea that they can find those things out for themselves. (LP2.146-8)

As I have said earlier in this chapter (Themes 1 and 2), this tension between didactic and heuristic teaching was always present. On the whole imparting knowledge is repudiated by the teachers, while investigations are valued. The same teacher had earlier described the difference between these two as a dichotomy:

I would think that it was kind of Attainment Target One... investigation and
observation, and giving them an opportunity to talk about... We’re not actually getting them to acquire knowledge. What I’m trying to get them to do is to be inquisitive and to find out about things. (LP2.22-6)

That tension is inherent in science teaching. The National Curriculum Council itself recognizes that. In fact, it proposes that two types of understanding need to be addressed in the Science National Curriculum: ‘Procedural Understanding’ (described in AT 1) and ‘Conceptual Understanding’ (described in ATs 2-4) (NCC, 1993, p. 6). This is not an innovation, neither should it be considered the sole source of influence over primary teachers’ ways of framing science teaching; past initiatives in science education should also be considered. Although these teachers may not have had direct contact with science projects such as Nuffield Science Teaching (1967) and Nuffield Secondary Science (1971), both had a direct influence on ‘primary ideology’, for instance through the Plowden Report (CACE, 1967, para. 667). The importance given to practical activities, and emphasis on the relevance of science in everyday contexts, are just two examples of that influence.

The question here, however, is how these influences come to shape teachers’ actual practice. There are different ways in which practical activities can be carried out and each implies different principles about the nature of science. The same might be said about the effort to bring in everyday contexts into science lessons. There was a noticeable tendency among the primary teachers to portray science in a fairly functional fashion. Most of what they describe as ‘investigation’ turns out to be problem-solving geared towards the construction or understanding of technological objects or similar end-products. A.W., in the passage cited on page 233, for instance, expresses her concern about the academic fashion in which her secondary colleagues portray science, making it clear that she finds it more useful to envisage science as applied knowledge. And, in the passage LP2.146-8 above (page 235), when recalling the questions she asked as a child and as a teenager, teacher L.P. also showed that she expects science to provide children with the means to comprehend the functioning of apparatus such as a camera. Arguably statements made in the Plowden Report lie at the root of this feature of primary teachers’ common ideology:

Though constant dialogue between teacher and children is an essential feature of [learning by discovery], it would be wrong to picture it all as taking place in a classroom or laboratory. Essential elements are enquiry, exploration and first-hand experience... The making of models and the construction and repetition of experiments will also play an important part. Young children may want to repeat experiments over and over again and the comparison of results will
often lead to further enquiry (CACE, 1967, para. 669).

This image of pupils as scientists drawn by Plowden is certainly the ground upon which many of my teachers' propositions are based. The following passage shows not only how valuable it can be to adopt this inductive approach Plowden suggests. It also shows that primary teachers are in fact able to foster procedural understanding well, precisely as National Curriculum Attainment Target 1 lays this down.

When we do the sun and the sky and the shadows, we go out and we do it very practically.

We go out and we put a cross on the ground, and we choose a child and we draw around that child and we write the time. We go out an hour later, that child stands on the same cross, and we draw around the child, we write the time, and we do that for one whole day. So, we look at what's happened and discover that the shadow has got smaller and smaller, then bigger and bigger because the sun is quite low and then it gets quite high, and then it gets low again. The next day we predict. I say to the kids, "Where do you think the sun will be when we come out in an hour?" We've done it before but now we're having to think about what we saw last time. About the second time of predicting, the children are all in line. They're being able to look back at their observations and see how it works. And then you go out and you do it with things like a book. Can they apply it again? To a person, to a book, to a ruler, to a pebble, to anything? (CP2.127-9)

We can see that this is an application of the formula "observation, hypothesis, test, conclusion, prediction". There is no doubt that this works. Children do enjoy this kind of activity - teachers like C.P. are the first to confirm that. Besides, these are important experiences for pupils to have. They are the sort of activities likely to raise their awareness of the existence of regularities in natural phenomena; hence the seeds of a comprehension of the scientific enterprise. However, that does not mean that this issue of procedural understanding is unproblematic. There are at least two questions that deserve consideration here; one concerns a simplification of the matter by the teachers themselves; another relates to science educators' reservations about the inductive approach usually associated with activities geared at fostering this type of understanding. Here is an example where the first question is an issue:

Myself: Do you, do you see any situation when, in terms of science, it's more important to have the result than to have the process?
Teacher: Um, no. I think the process is very important. I mean, the end result is... um... If something should definitely happen in order for something to work, then the end result is very important. But then, so is the process of how they get there. The process can be more important, in incidents like the bridge building, because the result didn’t matter. In the end, I didn’t mind if their bridge didn’t stay up. It was the fact that they’d worked in a group, they had tried, they’d tested, they’d re-evaluated, they’d redesigned. You know, they’d communicated to one another, they’d observed their bridge, they drew their bridges... so that was more important than the end result, that they’d made a perfect bridge. (SS3.253-4)

Teacher S.S. also draws on the formula "observation, hypothesis etc". Yet, in this passage it is noticeable that such a formula has lost its scientific flavour and savours of technology.

One feature of science is the search for general rules and natural laws. That was clearly implied in the Science National Curriculum Attainment Target 1 by its authors. Apparently, however, this is not how AT 1 is interpreted by primary teachers. Where it reads "develop an awareness of the importance of science in everyday life" (DES 1991 p. 2), primary teachers seem to think of 'applied' science.

Primary school science investigations are not supposed to be general and original, but from the moment they lose certain features, they turn out to be investigations more appropriate to technology. This, of course, is not a problem - provided it is done deliberately. When there is an unconscious confusion however, it becomes necessary to explain the differences between enquiries pertaining to each of these areas and the possible consequences of not making clear the difference between them to pupils. Since the distinction between science and technology is not a trivial issue, such discussion may turn out to be irrelevant to these teachers, unless it is firmly linked to the subjects of their concern. I would say that the best way to do this is to focus on the distinction between practical activities which suit each of these areas of school curriculum.

Take, for example, the activity based on the construction of paper bridges, mentioned by teacher S.S.; many participants in this study said they had developed it in the classroom. They argue that this is a good way of introducing the idea of a 'fair test', which is in the Science AT 1 Programme of Study. The same activity, however, could relate to the National Curriculum attainment targets and programmes of study in technology. After all, by building bridges, children are "working with materials" to "develop an artefact", so they ought to "recognize patterns
in the structure of objects" and, eventually, "generate a design". Although, in practice, differences might seem subtle, they represent two ontologically distinct enterprises, namely the scientific and the technological. As primary teachers seem not to be conscious of such differences, they take courses of action that are not always consistent with what they believe they are doing.

As I mentioned earlier, however, that is not the only question concerning the issue of procedural understanding which deserves consideration. There is the fact that science educators have reservations about the inductive approach usually associated with activities geared at fostering this type of understanding. I would like to discuss this issue in detail.

2. Content and Process

In the light of cognitive psychology (particularly Piaget's work) and philosophy of science (for instance Kuhn 1970), science educators have long been critical of the image of pupils as scientists (Driver, 1983). This stems from empirical evidence of the difficulties children of school age have in understanding abstract or formal ideas involved in the study of natural phenomena (Gilbert et al, 1983; Driver, 1991; Pfundt et al, 1994). So, I confronted my teachers on this subject. I hoped this could bring about a reasoned argument for inductive teaching and this great emphasis on the process of enquiry in science. Here is a frustrated attempt:

Myself: Perhaps you see physics as a means to an end?

Teacher: Yeah, maybe. I'm not too concerned about AT 1, but... We were always taught that the way of working is important and... I do value experimentation and all that, and so I think you're right. Maybe there's the right for physics on its own without it having to be so much... linked. I mean, it's made me think. Perhaps I'm doing it too much. It's, you know, there's a case for this [theoretical] stuff. (JC3.113-6)

Indeed, what might lie at the centre of the discussion above is the construction of science as 'content plus process'. The disposition of teachers to foster 'procedural understanding' might be due to a confusion between what is content and what is process in scientific and technological investigations. Many investigations in primary school science are problem-solving sessions leading to the construction of an artefact rather than an idea or information such as would be expected of scientific investigations (Wolpert, 1992, pp. 30, 32). In other words, teachers might think they are engaging children in scientific processes when in fact their activities have features to do with design and practical ends more akin to technology.
On the other hand, there is this dread of being "left thinking one thing and the children being left thinking something else" (AW2.196), also expressed through metaphors such as "being one step ahead of children" or "being the blind leading the blind" (LP2.56). These are all expressions of reverence for the established content of science. Apart from returning to the discussion I associate with the expression 'Truths or Theories', this point raises questions about the features which the teachers believe to be characteristic of science. It seems clear that these primary teachers do not favour the openness and controversy regarding the content which science educators would like to foster. They repeatedly make reference to 'rights' and 'wrongs', which they can distinguish clearly in so far as the content is concerned. Open-ended investigations and other usual procedures in science, however, seem to have no place for this.

Nevertheless, although this attitude might be widespread, it ought to be said that the teachers interviewed for this study were under the pressure of repeated changes in the National Curriculum. Maybe this pressure is to blame for the sort of concern with content noted above. The passage below provides substance for such inference:

One thing that worried me when the National Curriculum first came out, was that we could get too bogged down and, "God, they've got to know this, that, that fact," and we'd all get too much into that and forget the, the kind of way of working. We'd all be trying to say, "Right, the earth is that, the sun is this, the moon..."; "Right, circuit, look draw this, this is what it looks like," and forget the actual way of working. "They need this knowledge, they need these facts. Um, so this is what we're going to do." So we get it and look, "What's the next Attainment Target? Right, I'll work on that today. I'll work on that." (JC3.60)

In any case, all in all the construction of science as 'content plus process' is a generative theme in its own right. But, one has to acknowledge what underpins such thoughts and the accompanying discussion within the realm of science teaching. Teachers may be interested not in the philosophical but in the pedagogical implications of this distinction. This means that, as undertaken by teachers, such discussion is likely to be more fruitful if it moves around the question of what is the most appropriate content of science teaching.

Take as an example the role of experiments in building theory. The importance of practical work in the teaching of science is virtually unquestioned (see above, Themes 1 and 2) as is reinforced by OFSTED (1995). If we take a philosophical line of argument, we will point out that this attitude implies principles akin to
inductivism. This attitude can, in fact, be noticed in some teachers’ statements; for example:

you would have the questioning, so that you are getting the knowledge as well, but still I would have done it in an experimental way first. (JC3.80)

According to an inductivist conception of the scientific enterprise, observation takes priority over deductive reasoning. Indeed, inductivism does not necessarily manifests itself only in its naive form. The following excerpt, for example, suggests that the teacher considers that observation may be guided by and presupposes theory, which resembles a form of falsificationism (Chalmers, 1982, p. 38):

The way they learn, is that they’ll make an assumption that something will happen if they do something, and you say, ‘Well go and do it’ and then come back: ‘Were you right or were you wrong? What happened?’ I did a lot about work with water… capacity, um, volume, and they made assumptions as: ‘That container holds as much as that container.’ ‘Why?’ ‘Because it’s fat and that one’s fat’ and you: ‘Well, test it out. How are you going to test it out?’ And get them to find out how to test it out: ‘I’ll put that one in there and if it spills over it’s more’, so setting up those sort of strategies for children to test out their own theories. (LP2.320)

Both these examples, however, can be interpreted as instances of the teachers talking about science teaching and not about the scientific enterprise. Inductivism can either be a learning strategy or a conception of science. As the first and foremost concern of teachers is with teaching, the philosophical discussion about the nature of science needs to be pushed back, and the pedagogical dimension of this issue come to the fore.

It is important to clarify whether the aim of science teaching is to tell pupils what are the products of science. In that sense, it is important to know if the scientific process of enquiry is itself one of these products. Teachers will also want to know what is the best teaching process for teaching that process of enquiry to children. To tell pupils how scientists do science may not seem as good an idea as to let pupils learn this by doing. But, what if this turns out to be ineffective, at best, or, at worst, leads to a distorted view of science? This is a case where Freire’s dialogicity principle, discussed earlier (chapter 2, section C) needs to be applied by teachers. In order to be able to strike a balance between science content and science process, as well as between didactic and ‘hands-on’ teaching processes, teachers first need to understand that these are the tensions involved. It is the task of teacher educators to help them in this process. And, as the best way I see for
science educators to achieve that, as teachers of teachers, is for them to apply the
dialogicity principle themselves, I propose that the product of this Thematic
Investigation be used in such a dialogical process of professional development.

THEME 5: THRUST OF TEACHING

This theme contains one subheading (Understanding?). In discussing the 'Thrust
of Teaching' I argue that the thrust of this study is the assumption that teachers of
teachers need a common language with practising teachers. If that common
language is not found, teacher educators will not accomplish their task of
communicating the cultural capital of academic research on teaching and learning.
My assumption follows the premise that teachers and teachers of teachers do not
necessarily share the same 'language' - the latter talking in terms of models and
theories, of teaching and of learning; the former talking in terms of exemplary
cases and metaphors. This premise in turn presupposes that these parties are not
at cross-purposes. If one party's main thrust of teaching was antagonistic to that of
the other, dialogue would be impossible. It is worth citing again a passage where
Freire discusses the meaning of 'dialogue' for him:

If it is speaking their word that men transform the world, dialogue imposes
itself as the way by which men achieve significance as men. This dialogue
cannot be reduced to the act of one person's 'depositing' ideas in another nor
can it become a simple exchange of ideas to be 'consumed' by the discussants.
Nor yet is it a hostile, polemical argument between men who are committed
neither to the naming of the world, nor to the search for truth, but rather to the
imposition of their own truth (Freire, 1972, pp. 75/7).

'Dialogue', according to the principle of dialogicity (chapter 2, section C), is a
synonym neither of 'conversation', nor of 'altercation'. 'Dialogue' is understood
here as the attempt two parties make to find a means to accomplish something of
common interest. Hence, it becomes part of this Thematic Investigation to ask
whether, in fact, there is a common thrust of teaching. Looking at the way primary
teachers talk about 'understanding', one can see that, although they are not at
cross-purposes with science educators, there is a slight difference of emphasis
between these two groups of teachers of science.

1. Understanding?

Earlier in this chapter (Themes 1 and 2), I have argued that the primary teachers
are more concerned with the participation of as many pupils as possible -
regardless of their aptitudes - than with attaining targets of a more academic nature. Basically, these teachers show a preference for a heuristic approach to learning as well as an emphasis on the processes of science rather than its products. These are signs that they opt for understanding as opposed to knowledge acquisition. However, once we begin analysing the educational component of their propositions, interesting issues arise for discussion. For example, in the course of an interview, the teacher, S.S., was challenged to justify why she had framed some emotional episodes in a particular fashion. As she was responding to the challenge, I problematized her propositions, asking what her role was in the events in question. That prompted her to expose propositions about learning, as well as educational propositions. Here is the passage where this occurred:

Myself: What’s your role?
Teacher: My role?
A.V.: Yes. What role do you play on this type of event?
Teacher: My role is to build on their curiosity... suggest things that might challenge... some of their preconceptions... and also to set up a secure environment for them, in which they can express their opinions. (SS3.94-9)

Two distinct roles, as it were, stand out from her answer. The first role she sees herself playing concerns an objective of a cognitive nature. Proposing to foster pupils’ curiosity, teacher S.S. hints at propositions about learning. On top of that, she also suggests that she adopts ‘understanding’ as a pedagogical aim. She adds that her role is also to provide children with a secure environment in which to express their opinions. Naturally, this preoccupation with creating an encouraging ambience is not peculiar to primary teachers. Jofili (forthcoming), for example, shows that secondary science teachers are themselves concerned to create what Bentley and Watts (1992, pp. 27 ff.) call a ‘non-threatening learning environment’. Despite the prospects being alike here, a slight difference of emphasis seems nevertheless to point to a dissimilarity of perspective. The prospect of understanding concepts would be familiar to science educators. That, however, does not seem to be precisely the sort of understanding the primary teachers prefer to foster. The following passage demonstrates this:

My role as teacher is to see those children develop as young children, so they develop socially, they develop emotionally, they develop intellectually. So, by giving a consistent response they can ask me academic questions, social questions... or emotional things. So there is a trust there. My role is not simply to pass on a body of knowledge to those children. It’s to get them to
develop self disciplines, self-esteem, self-awareness, awareness of others. So in doing that I cannot divide things up. My approach is the same so that they can respond to me in the same way. (MK2.142)

This particular statement crowned a long dialogue about 'understanding' which began when we discussed what was the purpose of an activity with nine to ten year-olds on light, reflection and refraction. The long-term objectives explicated in this passage may be vague. Notwithstanding, these objectives are arguably less commonly found in the discourse of specialist teachers. This passage, in fact, was preceded by the statement of a number of other propositions, illustrated by fairly practical examples and references to short-term pedagogical aims:

* get children to predict rather than just describe (MK2.10);
* allow pupils to appreciate the possibility and the potential of 'translating' something they already know towards a new experience, for instance, using an analogy coupled with experience (MK2.24);
* get pupils to put their theoretical understanding in use, for instance, posing practical problems to them (MK2.116);
* care with the wording of questions so that children of many abilities could contribute, whether understanding had taken place or not (MK2.42).

These short-term aims may show that teacher M.K. is concerned that his pupils learn certain skills and knowledge. This is hardly surprising, as he was working with nine and ten year-old pupils. However, these aims do not deny the caring attitude imparted in his statement. This attitude conveys educational propositions which are peculiar to primary teachers.

**Theme 6: Children's Diversity**

This theme contains one subheading (Fairness, Equity and Justice) under which I illustrate the role an emotive event has had in the development of a teacher's strategic knowledge. In fact, the description I give is of the moment when a teacher tried to communicate to me, an 'other' (see chapter 3, part I, section B), the reasons for his professional decisions and actions. So, the discussion of the theme "Children's Diversity" plays two roles. First, it gives empirical evidence of contradictions between a teacher's rhetoric about his actions and the actions themselves. Second, it shows that, although the teacher is capable of reflection and that this can lead to self-knowledge, his construction of explicit propositions
involves a lot of difficulties. These difficulties can be smaller when an 'other' assumes, as suggested by Freire, the role of the critical interlocutor who destabilizes and challenges teachers to reflect on their rigidly held convictions about their own practices and taken-for-granted elements of their discourse about teaching (see Elbaz, 1988; Fenstermacher et al, 1993).

As much as practising teachers need to communicate with educationists and so keep abreast of academic research on teaching and learning, they also need to learn how to translate their own thoughts into action. This translation seems essential in order for teachers to transform theory into practice. I would prefer teaching to be seen as a profession, rather than a craft. In that sense, I support Shulman when he says that "what distinguishes mere craft from profession is the indeterminacy of rules when applied to particular cases" (Shulman, 1986b, p. 13b). To his assertion I would add, however, that being able to apply rules the way described, and being capable of explaining why something is done are two rather distinct talents. The development of each of these talents involves particular aptitudes and contexts.

Firstly, the application of general rules to particular cases demands the kind of judgement that characterizes strategic knowledge: professional judgement. As I have explained (chapter 3, part I, section C), strategic knowledge develops as teachers confront particular situations or problems, whether theoretical, practical or moral. It is worth using here the terms which Freire adopts; in this way it becomes possible to understand these terms with reference to teacher development - note that these terms were discussed in chapter 2 with reference to adult education but can have a wider application. As representatives of a professional category, teachers face common 'limit-situations' in the process of conscientização. Each transition between different levels of consciousness is accompanied by extremes of self-confidence and self-consciousness. They are thus marked by emotive events, such as the following.

1. Fairness, Equity and Justice

A principle to which all teachers refer when describing their relationship with young children would be a good example of how difficult it is to be challenging and provocative with regard to propositions about education. In that sense, the principle of fair, even-handed and just dealing is perhaps the best of its kind. It is difficult to question why there is a need to be fair, even-handed and just. Any attempt to do so would sound blatantly absurd. My volunteer teachers accepted without hesitation many questions about teaching strategies and the nature of
science. They possibly did so on the grounds that I come from another country, so I might well be unfamiliar with local teaching strategies; also I belong to a different intellectual lineage being a science expert and a teacher in post-fourteen education, so I might well be genuinely interested in making sense of primary school science. However, it would be quite odd to have the principles of fairness, equity and justice questioned.

Despite the fact that I did not deliberately problematize the teachers when they reported several cases where this principle was illustrated, this turned out to be a good example of how much one can help a teacher to gain new perspectives on his/her classroom reality. Teachers do experience some internal conflicts concerning fairness, equity and justice, but these do not always come to the fore. Indeed, some of these conflicts have been mentioned in the course of this analysis of the teachers’ discourse. During the interviews, however, there was one particular episode worth noting because it illustrates the fact that Thematic Investigation does not aim to explain patterns of thoughts or of action, but rather to identify those instances where there are tensions or dilemmas impeding action to comply with thought which inspired such action. This is the transcription of the dialogue which preceded the event in question:

Teacher: Your time is spent managing very demanding children, or children who have been quite naughty, and there’s a small band of children, somewhere in the middle, who quietly get along but you really aren’t focusing in on them properly.

A.V.: Seems interesting. What are the problems of doing this?

Teacher: Do you mean what are the problems of tackling that group of children?

A.V.: Yes. Probably there are some drawbacks, I mean...

Teacher: Well, the thing is to actually try and approach your work by saying, "I am going to focus in on these five children today, at the expense of the others". Perhaps because you’ve realised that certain children - usually boys - are either very naughty or very dominant in the discussions and demand a lot of your time. So you need to say, "Who haven’t I spent a lot of time with. Right, I must focus in on these children." And they tend to be girls. Not always, but they tend to be girls, who get a raw deal, you know, because they don’t demand it from you. (MK3.123-7)

The teacher here is clearly concerned because a group in the classroom ‘gets a raw
deal'. He feels that it is not right that this should be so, and takes action to rectify that, as he reports. Then, suddenly, during the interview, he asked me to switch off the tape recorder. He was clearly very uncomfortable, very concerned, and needed some time to re-orientate his thoughts. He then explained that what he had said (cited above) might have given a wrong impression of himself and his practice. He said he wanted to discuss the point further. When we switched the tape back on again, his dilemma became clear; he recognized that in trying to be just and righteous, his upright actions had created an undesirable inequity:

There's this hidden kind of agenda that, if you're not aware of it, you just get sucked into it. If you're not able to analyse your body language, or the amount of hidden messages you give to the children, then I think... you will... you will not do justice to all the children in your class, and I think there's a lot of research that's been done, in this country anyway, to show that. I think you do have to step back and really focus in on that and, you know, think whether you're giving different messages to girls and different messages to boys, ask yourself whether girls think that science is boys' stuff... (MK3.141)

This was quite a dramatic moment in the middle of an otherwise calm conversation. It is interesting to note that teacher M.K. had an insight into the episode described in the first passage, seeing it from a different perspective even while talking about it. It is not my purpose here to make a distinction between fairness, equity and justice. My purpose is not to judge this or other cases and, in summing-up, state whether teachers are fair, even-handed, just, or none of these. I am not even discussing fully here whether teachers act on principle or by instinct. That is because I just want to illustrate the reflection on dilemmas such as this; for this helps to show their complexity.

It is very significant that teacher M.K., who actually experienced the dilemma, could not find a solution to his difficulties himself. However, later in the dialogue, he hinted at how he consoled himself:

A.V.: Do girls think that science is boys' stuff?

Teacher: I don't think they do. I'm not sure whether I've really focused in on that, or asked them, when I've approached the science work. I've never asked them explicitly.

A.V.: Yes, sure. It wouldn't be fair, would it?

Teacher: No. But, for example, if I say to the children towards the end of the day, "Right. I'll give you a free choice now for the last twenty minutes".
would probably see, nine times out of ten, boys playing with construction toys and girls, perhaps, doing little pictures or making greetings cards. You would definitely see a very, kind of, fixed division of labour, if you like. I can sort of forcefully change it and say, "Right, boys are banned from using construction toys today, girls you can go and play with it". But then, again, I'm sort of saying that all the girls have to do things together and all the boys, you know. It's very, very rare to see girls and boys playing together with the construction toys, and boys and girls cooperating over making greetings cards. It has tended to be... boys doing one type of thing, very sort of macho and loud, and girls doing another thing which tends to be very nice, and prim and proper, and neat and tidy. That's a bit, that's a crude example, but there is this general pattern.

A.V.: But on these examples, they were free to choose. What about on tasks they have no choice? I don’t know, working on computers. Or placing the mirrors to get the candle's image, as in the activity you recorded. Or other situations...

Teacher: Well, there have been no problems there. Last year, a lot of the girls in my class had a far better attitude to general classroom work. Whether that was because they wanted to please the teacher simply, or not, I don't know, but many more of the girls were much more willing to tackle work that I had asked for them than the boys were. Not in all cases, but some of the boys tended to be very strong characters who kind of wanted to do things on their own terms, and not always on my terms. That wasn't so much the case with the girls. They were much happier saying, "Right, this is what we're going to do", and they would go, "Great!", so I didn’t feel there were any negative attitudes towards science. (MK3.142-49)

Teacher M.K. thought it was not morally just or right that some would 'get a raw deal'. He recognized that for all 'to get a fair deal' some partiality is needed. If he was impartial he would be bound to reinforce the inequity he does not want to foster. The balance might be fair if he is honest both with his pupils and with himself. Reasonableness and moderation in the exercise of his authority, as well as a disposition to avoid insisting on this authority too rigourously will probably allow him to deal even-handedly with pupils' differences of sex, behaviour and interests.

**Theme 7: Elements of Communication in a Teaching Process**

I propose the theme 'Elements of Communication in a Teaching Process' because
non-specialist teachers encounter aspects of science teaching that relate to theory of communication. Here, I give this theme three subheadings:

1. Objects of Communication in the Teaching of Science
2. Processes of Science as Object of Communication
3. Sources of Information in the Teaching of Science

In analysing how the volunteers refer to the teaching of science one notes their preoccupation with its content; with what is being taught. This, in terms of theory of communication, corresponds to being conscientious about the 'object' of the communicative process. It is one of the elements of a process of communication. A discussion of this element will help to point out mismatches between teachers' and science educators' intentions, as well as between intentions and actual practice. Another element I discuss here is 'interlocutors of the communicative process'. This element raises some problems in science teaching because science concerns our understanding of physical phenomena, which can be seen or tactually experienced, unlike historical events or geographical features of remote parts of the globe. A definition of source of information is therefore necessary; is it the case that this source can be the phenomena themselves? Or, would the source of information need to be teachers or books? In this section, the tensions involved in these questions are also considered. The third element of the communicative process, 'language' or 'means of communication', is a theme in itself, hence I discuss it later as a separate generative theme.

1. Objects of Communication in the Teaching of Science

One might had thought that, at the present time, the objects of communication in classrooms in England and Wales were determined by their current national curriculum. Nevertheless, as the following excerpts from the teachers' discourse show, however tight curriculum directives may be, there is always a degree of freedom left to teachers. Moreover, teachers have their own ideas about the way children learn and what is appropriate to teach them; about the nature of the subject being taught; and about the value of teaching this subject matter to pupils in the first place.

The case below is of a teacher questioning the National Curriculum Council guidelines. In this example, one can see that there is a slight indeterminacy about the object of communication. Teacher L.P. contrasts the activity developed for this research, which was about force, with activities related to sound and light. She would prefer the latter, where the object of communication would have been...
physical phenomena. The object of communication of the ‘pushing and pulling’ activity can also be the various phenomena associated with someone's acts of pushing and of pulling something. This, however, does not seem to be what teacher L.P. thinks about ‘pushing and pulling’.

A.V.: Did the text of Science Attainment Target 4 in that case [doing ‘pushing and pulling’ for the sake of this research] help you, or give you any hint that was particularly useful?

Teacher: No, I think it was horrible, I can’t stand it, I thought it was really boring. I don’t now, because I quite enjoyed doing ‘Pushing and Pulling’, but I’d go for the ‘Sound’ and the ‘Light’ and all that sort of aspect, but I haven’t taught that Attainment Target... I’ve kind of avoided that one before because I just don’t like it, didn’t like it, couldn’t see... where I’d go with it... I mean some of the things just don’t turn me on at all. I’m not very keen on science because I didn’t have a very good science education myself and I suppose I’m a bit wary of saying the wrong thing and of course you’ve got to be au fait with the subject yourself before you can feel confident. And most of... my level is stuff we did all the time anyhow, the light, the sound, and... the magnets and all those sort of things we’ve always done as good infant practice. Now, it’s just... it’s just sort of, formalised, isn’t it? (LP2.95-100)

As this excerpt shows, when teacher L.P. talks about ‘pushing and pulling’, she seems to suggest that this activity should inform pupils about our understanding of the physical act of pushing/pulling, rather than simply inform them of the act itself. Evidence of this is, for instance, that teacher L.P. says that she is wary of saying the wrong thing, because she says she is not au fait with the subject herself. In other words, she admits that she does not have a good understanding of the explanations physics has for the phenomena. On the other hand, in regard to her confidence to teach ‘sound’ and ‘light’, it is unreasonable to assume that the teacher is familiar with the explanations of either wave physics, acoustics or optics. The reason for her to prefer these topics is probably that she considers the phenomena in question, rather than their understanding, to be the objects to be communicated in these activities.

Earlier in this chapter I have discussed the fact that the products as well as the processes of science are the subject matter of science teaching. These, however, are not the only objects of the teaching of this discipline. At all levels of education, but particularly at primary school, physical phenomena are also objects of communication of science teaching. It is at school that, for the first time, many of
us encounter light spectra cast by prisms; electrified rods; compasses; crystals etc. It is also at school that certain common phenomena such as rainbows; evaporation, condensation and the freezing up of water; the daily and annual movements of the Sun across the sky; lighting up of electric bulbs etc, are brought to our attention. These encounters do not necessarily take the form of direct contact with phenomena; that is, practical activates in which nature itself acts as the source of information. The teacher, books or other pedagogic material may be the source of information, instead. But even if that is the case, the message may only be intended to carry this information: these are physical phenomena, and they surround us.

This case illustrates well the implications of selecting one object of communication at the expense of another. In the passage above, it becomes clear that teacher L.P. was happy with the result of her experience organizing the 'pushing and pulling' activity because she did not go beyond the phenomena. As it turned out, the activity simply concerned children's experience of the sights, sounds and tactile qualities of the physical world plus the words we associate with some of these qualities. Arguably, 'force' was not presented as concept, but simply as word to be associated with pulls and pushes. We can see that is the case as we read this passage:

A.V.: You said your aims are more clear. Can you talk about them?

Teacher: Um, I knew exactly... more exactly what I wanted out of the children. I knew that I wanted to introduce this vocabulary, to get out of them the words 'pushing' and 'pulling', and maybe 'energy' and 'forces'. I couldn't take it too far and so I knew how to gear the discussion a little bit more to get those sort of words coming, and how to perhaps structure the activity to allow... I altered the activity just a little bit so that it was more of 'Forces'... so that it had more implication for all the forces that they would have to employ to move the objects. So, I suppose I just sharpened the edges a bit of, of the presentation of the lesson. So, really it... it was, really just to focus on what makes things move. And I was far more clear in my mind when I did it the second and third time that that was my objective, just to get the children to look at different ways of moving things, and to introduce the vocabulary, the appropriate vocabulary. (LP2.13-8)

It becomes clear that teacher L.P. wants to introduce a vocabulary. She herself seems to construe the concept of 'force' as something necessary to make things move; a construction which is alternative to the scientific frameworks of this
concept (see Watts, 1983b). If teacher L.P. in fact construes force that way, she may impart an alternative concept to children. This, arguably, may be a problem for science teachers further up in the process; those teachers in charge of imparting the scientific concept of force to pupils. This is a problem that could be minimized if the primary science teacher was aware of the difference between two of the jobs of a science teacher: giving an account of the scientific understanding of physical phenomena and drawing the attention of children to these phenomena. In spite of a lack of interest in science, little understanding of its concepts and inexperience with a particular activity, the teacher in this case was pleased with what she got out of the activity in question. I would explain this as follows. Teacher L.P. apparently used her understanding of the concept of force only as ‘script’ to set the activity. She did not expect children to understand the scientific meaning of ‘force’. What she tried to do was to set children to experience force, to be in situations where forces are at play. She then introduced the use of words such as ‘pushing’, ‘pulling’ and maybe ‘force’. It can be argued that teachers with misconceptions would not associate these words with phenomena as precisely as expected. Thus they would allow for alternative conceptions to be developed or reinforced. Although I agree with this argument, this case shows me a possible solution to the dilemma concerning science teaching by non-experts. It is reasonable to assume that if the teacher is conscious that his/her job is ‘to introduce a vocabulary’, rather than to introduce scientific concepts, it is likely that,

* firstly, the teacher will do activities he/she would, in principle, avoid;

* secondly, primary science will play the important role of widening pupils’ range of experience of physical phenomena and widening their ‘scientific’ vocabulary;

* finally, pupils, who will inevitably develop their alternative conceptions, may later appreciate with more ease that they have been thinking in an alternative way. They may do it with greater facility because they would not then also be asked to acknowledge that their teacher in primary school was wrong.

2. Processes of Science as Object of Communication

Apart from differentiating the twin objects of communication discussed above, this analysis highlights the fact that it may be unreasonable to expect primary teachers to deliver formal knowledge and understanding of physical phenomena. It seems fair, however, to expect these teachers to introduce young children to these phenomena. This task is quite legitimate in terms of science teaching. Besides,
taking it as the objective of primary science, particularly in the early years of schooling, would allow a number of practical problems to be simply avoided; from children's epistemological immaturity to teachers' lack of content knowledge.

If, on the other hand, we decide on the formal knowledge and understanding of physical phenomena as the object of communication, as it were, there naturally follows the need to determine whether the focus will be on the products or on the processes of science. One problem with this differentiation, as I have stated earlier in this chapter (section entitled 'An Example: The Thematic Investigation of A.W.'s Discourse'), is that it requires knowledge beyond that of the facts or concepts of science. It implies knowing the ways in which truth and falsehood, validity and invalidity, are established in science. Another problem is the possibility of teachers presenting science processes out of context.

Teachers can sometimes talk of 'scientific method' as if this was a fixed investigative and reasoning procedure that can be used in any context; a procedure able to tackle any question of human concern. There may be no explicit intention to impart such an idea, yet this idea may well be subliminally communicated; hence, once again, the importance of being clear about the object of communication. As described below, teacher S.S. conducted an activity on bridge building for the purpose of informing children about the processes of science. She declares that the final product of this activity is not important.

A.V.: Do you see any situation, in terms of science, when it is more important to have the result than the process?

Teacher: Um, no, I think the process is very important. I mean, the end result is... I don't know really, it just depends. I can't think of anything right now - um, but if something definitely should happen in order for something to work, then the end result is very important. But then, so is the process of how they get there. The process can be more important, in incidents like the bridge building, because in the end, I didn't mind if their bridge didn't stay up. It was the fact that they had worked in a group, they had tried, they had tested, they had re-evaluated, they had redesigned. You know, they had communicated to one another, they had observed their bridge, they drew their bridges... so that was more important than the end result, that they'd made a perfect bridge. (SS3.253-4)

In fact, the product of the activity on bridge building, whether relevant or not from the teachers' point of view, is only marginally related to science. If nothing else, the isolation of science processes from science products is a loss in terms of space in
the timetable. In terms of communication, it corresponds to waste an opportunity to communicate two kinds of information in a single message. Unless 'bridge building' is regarded as technology, it could be more effective to choose a topic in which the search for a product of science would also give pupils the opportunity to observe, suggest hypotheses, test these, and so on. Naturally, there may be reasons to avoid mixing product and process in a single activity. These reasons however do not concern the identification of the object of communication, which was the subject of this and the previous sections.

3. Sources of Information in the Teaching of Science

Another way of dealing with the question of communication in the teaching of science is to look at the interlocutors within the educative process. At higher levels of education, the main sources of information may be the teacher and the textbook. In this study, the teachers have tended to express their preference for other methods. Indeed, this was discussed earlier in this chapter (Theme 1), under the heading 'Hands-off' Teaching for 'Hands-on' Learning. It is worth repeating here a passage cited there:

I think far too much teaching comes [from the teacher]. I think [the children] think that the source of knowledge is up there [on the blackboard]. I mean, often I am moving around the room, but there are times when I'm standing up there. And I think I need to say that not all knowledge comes from me, a lot comes from them. I perceive there are certain things they need to know, so I direct their learning. But a lot comes from them; I don't feel that me saying: "write: light refracts... write that down, because I told you so" is the best way for them to understand science, just for me to tell them. (MK2.102)

In our dialogue, I did not ask teacher M.K. why he thinks telling is not the best way to teach refraction. I did not do so despite the fact that to tell is a way to direct. In other words, I did not ask teacher M.K. more about telling in spite of an apparent contradiction in his statement, since he also said he directs pupils' learning when there are things they need to know. Probably because I share the opinions he expressed, I did not see the need to question teacher M.K.. Now that I analyse his discourse, I can see on what grounds his statement could be justified.

When the object of communication is a physical phenomenon and not formal knowledge about it, the 'message' may not get across adequately if the source of information is the teacher and not nature - whether raw or human-made. This line of argument can be inferred from the above - but only partially - when teacher
M.K. contrasts the act of writing with a phenomenon whose visual aspects are its main characteristic.

The strongest argument in favour of nature itself being the best source when the object of communication is physical phenomena, is primary teachers' wisdom of practice. Teachers know from experience the advantages of pupils interacting with sources of information other than teachers themselves, particularly with actual phenomena. In their wisdom, the primary teachers have intuitively noted that in part the function of primary science is to give children a kind of ‘phenomenological literacy’ - a term I use to distinguish the skill of perceiving physical phenomena from the skill of making sense of physical phenomena. I suggest that, for primary teachers, science teaching is precisely about allowing children to ‘read the world’. This proposition may seem simply a paraphrase of Freire’s own words (Freire et al, 1987), but it is most definitely not. If we listen to what these teachers are saying, we find that they want children to perceive the physical phenomena surrounding them, interpret their signs, and then, communicate this very experience. Here is an example that illustrates this:

I don’t think they had any kind of experience like that. They’ve never met that before. That was just an introduction to the fact that when light passes through different means like glass, or water and air it behaves in a slightly different manner. I was wondering whether they could really, really see it. So it was a question of, you know, move around, see it from different angles... And perhaps in some angles they could see it very, very clearly and others they couldn’t. (MK2.90)

What the teachers seem to recognise, albeit at an intuitive level, is that there are moments in which communication needs to be established between the student and the phenomenon. Teachers seem to sense that when they assume the role of intermediary and describe a phenomenon to pupils, the message does not always get through. That is, pupils fail to understand the phenomenon in the same way that the teacher does. This could perhaps be because they do not perceive it the way the teacher does, or because they refer to the phenomenon through terms incompatible with those used by the teacher.

The teachers do not suggest that first hand experience is the only way to learn about a phenomenon; but rather that pupils’ comprehension of the terms used by teachers when explaining the phenomenon is facilitated by first-hand experiences. Having been challenged to report these experiences in their own words, pupils can find in the teacher’s explanation the terms they initially lacked. When, on the other
hand, pupils are presented with explanations without previous experience, they are meeting new words for which they have no referent.

The teaching of science, particularly with regard to phenomena studied in physics, has this peculiarity; the objects of communication are ideas, concepts, understandings, procedures; in a word, entities which are essentially social constructions. Fortunately, in primary school, a great deal of the content refers to phenomena of which one can have first-hand experience. Here, the phenomena are the very source of information. This allows the teacher to play, not so much the 'presenter', who gives information, but rather the 'enabler' and 'challenger', facilitating the learning opportunities and commenting critically on procedures and outcomes (NCC, 1989, p. A12). In that respect, an extract from an interesting dialogue comes out as illustrative of the sort of difficulties involved in the communication of abstract, social constructions. As she was working with very small children, teacher C.P. considered it more appropriate to use units of mass other than the conventional ones:

To determine which roll of newspaper would be stronger we thought we could hang a weight from it. We talked about the weight being 200 grams. Well what’s 200 grams? We don’t know. We’re too young. It’s too high context. But we can cope with six scissors, so we use that weight unit of measurement to get the best roll. (CP3.34)

The question here could be portrayed as one of pupils' epistemological immaturity, when in fact it is a great deal simpler than that. The problem is only that words such as 'grams', 'ounces', 'kilograms' or 'pounds' refer to abstract entities. This fact can interfere in the process of the communication of, say, the act of weighing. It seems more likely that pupils will 'read the act of weighing' correctly, and understand that it is actually a comparison with a standard, if we avoid, for a while, the names of the standard units of mass. Eventually, when the need arises the standard adopted by society as a whole can replace the standard agreed in the classroom.

Naturally, this preference for direct contact with the physical phenomena has its costs, as well as its benefits. One of these costs was noted by some of my teachers. It provides an important argument regarding the importance of the materials available:

A.V.: But has this anything to do with, um... the grasp, and the delight and... has it? I mean, the resources...
Teacher: Well it does, actually. It does very dramatically. If you want to delight children in their first experience of using a magnet, and you've got a dud magnet that's been dropped on the floor twenty five times and it doesn't work, then there's no delight. You get another scientific experience, you don't get the fact that this magnet attracts steel and iron objects, you get the fact that it doesn't attract anything at all. So, from a resource point of view, it does directly affect the delight, and if your batteries don't work, then your light bulb is not going to light, but if you don't know the battery's dead, then you don't know that is that, it may well have worked if you had a different battery. (DH2.343-4)

In sum, teacher D.H. reminds us that the choice of sights, sounds and tactile qualities of physical phenomena as object of communication, combined with the choice of nature itself as a source of information, does not assure the success of the process. Moreover, this assertion highlights another peculiarity of the teaching of science. Let's take the case teacher D.H. mentions above to illustrate this further point. Magnets have the physical property of attracting metals. Suppose that this is the object of communication - the information I want to impart to pupils - and that I decide that pupils will benefit from playing with magnets to obtain this information. In this setting, magnets are at the same time both the source of information and the media for the transmission of this information. It is possible to see this as we compare such circumstance with others of similar character. When children receive magnets that have lost their properties of attraction, they are in the same situation as someone who receives a blurred picture and is expected to see on it a UFO, an animal suspected of killing livestock, or a monster haunting a lake. Such a photograph does not impart a clear picture of the object (or beast) in question. It is basically a flawed medium of visual communication. The same applies to the worn or defective magnet, which does not impart the tactile impressions of magnetic attraction.

**Theme 8: Schemes for the Articulation of Messages**

Theory of communication has been helpful in that it has provided useful parameters of analysis. By identifying the elements 'source' and 'object' of communication in regard to teaching, it has become possible to consider whether or not the actual actions of the teachers were in accordance with their intentions. It has also been possible to consider whether or not it is reasonable to expect non-specialist teachers to perform particular tasks.
In ‘Schemes for the Articulation of Messages’, I have four subheadings:

1. Obvious and yet not Trivial to Communicate;
2. The Scientific Ways to Represent the World;
3. The Use of Analogies;
4. Follow in Scientists’ Footsteps.

Under these headings, I draw attention to dilemmas concerning the choice of media of communication in the teaching of science. There are different ways to convey any one object of communication; some more appropriate than others for its later de-codification and correct comprehension. I present below some forms in which information was articulated in order to impart some knowledge of or about science to children. At the same time, I consider whether or not they seem suitable or particularly well chosen and why.

1. Obvious and yet not Trivial to Communicate

In my discussion of theme 7, ‘Elements of Communication in a Teaching Process’, I mentioned that the teaching of science may convey two types of message which are very different in nature. I said that the message may be simply, these are the physical phenomena that surround us. As I said, the message can include the scientific understanding of these phenomena, our explanations for its causes and effects. I want now to focus on the ways I have observed that each type of message may be conveyed.

The obvious way to focus on a phenomenon is to allow pupils to experience that phenomenon. To experience a phenomenon may seem fairly straightforward, but in actual fact it is no small matter. In my dialogues with the teachers I found examples of two types of phenomena that may be difficult to get pupils to experience:

* first, those that can be described as obvious and yet remote;
* second, those whose presence in our lives is so constant that we would simply ignore them if nobody called our attention to their existence.

With regard to the first type, teacher L.P. provided an interesting example for discussion. She said (LP2.266) that one of the statements of attainment of the Science National Curriculum was to teach children not to look directly at the Sun. This, she said, one could do in assembly, simply by asking pupils to raise their hand if they thought it was a good idea to look directly at the Sun. This particular
statement of attainment does not seem to be written anywhere in the curriculum documents; nevertheless, it can still function as a prototype, and exemplify a theoretical principle. The fact that sunlight blinds is as obvious as it is unlikely to be shown to be true. Therefore, a teacher can do little more than tell pupils it happens; the assembly approach stands as a possible alternative. Another example of the same type was provided by teacher J.C.. She expressed her difficulty in finding a way to impart the information that "there is a range of fuels to be used in the home" (AT 4, KS1, level 3. DES 1991, p. 6):

I've had exciting things with the sound or the magnets, things like that. I think it is... mainly these ones I'm not... as keen on, because I think I'm limited, I am limited on what I can think of to show or to do, apart from bringing in a range of fuels. (Laughs) It's more sort of factual. With the [sound and magnets] you can experiment or do things with, I think that's what it is. I can't think of that many different ways of doing [the range of fuels]. But the ways I do it seem to have been pretty successful, and they can enjoy it. You could make little games or something. Or move things around. I dunno, it's almost like they've found out something, but then they're able to use it more... practically, to make or do something or have a bit of fun with. (JC2.148-50)

Here again we see that there is no alternative medium of communication to impart the information in question; or, rather, this information does not require that anyone design a special medium in order to impart it, because it is essentially straightforward, 'sort of factual', information. In that sense, teacher J.C.'s reference to 'games' as a possible alternative would come as a surprise, if it were not for the previous references to primary teachers' preference for practical activities. Games, as the teacher says in the passage above, have greater appeal. I will return to other media of communication chosen for their greater appeal, but, for the moment, I want to move on to the discussion of those phenomena whose presence in our lives is so constant that we would simply ignore them if nobody called our attention to their existence.

While the previous type of phenomena do not need any special media to announce their existence, this second type of phenomena does demand special forms of communication to indicate that they exist. It was teacher C.P. who provided the best example of this type of situation.

Teacher: When you start having to think about the National Curriculum and what the children are to achieve, well then it's a longer term process. And if there's excitement in it, all the better. I hate to be dull, because if it's dull
they're not going to want to know. You have to make everything seem...

A.V.: But can you afford doing exciting things for the excitement of them, full stop?

Teacher: Oh yeah. Yeah, well again like under light well you see, you make your science exciting. So by showing sound... Showing sound, just by taking a ruler and blowing it up and down isn't as exciting as getting that [activity with the tuning fork]. It just doesn't sort of give the idea. Then you bang your tuning fork and you put it in the water, and the water spits everywhere. That's much more exciting than just watching a ruler blowing up and down.

A.V.: And what sense do they make of this water going everywhere?

Teacher: They're just amazed that it can do it. You should see them, Arnaldo. They walk around with a tuning fork like that, and they hit everything. And they put it against something and watch the thing vibrate, and they bang it and then put it up to their ears. They really whack it on the table, and they listen to it like that and you hear the buzz. Or they touch this... and all around the classroom, wooden things, plastic things. They touch each other's hands... You know, I think they just find that interesting that when you hit it it can, it does what it does. (CP2.67-77)

The description teacher C.P. gives here is interesting in that it compares the communicative value of two apparently similar activities. Sound is a phenomenon which we experience continuously. It is therefore necessary to have some sort of artificial arrangement for us to pay attention to it. Both the ruler and the tuning fork impart the idea that sound is a result of vibrations. However, one of them communicates this information more effectively because it reaches pupils as a sharp signal, whilst the other is only a dull one. Teacher C.P. says that the reason for this success is that one is more exciting than the other. When she says that watching a ruler blowing up and down is not exciting, she is actually saying that it is not unusual enough to catch pupils' attention. Excitement has already come up as a meaningful theme when I discussed 'discovery learning', earlier in this chapter (Theme 1). However, in the case described here, the excitement results from a felicitous practical-pedagogical arrangement; it contains at the same time sights, sounds and tactile qualities which all have great impact. It carries the message like a well-chosen word.

Since this happy choice of medium of communication is related to the topic 'sound', it can be argued that this is an interesting topic and, therefore, particularly suitable for the design of an 'exciting' activity. The argument is basically that other
ordinary phenomena, such as pushes and pulls, for example, would not lend themselves to such a felicitous activity. This may, in part, be true. However, this does not mean that the teacher's strategic knowledge has not played any part in the choice of presentation. 'Sound' can simply be associated with musical instruments; incidentally, in the early version of the curriculum, this is a statement of attainment (DES, 1989, p. 30), and, in a later version, it is used as an example to elucidate the programme of study (DES, 1991, p. 6). In that respect, it is interesting to note what this Thematic Investigation revealed with regard to the strategic knowledge of another teacher.

Teacher J.C. recalled children making blowing instruments after the visit of a brass band, describing it as an unexpected event in her professional experience (see her answer to my emotive question on table 3, page 185). She considered this episode a good example of her strategic knowledge and chose it, together with another eight episodes, as an element to analyse in the Rep Test (chapter 3, part II, section C). The FOCUS Analysis of the way she graded these nine episodes showed a high level of consistency in her description of both this activity about sound and an activity she recalled as remarkable because of the way a child made a car move (see result of FOCUS Analysis in Appendix 2). However, as I discussed with her the aims of the activity involving musical instruments, she showed that it fitted in with the way she likes to conduct science activities, rather than being chosen because it was a good medium to impart a particular message about the phenomenon of 'sound'.

A.V.: What's a target concerning sound? What do you want to achieve?

Teacher: Er.... I'd say it was finding out a different sound they made, but... I'm just trying to think how to challenge... Yes, I can't think of the same kind of challenge in the same way... Obviously, using the instruments they've made then. I've done it all. This is using the instruments they've made either for music or sound stories, or something like that. (JC2.195-6)

As teacher J.C. reiterated a number of times, she always tries to get pupils to apply the knowledge they have acquired. In that sense, most activities she develops with her pupils do not focus on the phenomena themselves, but rather on ways phenomena can be made useful or amusing. It is noticeable that she tries to skirt round the subject of 'sound' as a phenomenon of interest, by switching the argument and talking in terms of musical instruments, and applications for those instruments, rather than for the phenomenon of the generation or travel of sound itself.
To summarize, an ordinary and frequent phenomenon can be difficult for a teacher to make remarkable, because it needs to be presented in a particularly unusual, striking way to catch pupils' attention. If it happens that this phenomenon is itself exciting, it may be difficult to find a way to present it that is instructive as well as interesting and attractive. The ability to juggle with these ideas in order to choose or design appropriate media to impart the information intended is an important feature of teachers' strategic knowledge.

2. The Scientific Ways to Represent the World

One type of information to be expressed in teaching science is the actual concepts of science. We may think this is what is meant when a teacher says, for instance, that she aims to get the vocabulary out of pupils (CP2.13-8, above), or another explains that talk-back sessions are...

an opportunity for me to reinforce the key principles of that session about load bearing, or strength, or centre of gravity, or whatever it was. It's a chance to reinforce that and to try and hope that the children got that.

(MK2.204)

These, however, are rather ordinary ways to communicate ideas. This Thematic Investigation has helped to reveal the fact that primary teachers also use other 'languages' apart from the transmission type exemplified above. It has been interesting to note that in doing so they introduce pupils to an important feature of science: its peculiar forms of representation.

Earlier, I mentioned the example in which scissors are used as units of weight and help to 'quantify' comparisons, associating numbers with physical differences between materials or objects (CP3.34). That is in itself a good example of how the message that measuring is a fundamental aspect of science can be articulated. In this way, young children get the message of what, say, the word ‘kilogram’ basically means - a message which they would otherwise either simply ignore, or recall only in its most incidental or accessory aspects which is . This attention to the expression of such messages according to the audience is critical, since the intention is that people should retain the essential aspects of them. Having said that, I must stress that the incidental aspects of a message are an indispensable part of it. Stephen Hawkin's's book *A Brief History of Time* illustrates this assertion cogently; at least one mathematical expression could not be omitted from it: Einstein's equation (\( E=mc^2 \)).

I have chosen two further cases to exemplify ways in which the primary teachers
communicate with children, and seem subliminally to impart the idea that to represent something that has been observed about a phenomena is itself part of what science is all about. In the first case, the teacher considers that she is stimulating children to predict, as she works through the processes of science. I consider that she is actually making children develop yet another skill: to work with representations of actual objects such as light bulbs, and, indeed, abstract entities such as the notion of electric circuit. In the second example, the teacher says he is using an analogy to help children see something they cannot look at. I consider that he is actually introducing his pupils to the use of conceptual (Mayer, 1989) or consensus (Gilbert et al., 1995) models.

Teacher C.P. and I talked at length about a 'prediction sheet' she had asked children to fill in. Basically the children had to mark a tick or a cross beside each one of a series of drawings in which a bulb is in contact with a battery. The tick or the cross showed whether or not, in the children's opinion, the bulb would light in each situation. I am presenting here only the main points of our conversation. To aid this presentation, I reproduce in figure 13 one drawing as it appears on the prediction sheet in question.

When I first saw this picture, I was puzzled by the black stripe where the line representing the wire touches the bulb. I wondered - and said so to teacher C.P. - whether or not she wanted to draw children's attention to a piece of electric insulator at that spot. I wanted to know if she had drawn the black stripe on purpose or by chance, and, if it had been on purpose, what (pedagogic) importance she attributed to noticing that piece of insulator. She said it had been on purpose and, more or less, explained what she intended by the activity.

Teacher: I'm wanting them to see that, because it's a part of the bulb... and it doesn't actually work when you touch it. And it's important that they realise that.

A.V.: Were you disappointed that they didn't see it.

Teacher: Well... this is the first time they've done it. So... they need a lot more practice on it, because they're not... looking, they're not following the instructions very effectively. So,
many of them... they didn’t look to see that the wire was actually just touching the top of the battery. They touched the bulb. They’re not, they’re not looking.

A.V.: What’s the conclusion you draw from that?

Teacher: They’re not very good at following instructions. They’d be dreadful at English. (Laughs) Um. [pause] We need more repetition or something like it. We need to look quite carefully at where the wire is going. (CP2.181-7)

It is evident from what she says that the intention was to skirt around practical snags that might jeopardize the pupils’ task which was to use their understanding of what an electrical circuit is in order to tell whether or not the filament of the bulb is part of one such circuit. In other words, teacher C.P. is concerned with the concept of a circuit. This becomes even clearer when she emphasizes that pupils "are getting in tune with where this wire actually does have to touch [because] there's specific places where the wire has to touch so it will work" (CP2.189). As far as I am concerned, the activity in question will, in all likelihood, give the pupils a conceptual understanding of what a circuit is. To put it another way, I would conduct this activity exactly as teacher C.P. does, to get pupils to develop the concept of electric circuit. In that sense, the gap that I notice here between teacher and teacher of teachers concerns the question of representation which I mentioned earlier.

Teacher C.P. does not seem to be aware of it, but, to me, she is actually doing a second and equally important job as she struggles with children’s difficulty in seeing precisely where the tip of wire is touching, or what a drawing actually shows. I think that in doing this with this degree of care, teacher C.P. sows the seeds science educators would like to see sown in the primary school. Her pupils are clearly learning to deal with representations. Without going any further into this issue, I would just like to support this conclusion with one last excerpt from our discussion, where teacher C.P. expanded on the exchange of drawings between pupils; incidentally, these were drawings made by the pupils themselves.

A.V.: What about when you asked them to swap drawings, to test their colleagues?

Teacher: That’s when they came up with the fact that it didn’t work and I said, "Why not?" And the ones who were testing it weren’t sure why, but the ones who did [the figure], when they were watching their friends do it, realised it was because their drawings were inaccurate.
A.V.: And were they able to...?

Teacher: Oh, they were able to fix it like that! Because when they showed them to me and so-and-so came up and said, "That one didn’t work. That one didn’t work. That one did. That one did." I said, "Well why don’t they work?" And they said, "Oh, I don’t know." But the person who drew them said, "It’s because - look miss - I haven’t put the wire in the right place." Because they could see their friend putting the wire down there when it ought to have been up there. And so they could self-correct themselves.

A.V.: Right. So what effect did you expect the swapping to have on them? To get it right?

Teacher: Yes, because otherwise they would just assume it was fine. They hadn’t checked it themselves. Where they’ll check it themselves on another one. They’ll say, "Yes it works." And you’ll say, "Are you sure?" And you’re looking at this thing and there’s no way it’s gonna work. (CP2.190-201)

These episodes teacher C.P. describes leave no doubt in my mind about the importance of what she is doing in terms of communication in science. The whole strategy is about exchange of information and cross-checking of representation and of interpretation of the representation itself:

* get pupils to place elements of a simple electric circuit in different dispositions;
* draw pictures of the elements in these dispositions;
* send these pictures to colleagues asking them to tell which drawings correspond to circuits;
* check the reasons for their colleagues’ failures;
* correct the drawings when that is the case.

The constant comparison between target system (bulb, battery, wire set) and its representation seems an invaluable training in terms of learning to use scientific notation, not to mention its value as a way of discussing circuits simply for the purpose of communicating the concept of a circuit to pupils.

3. The Use of Analogies

I will now go on to the second case that exemplifies ways in which primary teachers can subliminally impart the idea that learning to represent an observation about a phenomenon is part of a science education. In this example, teacher M.K. says he
is using an analogy in order that children may see something that is actually invisible: light beams. My argument is that he is actually preparing his pupils to be introduced to conceptual or consensus models such as those of light ray and wave motion. Here, again, the dialogue was long. The first thing to note is that teacher M.K. affirmed that he had set out to get pupils to understand the laws of light reflection:

A.V.: You asked them to draw the beam path and you were very careful on asking them to do it properly using rulers etc. At what were you aiming then?

Teacher: For them to have an understanding of how the reflection... how they can predict the path of the light so that they could place the mirror in the correct position in order to reflect the image in all three mirrors. So they would have an understanding, being able to predict the angle of approach and the angle of reflection. (MK2.9-10)

Prediction comes in, like in the case of teacher C.P.'s prediction sheets, as the final stage of the process, after preliminary activities whose main aspects were observation, use of new vocabulary, raising of hypotheses etc. The logic seems to be that pupils will be able to predict if they have understood the subject, and, if they have not understood, the teacher has a chance to put that to rights. I wanted to make sure that his reasoning was in fact as I imagined, and so asked teacher M.K. what is necessary for him to get that understanding over - for him to get pupils to predict the angle of approach and the angle of reflection correctly and so place the mirror in the correct position. As he replied to my question, he introduced the subject of analogy into the conversation:

Teacher: There are two points. The practical aspect of them experimenting with the actual physical movement of the mirrors. So, to see if they could actually do that. Then, I also tried to use the analogy of the snooker ball, if you remember. That was because I felt that was something they might had encountered. So, I tried to place that in their own learning. If they had had a real understanding of that, I thought, that might have helped them to actually put that into practice.

A.V.: Fine. Let's take the snooker ball as an example. What was your aim? Why use something different from light at that time?

Teacher: Because I felt that... Because they can't actually see. Because we couldn't get into a complete dark room. Because I couldn't show them a beam of red light or something. Because they couldn't actually see it, I needed to give them the closest an example as I could to try and make sure
that they had a good understanding of that reflection of light. (MK2.14-6)

So, at first sight the resort to analogies seems to be a question of material availability. The teacher seems to know the laboratory experiment in which a light beam is cast by, say, a laser projector. It is not clear whether he has experienced this activity or not, but he seems to believe that it is an effective way to show a light beam. However, he does not have the equipment, and so looks for an alternative solution. As he searches for an alternative way to illustrate what a light ray is, he abandons the simple sight of light beams the laser projector makes possible and turns to an alternative that involves less of the sense of seeing and more of the rational construction of light rays. This is a resort science teachers have to use all the time for the same reasons that this primary teacher uses it. He contended that, as a teacher, you often have to try and pick an example that pupils have encountered, so I asked:

A.V.: Why do you think it works?

Teacher: Because they will be able to translate something they know to another experience. So they will be able to use that experience they’ve had to explain something new. (MK2.23-4)

The use of the word ‘translate’ could not be more cogent as evidence that the issue is one of communication theory and semiology. The value of this example is not that the approach is innovative and unprecedented; as I said, science teachers use analogies all the time. Indeed, the snooker ball analogy is perhaps the commonest analogy of all for reflection. Nevertheless, it is interesting that the example and these arguments come from a primary science teacher. Teacher M.K. seems to have assimilated something of the culture of science teaching. Moreover, like most science teachers in this respect, he seems unable to articulate his strategic knowledge in clear terms, explaining his ability to find a good analogy in terms of his experience, placing the matter within the intuitive domain of his professional knowledge; though the word ‘intuition’ is not actually used.

A.V.: How are you able to find this example?

Teacher: Ah... I think partially by guessing, partially by asking them what experiences they had, partially by drawing on the experiences that I know they’ve had. For example they have... There is a computer game that they have played with a snooker ball that has to do with angles in Maths. So that I knew that lots of them have encountered that game. So, that was a real experience I knew they have. (MK2.25-6)
It may seem remarkable that this primary teacher is able to articulate:

* his assumptions about the process of comprehension of the phenomenon;
* the information about pupils on which he draws;
* the repertory of 'signs' from which he could select those which are necessary for him to articulate the message to be imparted.

Although the capacity to express them clearly may not be common, I do not think that the abilities listed above are particularly rare. To reveal such abilities is a matter of having the opportunity to analyse with the help of particular theoretical frameworks such as that of communication theory and semiology.

4. Follow in Scientists' Footsteps

Apart from demanding some understanding of scientific concepts, Science in the National Curriculum has also established that pupils have to know the scientific process of investigation (AT1, DES, 1991). Concepts, the products of science, are different in nature from science processes. Considered as two different 'objects of communication', products and processes require different languages to be conveyed to pupils. In terms of school teaching, this means that they need to be developed through different kinds of activities; the NCC expresses it thus:

Some activities are more effective for developing one type of understanding than another. For example, conceptual understanding may be best developed through direct teaching and illustrative practical work. Investigations can be used to develop knowledge about procedural understanding (NCC, 1993, p. 6).

Teachers in my study have declared a lack of content knowledge. This lack of conceptual understanding, however, has not prevented them from finding their way through science lessons where processes of science need to be imparted. If they find it more difficult to teach concepts than to develop knowledge about procedural understanding, this is apparently due to the 'kind of activity' they prefer to develop. That is, it is due to the choice they make of the type of 'language'. Conceptual understanding is sometimes best imparted through direct teaching and illustrative practical work, which is exactly the sort of practice they reject (see Themes 1 and 2). So, teacher J.C., referring to a 'range of fuels' (JC2.148-50, heading 1 above), teacher L.P. when she first considered 'forces' and "could not see where she would go with it" (LP2.95-102, heading 1 above), and many others in similar examples, while showing their discomfort with having to 'deliver' a concept, demonstrate the effort they make to address pupils in more investigative
ways. In that sense, it is interesting to compare the different attitudes the teachers have in face of some of the statements of attainment in the National Curriculum.

Here are two such statements that are shown to have been interpreted in quite opposite ways by my teachers:

* Pupils should be able to describe the apparent movement of the Sun across the sky (AT4, level 1, DES, 1991, p. 6).

* Pupils should interpret findings by associating one factor with another, for example, the pupils' perception at this level that 'light objects float' (AT1, level 2, DES, 1989, p. 3).

As regards the apparent movement of the Sun across the sky, teacher C.P. developed, as mentioned earlier (Theme 4), an activity where a piece of scientific knowledge resulted from concentrating on scientific process. "Where do you think the Sun will be when we come out in an hour?", she said she asked the pupils after drawing the shadow of a child standing on a cross on the ground at various times during the day, over several days (CP2.129). Her pupils saw that their classmate's shadow had grew smaller and smaller, then bigger and bigger as the Sun, which was low early in the morning, got quite high and then quite low again. So they were able to predict with some accuracy where the shadow would be. Teacher C.P.'s objective was for pupils to know that the altitude of the Sun changes in a regular and predictable manner (AT4, level 3, DES, 1991, p. 6), yet she did not tell them anything; she did not explain anything to them. What she did was to ask them to observe and try to explain the regularity of the changes. So, it was by exploring with their teacher the phenomenon in question, that the pupils gained an understanding of it. In contrast with this case, is this statement made by teacher L.P.:

A.V.: You mention the Sun moving in the sky, but already putting the Sun as the centre of the Universe, rather than seeing the sky as that thing, that blue thing over there, and asking them to just notice the changes the Sun goes through during the year, or along a day, changes on the position of the Sun. Why don't you look at the shadow on the ground, or something, which, it seems to me, is what the National Curriculum Attainment Target 4 suggests for Level 1?

Teacher: But with the passage of the Sun... That one [pointing to the window]? I think that's very difficult...

A.V.: Oh, it is, yes. And is it not for Level 1, Key Stage 1?
Teacher: Mm.

A.V.: It seemed strange that you find it so absurd... because it could be just that, just for them, um...

Teacher: I think it was the passage of the Sun bit that, I mean, I can, I, I, I still think that it's a very difficult concept to expect five-year-olds to understand.

A.V.: But you just said that you want them to be inquisitive!?

Teacher: That's right, to find out for themselves. On the other hand... um... you can't expect them to keep reinventing the wheel... (LP2.137-46)

Here teacher L.P. changed the drift of the conversation away from the apparent movement of the Sun, moving on to a series of statements which, incidentally, have already been discussed (Themes 3 and 4). I tried to return the conversation to that subject:

A.V.: So you wanted to get off the stream of people who just say things and give pupils [opportunity to have] hands-on activities... On a subject like the Sun and the sky, can't you put them, their hands-on?

Teacher: Not a lot, no. Not the Sun in the sky, no! [laughs]

A.V.: Why?

Teacher: Well, I mean, I, I give, as I say, I give, you know, I've got visual aids for them to do it, but I mean, I still think it's-

A.V.: But what about the actual Sun?

Teacher: No, they can't actually do that, can they? [pause] I've got to tell them that it's made out of fire (LP2.149-54).

Apart from the unlikely possibility that teacher L.P. understood 'hands-on' literally, what this case illustrates is that the teachers may find it impossible to attain a particular curriculum target when they construe it in only one way. In this case teacher L.P. could conceive of the Sun passage across the sky only as a piece of knowledge. Moreover, it seems that in her opinion the only way to impart this knowledge is by direct instruction. It is interesting to note that teacher L.P. started the conversation that followed between us with the following remark:

Teacher: I was talking to the staff about the passage of the Sun across the sky, and they all agreed it was the most stupid attainment. They said it's such a difficult concept for the children to get. And the National Curriculum says the 'apparent movement of the Sun'. So, that kind of puts a different slant on
it as well, doesn’t it...

A.V.: Oh, yeah...

Teacher: ...and so they all said that that’s what they felt was the most difficult thing, and they didn’t even think that year three got it. (LP3.2-4)

This initiative demonstrates that our previous encounter had been challenging. In fact, challenging enough to generate reflection and an exchange of ideas with peers but not sufficient to raise teacher L.P.’s level of consciousness. The excerpts above show that she holds a naive transitive consciousness (chapter 2, section D) about this issue. This is obvious from her use of slogans; for instance, when she says the topic in question was the most stupid attainment target; and also from the fact that she comes back to the issue only to express little hope that people’s attitudes regarding this attainment target can possibly change. This situation is archetypical of the kind of challenge teacher educators working on INSET programmes have to face; particularly those teachers of teachers who are subject specialists. Precisely because it is such a typical situation, it illustrates well how much Freire’s theory of education and pedagogy gives insight into and provides solutions to these challenges faced by teacher educators.

The case I have reported here illustrates the fact that simply offering teachers an alternative at the level of discourse is not sufficient. It illustrates the fact that simply challenging teachers’ propositions is not sufficient. It illustrates the fact that the provision of content knowledge to non-specialist teachers would not in itself bring about a change in their attitude towards the teaching of science. Above all, this case shows that neither giving emphasis to teachers’ wisdom of practice nor imposing the accumulated knowledge of science educators as regards children’s learning, and as regards the practices of ‘good teachers’, are answers to the question of teachers’ professional development. What is needed is the adoption of a radical-democratic stance (chapter 2, section C) and promotion of a dialogical type of teacher education. I will illustrate, in the next chapter, how I would attempt to devise a teacher education programme substantially based on these ideas of Freire.

SUMMARY OF ANALYSIS OF TEACHERS’ DISCOURSE

Drawing on Freire’s Method to de-code the professional reality of primary teachers of science, this Thematic Investigation has allowed me to propose a host of themes capable of generating teachers’ meaningful reflection. The use of Kelly’s Repertory Test has been useful in that it has helped me to be provocative and
challenging without necessarily confronting teachers. In other words, this methodological approach has afforded me the opportunity to avoid being a neutral observer, and to 'problematize' propositions made by the teachers. In this way, I could get to know how they perceive their experience and reality; even though my enquiry was not based on a previously established research agenda. Indeed, a number of dilemmas felt by the teachers emerged during the dialogical process, almost of their own accord.

The complexity of the teachers' narratives is noticeable. Moreover, in their discourse there was a constant resort to metaphors, analogies and descriptions of cases, as well as the expression of propositions, beliefs, assumptions and ideas. My own recourse to the Tetrahedron of Principles has helped me to deal with this complexity, directing my attention during the analysis of the transcripts.

Hence, a summary of the outcome of this investigation of the teachers' discourse will certainly be helpful, in that it can function as a sketch of the complex whole I attempted to describe here: teachers' strategic knowledge. The following paragraphs thus outline the results. In the next chapter (section B), however, I offer a more detailed discussion of the themes proposed here. These themes, presented in this chapter as meaningful for the teachers, are scrutinized in the next chapter, so that we may consider the extent to which practising teachers' ideas relate to the formalized ideas generally discussed and proposed by science educators. In other words, the themes selected from the strategic knowledge of primary teachers will be codified in terms of my formalized knowledge of education in general, and of matters concerning science teaching in particular.

Starting with themes 1 and 2, 'Discovery Learning' and 'Direct Instruction', it is interesting to note that, although I have proposed them here as separate themes, some of the teachers consider them as two sides of the same coin. Apparently, the teachers have grown critical of the progressive education movement (e.g. Walberg et al, 1971) of the sixties and seventies, but, nevertheless, still maintain some of the criticisms this movement itself had with regard to instruction. A return to the practice of sitting children in rows and asking them to recite over and over again some theory or piece of information is ruled out by the teachers. Yet, the teachers clearly seek an alternative form of instruction in view of the current demands that children be given a broad knowledge base. Moreover, the imposition of regular assessments of achievement, recently introduced, has made the teachers afraid of pupils failing knowledge tests. These latter factors seem to have created a climate of anxiety amongst the teachers which, in turn, has led them to wonder about the
value of teaching children by problem-solving methods. Their experience has
shown that children's learning and general attitude towards school knowledge
profit from inductive approaches. However, with their own self-esteem low,
teachers seem to bow to arguments for the imparting of skills and knowledge and
have lost a bit of their former impetus to develop self-confidence in children and a
positive attitude to learning. In the next chapter (section B, subsection 1), I discuss
these themes in the light of propositions about learning found in the literature.

The second pair of generative themes proposed can also be considered together.
'Scientific Knowledge' concerns the products of science, while 'Scientific
Enterprise' concerns the ethos of science. The teachers acknowledge the fact that,
at the same time as it produces facts and ideas, science also generates methods of
enquiry and research. Incidentally, the National Curriculum also emphasizes this
fact, and presents one separate attainment target for scientific processes. It is,
however, the nature of the products of science that does not seem to be clear to
some volunteers for this study. The notion of truth with regard to scientific laws
exemplifies this. As we see in the discussion of themes 3 and 4, the primary
teachers seem to swing between a kind of reverence for the dictums of science and
a certain degree of scepticism about it. This mix of awe and apparent contempt
tends to jeopardize the teachers' efforts to improve their practice, which, in turn,
annoys them. This contradictory attitude is accompanied by a certain difficulty in
separating two different objectives: that of giving children knowledge about natural
phenomena and that of giving children knowledge about science, that is, human
beings' knowledge about nature, certainly an important theme with regard to
science teaching. More about this in the next chapter (section B, subsection 2).

To talk about the Theme 5, 'Thrust of Teaching', is to talk about values held by
the teachers. The same applies to Theme 6, 'Children's Diversity'. Some of the
teachers did not need to be asked to lay bare their educational values, the reason
for their choice of teaching as a profession. These teachers talked about their
hopes and expectations as people talk of their vocation: with a certain passion and
even pride. This has sometimes raised themes which are clearly difficult to discuss.
A young teacher's urge to teach might seem naive to an experienced teacher. One's
motivation might have political tones which do not match those of the school.
However, these difficulties do not lessen the relevance of such themes. They can
reveal values which the teacher has not been aware of having. Equally, they can
prove to be in contradiction with the teacher's attitude towards other issues.
Indeed, with regard to the teaching of science, primary teachers may well have
values which are, in fact, at cross-purposes with those of science experts and
curriculum designers. Moreover, some attitudes and values have a bearing on very practical measures, such as coping pragmatically with children's diversity of background, ability and interest. In the next chapter (section B, subsection 3), I refer to the literature on 'primary ideology' to discuss such aspects of Themes 5 and 6.

In section B, subsection 4 of the next chapter, I discuss the relationship of Themes 7 and 8 to some of the themes already presented. Theme 7, 'Elements of Communication in a Teaching Process', refers to issues particularly relevant in the teaching of science. Teaching is a peculiar form of communication since pupils interact with many sources of information and do so through different channels of communication. The teacher is just the most obvious interlocutor to communicate with pupils. Besides, pupils' interlocutors may also be books; a computer; pieces of wood and a tube of glue; wires, batteries and light bulbs; a tank full of water and a host of different objects to be put in it; an instrument such as a thermometer, a clock or a scale. What each alternative represents in terms of the message being transmitted, is worth discussing; after all, it is ultimately the teacher who sets the alternatives up. Each type of interaction involves a particular means of communication. One of these options might be excellent for transmitting certain messages about science, but not every message lends itself equally well to any one such means. Pupils' verbal communication skills, for instance, might be poor, but their handling of experimental apparatuses could bear witness to their capacity to manipulate variables or hypothesize.

An awareness of the intervening elements of such processes of communication is incomplete, however, without a reflection on the subject of Theme 8: Schemes for the Articulation of Messages. Teachers articulate these schemes bearing in mind the frame of reference within which children will be able to determine the meaning of such a message, whether the aim is:

* to introduce new vocabulary;
* to improve pupils' usage of it;
* to give an explanation;
* to provide pupils with first- or second-hand practical experience; etc.

If the teachers use an analogy in an explanation, it is because they know the children are familiar with the referent chosen. If a topic lends itself to practical experiments, the teacher might choose this approach to introduce that topic. Similarly with regard to carpet discussions, school outings and many other
approaches. However, this intuitive semiological judgement teachers possess may, at times, backfire.

In the case of drawing on an analogy to introduce a concept or phenomenon, for example, a teacher may not be aware of the fact that pupils may take into consideration features of the referent which do not apply to the concept or phenomenon in question. This transference might result in pupils developing a misconception about the topic. Likewise, in trying to conduct practical experiments for each and every topic of science, teachers may get into hot water. Unexpected outcomes and pupils' questions about these outcomes might undermine a delicate process in which the experiment played a key role. All these occurrences were reported in the course of this study, which means that the corresponding themes were found in the teachers' discourse. Thus, even though no reference to terms like 'coding', or 'interlocutors', or 'channels of communication', or anything of this kind was ever made by them, these are the terms I use to express the way I perceive the themes I notice running through the discourse of the teachers.

To summarize, this Thematic Investigation has yielded themes which conform with the common view of 'primary school ethos'. Primary teachers' heuristic approach to teaching is very much geared towards 'child-centredness'; it is here that feelings such as excitement, enthusiasm and 'competitiveness' are clearly demonstrated as having a key role in the teachers' construction of pupils' learning. These teachers' attitude of care, concern with issues of fairness, and attention to the different learning paces of pupils, are observable both in their propositions about education and those about learning, especially in the teachers' conventional approach to this. In relation to the nature of science, these primary teachers have shown a mixture of respectful submission and latent rebelliousness which, to some extent, signals a somewhat stereotyped view of the scientific enterprise, which is certainly common among the general public. Finally, the communication that takes place in the classrooms usually gives priority, according to these views and propositions, to practical experiments or constructions, analogies, and playful (ludic) activities. In other words, primary teachers seem to avoid attempting the communication of intellectual models (which their secondary school counterparts do) and value, instead, situated cognition.
CHAPTER 5

REFLECTIONS ON THE CONTRIBUTION OF FREIRE’S WORK TO TEACHER EDUCATION: CONCLUSIONS AND IMPLICATIONS

A. Overview

B. Generative Themes of Science Teaching
   1. Generative Themes Relating to Learning
   2. Generative Themes Relating to the Nature of Science
   3. Generative Themes Relating to Educational Aims/Values
   4. Generative Themes Relating to Communication

C. Scope and Limitations of Freire’s Contribution to Teacher Education

D. Proposal of Dialogical Teacher Professional Development

E. Conclusion
A. Overview

This work has attempted to describe practising teachers' strategic knowledge, within the domain of science content knowledge in teaching, in relation to science educators' formalized knowledge. At an abstract level, the thesis has attempted to look at four general issues:

a) the distance between theory and practice in teaching;

b) the distance between theory and practice in educational research;

c) the problems of elicitation and development of professional knowledge in teaching;

d) the differences and the similarities between the discourse of practising teachers and that of science educators.

My discussion of the specific aspect of professional knowledge studied in this thesis is based on an empirical study of primary teachers in England and Wales post-National Curriculum. In chapter 1, I have characterized the problems of eliciting and developing professional knowledge in teaching and proposed that issues related to teachers' thinking and action could be studied in the same way as Freire studied the vocabulary of people, when his goal was to teach them how to read and write. Chapter 2 describes Freire's method and discusses his premises as well as his principles. Thus, in part I of chapter 3, I set forth a way of thinking about the concept of strategic knowledge (Shulman, 1986b, p. 9a) inspired by Freire's philosophical framework.

I designed my empirical study according to Freire's methodological strategy but adapted it to take account of the fact that teachers' strategic knowledge is different in nature from labourers' vocabulary (chapter 3, part II). My methodological approach combines Freire's concern with people's feelings, when they are challenged or face adversities, with Kelly's Repertory Test and its mechanisms for allowing issues for discussion to arise and, at the same time, posing problems as regards people's constructions related to these issues. The empirical analysis consists in a Thematic Investigation of teachers' discourse.

In practical terms, I started with questions about the communication between teachers and science educators. I asked the teachers about the implementation of the science curriculum, particularly as regards topics of physics. This resulted in the teachers providing a series of precedents, anecdotes, allegories and propositions. Through these, I was able to look at strategic knowledge as an entity
which is:

* socially bound;
* historically situated;
* subject to the emotional states of individuals;
* where thinking is inseparable from action.

A total of approximately 28 hours of interviews constitutes the main source of data. Nine teachers were interviewed: six of them were met in three sessions each; the others twice each. Sessions lasted at least one hour. The first session was used to conduct a Repertory Test, the following two were used for discussions about semi-qualitative scores which the teachers attributed to aspects of their experience in order to characterize this. The enquiry was conceived as a process of confronting seemingly internal incoherences and potential areas of external tension appearing in the discourse of the teachers.

Reflection thus became a collaborative enterprise. The individual teachers were thinking about personal and often idiosyncratic propositions and exemplary cases. As the collaborative researcher, I was acting as an ‘other’ - someone who, being knowledgeable of formalized propositions, established and documented patterns of action, could challenge these individuals, problematizing their ideas and their interpretation of teaching.

A goal of trying to reach an understanding in this dialogue was set, leading its interlocutors to think explicitly about elements of the pedagogical discourse which are usually taken for granted. This gave me, as the researcher, the chance to describe the themes running through the teachers’ discourse.

The data is mainly qualitative. The analysis of verbatim transcripts of dialogues looked at the discourse of all the teachers together from four perspectives: propositions about learning, about the nature of science, about educational aims/values and about communication. The issues concerning the analysis were discussed in chapter 3 (part II, section D).

The resulting eight themes concern propositions and strategies for teaching science in primary school. I would now like to discuss their relationship with the complex and more abstract issues mentioned at the beginning of this overview. This entails looking at teachers’ strategic knowledge in relation to formalized knowledge structures. Later, I discuss how these themes can be used as Generative Themes in a dialogical programme for the professional development of teachers.

CHAPTER 5

CONCLUSIONS
B. Generative Themes of Science Teaching

In the course of this study, I have considered the following themes found in the teachers' discourse to be meaningful for primary teachers and relevant for them to reflect on and discuss with experts:

Theme 1: Discovery Learning
Theme 2: Reception Learning
Theme 3: Scientific Knowledge
Theme 4: Scientific Enterprise
Theme 5: Thrust of Teaching
Theme 6: Children's Diversity
Theme 7: Elements of Communication in a Teaching Process
Theme 8: Schemes for the Articulation of Messages

I would now like to consider the relationship between these themes and formalized propositions, as well as between these themes and established or documented patterns of action. I want to show that these are also Generative Themes.

The previous chapter has illustrated the range of themes to emerge from interviews. During the analysis of interview transcripts, the intention was to identify two areas of tension:

* First, the seeming contradictions between the teachers' practice and the rationale for conducting or interpreting this practice as they do.
* Second, the possible friction points between the teachers' own rationale and practices and that of science education experts.

In that chapter, the purpose was to provide a descriptive analysis of the discourse of a sample of teachers (as stated in chapter 3, part I, section B). Here, I consider the themes in terms of the role they can play when used to generate reflection among teachers. The challenge therefore is to characterize these themes as issues primary teachers and science educators in general could discuss with each other - issues concerning the teaching of science which both parties would consider worth contemplating together.

1. Generative Themes Relating to Learning

Two themes relate to the topic of learning. They are:
Theme 1: Discovery Learning;
Theme 2: Reception Learning.

The analysis of the teachers' discourse on this topic shows primary teachers' support of, respect for, and above all, care for children. It seems clear that these teachers, being first and foremost attuned to children's curiosity, try to engage them in their own learning. At times, it even seems that reasoning is disdained as a pedagogical aim. Instead of being committed to getting pupils to learn, the teachers seem more concerned with captivating, conquering children's sympathy towards, for example, topics in physics. Apparently, therefore, reasoning is being closely associated with eagerness and emotion. Where the teachers concentrate on the emotional rather than the rational traits of the child, their intention is to build the child's confidence with a view to developing its powers of reasoning from a sense of engagement with the topic of study. This picture corroborates accounts of primary teachers' 'culture' given by academic researchers and educational officials in England and Wales.

The Plowden Report, prepared by the Central Advisory Council for Education (England) (CACE, 1967) makes a good point of departure to illustrate the fairness of this proposal of meaningful themes made here. When considering primary school science, the council endorsed the approach adopted by the teachers who tend to concentrate on the methods and techniques whereby discoveries can be made by pupils.

The treatment of the [science] subject matter may be summarized in the phrase "learning by discovery". In a number of ways it resembles the best modern university practice. Initial curiosity, often stimulated by the environment the teacher provides, leads to questions and to a consideration of what questions it is sensible to ask and how to find the answers (CACE, 1967, paragraph 669).

It is reasonable to argue that a number of propositions made by primary teachers today have their roots in the recommendations of that report. What these teachers say about learning resembles what Plowden and her colleagues recommended as a result of their survey; for instance, that "finding out has proved to be better for children than 'being told'" (para. 1233). The Plowden committee recognized that this involves a great exercise of judgement on the part of the teacher, as well as the use of high-level cognitive interaction with pupils. As they said, referring specifically to science:

The teacher will miss the whole point if he tells the children the answers or
indicates too readily and completely how the answers may be found, but he must not let them flounder too long or too helplessly, and can often come to the rescue by asking another question (CACE, 1967, paragraph 669).

As seen in the previous chapter, the theme "Discovery Learning" came up many times in the discourse of my volunteers. The same theme also appears in other academic studies. One such study is the Ford Teaching Project. The researchers working in it, according to Galton, Simon and Croll (1980), found that, in project work, for example, teachers tend to encourage pupils to explore ways of collecting and organizing information (Elliott, 1976). This perception has been reinforced by Galton and his colleagues, who report the findings of another study: the Observational Research and Classroom Learning Evaluation (ORACLE). This large-scale observational study of primary school classrooms was carried out in Britain over the period 1975 to 1980. The ORACLE team noticed that an important element in persuading pupils to acquire the skills of collecting and organizing information was for the teacher "to refrain from imposing her ideas too quickly on the class" (Galton et al., 1980, p. 135). As the interview excerpts show, for instance under the heading "'Hands Off' Teaching for 'Hands On' Learning" (theme 1), this was precisely the discourse of volunteers in this study.

The opinion of teachers may be contradicted in practice. Galton and colleagues, for instance, observed that teachers widely implement one aspect of 'progressivism', as prescribed by Plowden: individualization. However, central to Plowden's thesis is the questing, exploratory character of the individual child's actual activity - the emphasis on discovery methods, on finding out for oneself - while the teacher is seen as stimulating this activity by probing, questioning, guiding - leading the child from behind. It is here that ORACLE data shows that classroom practice does not match theory.

Individualized teaching (or interaction) is not 'progressively' oriented, in the sense of Plowden thesis; it is overwhelmingly factual and managerial. Such probing and questioning as does take place is to be found largely in the whole class teaching situation... paradoxically, the teaching situation popularly held to be best adapted to didactic teaching (telling) (Galton et al., 1980, p. 157).

This contradiction was also revealed by the present Thematic Investigation. Teachers, when it comes to stimulating pupils to discover by probing, questioning and guiding, encounter a number of hindrances. As discussed above, the theme "Receptive Learning" becomes highly relevant when the teachers consider how to overcome those hurdles as well as how to comply with present demands for
national uniformity of teaching standards and pupils' achievement. Not surprisingly, the relevance of this theme is even greater in the opinion of educational authorities. A recent report by the Office for Standards in Education (OFSTED, 1995) has expressed concern at the extent to which "Reception Learning" is, in practice, negated by primary teachers.

Why is it that in too many primary schools 'learning by doing' is preferred to 'teaching by telling' to the point where sitting pupils down and telling things becomes almost a 'marginal' strategy? (OFSTED, 1995, p. 7).

Such concern reports back to the 'great debate' that took place in England in the seventies (Cox et al, 1971; Bennett, 1976; Callaghan, 1976; DES, 1978). Therefore, the present situation, expressed here through my volunteers' allegories or anecdotes, and about which OFSTED reports, unfolds out of events whose analysis is beyond the scope of this study. However, it is important to mention these controversies here, since primary teachers in England and Wales are still experimenting tensions raised by those past events. The fact that these tensions are expressed in the discourse of my volunteers shows that they are relevant to these teachers. Moreover, this fact reinforces the probing power of Freire's strategy of enquiry that in the final analysis revealed these aspects of such 'primary culture'.

The literature cited above is evidence that "Discovery and Reception Learning" are meaningful and relevant themes for primary teachers. To be taken as generative themes issues have to be meaningful and relevant. However, that is not enough. The intention is that generative themes should stimulate teachers to reflect on theoretical propositions about teaching which science educators put forward. Thus, these themes need to point out areas of conflict as well as areas of overlap between the 'ideology' or 'culture' of primary teachers and that of science educators. Or, to paraphrase Alexander when he uses the concept of ideology in speaking of 'primary ideology' (Alexander, 1984, p. 14), these themes need to provide the opportunity for teacher educators to bridge the gap between the two distinct patterns of ideas. I want to argue that these two themes do that.

First of all, discovery and receptive learning, and their corresponding enquiry (inductive) and expository (deductive) teaching strategies, have long been both significant and distinct views in science education (Rutherford, 1964; Novak, 1979). These views need to be known by science teachers, not least because the products of science result from certain peculiar processes. Part of that debate relates precisely to whether or not science teaching should stress this fact and promote the learning of science processes as well as learning about the products of science.
Another reason for science teachers to debate these views is that there is some considerable confusion surrounding enquiry teaching. As noted by DeBoer (1991, p. 207), enquiry may be used in at least two different ways. On the one hand, it may be used to describe a specific aspect of the nature of science. On the other hand, enquiry can also be associated with a particular method of teaching. In the first case, enquiry refers to one process of science. Scientists follow particular processes of enquiry to generate what eventually become the products of science. Therefore, one of the aims of science teaching is to teach these processes, to develop in students an awareness of the skills needed to carry out a scientific enquiry. As a method of teaching, however, enquiry teaching is associated with a set of instructional practices and beliefs about learning that are inductive in nature. These approaches are based on the premise that students can be inquirers, that they can generate meaning by examining a variety of learning materials.

In conclusion, Thematic Investigation has not only shown that "discovery learning" and "reception learning" are meaningful and generative themes. This analysis of teachers' discourse has revealed that underpinning some propositions of the teachers is what has been described elsewhere (Alexander, 1984) as 'primary ideology'. Moreover, this analysis of teachers' discourse indicates at least three pairs of tensions between contrasting aspects of school learning; each pair consisting of a dilemma with which science teachers have to live:

* heuristic/reception learning;
* learning of products/processes of science;
* scientific enquiry as an inductive/deductive process.

Thus, Thematic Investigation has shown a 'primary ideology' and indicated that primary school teachers of science experience tensions similar to those experienced by other teachers of science. This fact strengthens the proposition that Freire's strategy of enquiry sheds light on the problem of science teacher education. Moreover, this fact indicates that generative themes related to learning are themes that can also generate reflection on other issues such as the nature of science, educational values or communication strategies.

2. Generative Themes Relating to the Nature of Science

Theme 3 (Scientific Knowledge) and theme 4 (Scientific Enterprise) concern dilemmas teachers face as a consequence of their views on the nature of science. In discussing these themes I have considered whether the teachers' conception of science, ideas about scientists, and about the product and the process of their
work, is complementary or goes against the grain of the corresponding views held by science educators.

I had no intention of providing an exhaustive account of teachers' related beliefs, nor an appraisal of the teachers and their views, by comparison with any established standard. My aim was to produce means of generating meaningful reflection and a common language between teachers and teachers of teachers. These means, I believe, will make a dialogue between these parties possible. Such dialogue probably will raise teachers' awareness of issues which are relevant and necessary for the enhanced practice of science teaching. The results of the Thematic Investigation give, in short, substance to the argument that Freire's work provides teacher educators with useful insights into teachers' ways of thinking and into their action - an insight that gives teacher educators the opportunity to enhance their own practice.

In spite of focusing on primary teachers' principles, maxims and other propositions in relation to the nature of science my impression still remains that their view of science equates to that of the public in general: a feeling of awe and a trust in the powers of science. Primary teachers are not educated the same way as specialist teachers. The latter are presented with what Kuhn (1970) calls scientific paradigms; those sets of procedures, facts, concepts, laws, ideas and premises which underlie the scientific thought of the time. As Smith, for instance, says:

While it is unlikely that elementary teachers will have knowledge of the history and philosophy of science, they often do have strong beliefs about what science is, how scientific knowledge becomes established and how it ought to be taught and learned (Smith, 1989, p. 4).

In other words, like any other citizen of a modern industrialized society, primary teachers are bound to have their own assumptions and conceptions concerning the work of scientists and, in fact, the whole scientific enterprise. These ideas may or may not comprise an integrated philosophy - that is, a coherent articulated logical position - yet they are bound to influence the way these teachers present science to primary school children.

In fact, the primary teachers interviewed in the present study have been forced to have a certain level of familiarity with science since they have been asked to teach it. Their practice, in that sense, might have been both an expression of their views about the nature of science, and a hostage to these very views. That, however, does not seem to be the case. The teachers' set of beliefs and assumptions does not
seem to correspond with that of those who, in the last analysis, determine the features of their practice: their peers, authors of textbooks, designers of the curriculum or prominent educators.

This Thematic Investigation has raised some issues which I believe will provide experts with a means to challenge primary teachers’ perception of this area of human activity and its achievements. My teachers have not sought to hide their lack of familiarity with the concepts, ways and means of science, especially physics. Neither have they tried to compensate for this with a display of pedagogical knowledge. However, they have actually showed that they suspect the superiority of the physical sciences as a complete area of exploration is a bit of a sham.

Caught between feelings of awe and mistrust, the teachers seem to be in a dilemma. On the one hand, they do not see the theories of science to be within their reach, or, by extension, within reach of their pupils. However, they strive to acquire the vocabulary and understanding which they are required to deliver within the curriculum; otherwise they feel they would be ‘cheating the children’. The themes proposed are therefore meant to challenge primary teachers to overcome their hesitancy. The idea of these themes is, first, to require teachers to consider their constructions of science as, on the one hand, special and, on the other, primarily concerned either with asserted truths or with critical enquiry (theme 3, subheading 1: Truth or Theories?). The second purpose behind these themes is to stimulate teachers to discover the source of their feelings of awe and inferiority towards science (theme 3, subheading 2: Whose ideas are these, anyway?). The third is to inspire teachers to strengthen their arguments for a particular way of teaching science in primary school (theme 3, subheading 3: Autonomy from the ‘Canons’ of Science). The fourth is to question teachers’ arguments for a ‘primary way’ of teaching science, making sure that the alternative does not mistake science for any other area of human activity (theme 4, subheading 1: Science or Technology?). The fifth is to ask teachers to move beyond their views about the teaching of science and really challenge them to express in greater detail their views about the nature of science (see theme 4, subheading 2: Content and Process).

3. Generative Themes Relating to Educational Aims/Values

The previous chapter contained two topics related mainly to teachers’ educational aims and values:

Theme 5: Thrust of Teaching
Theme 6: Children’s Diversity

In this present section, as in the last two, I will give my perception of what seem to be gaps, either between primary teachers’ and science education experts’ knowledge in teaching, or else between teachers’ praxis and their rhetoric about their content knowledge in teaching. This section is, however, distinct from the previous two precisely because of the nature of educational propositions.

Of all the principles primary teachers hold, their ones on educational aims and values seem the least flexible. Teachers present them cogently; as assumptions or commitments which stand as a kind of personal philosophy. Educational propositions seem to represent the sum of teachers’ moral, ethical, social and ideological values. These values may or may not be stated explicitly, nevertheless they clearly seem to guide teachers and help them set objectives appropriate to their pedagogic enterprise. Since the teacher’s propositions about education appear to be so closely related to moral, ethical and social questions, it is not surprising that there tends to be such a degree of sensitivity about this issue. When the teachers identified a model of education which they would rather avoid, they were straightforward in rejecting it. Consequently, challenging the teachers to reflect on educational propositions seemed to be quite difficult. It is not easy to ask people to reason about their own values. Consider, for instance, that according to Shulman’s description of types of propositional knowledge in teaching, educational propositions would be classified as norms:

Norms, values, ideological or philosophical commitments are neither theoretical nor practical, but normative. These are propositions that guide the work of a teacher, not because they are true in scientific terms, or because they work in practical terms, but because they are morally or ethically right (Shulman, 1986, p. 11a-b).

Like Shulman, I believe this kind of proposition to be at the very heart of teacher knowledge. However, I did not probe my volunteers’ thoughts or, worse, problematize their propositions in this area. I felt that might generate conflict between us rather than being a way to conduct a Thematic Investigation. I chose Freire’s strategy of enquiry because it would allow me to be challenging and provocative, which is not the same as generating conflict. In view of this, during the analysis of the interviews I did not make a point of searching for propositions of this nature. Notwithstanding, some allegories and anecdotes in the teachers’ discourse emerged as illustrative of propositions that are common to all teachers or at least to primary teachers. For example, some of these propositions were in
accordance with what is described as ‘primary philosophy’ (CACE, 1967) or ‘primary ideology’ (Alexander, 1984): to be concerned for pupils’ individualities; to care for the less able or the underprivileged; to be less concerned about the acquisition of knowledge than their secondary school counterparts; to be attentive to issues of the relationship of school with life as a whole; and so on.

In view of these findings I conclude that, despite the fact that educational propositions are developed mostly on moral and ethical grounds, there would still be room for reflection on the range of alternatives to one’s own personal propositions. In fact, I now think it is possible to stimulate teachers to perceive and understand the nature and origin of their values, which may be socio-cultural and historical. I suggest that the principle to follow in order to create this opportunity is the same as that which guided the design of this investigation.

I have argued (chapter 3, parts I and II) that teachers may be expressing the whole basis of their teaching when they talk about meaningful events in their professional life. I contend that this is possible because transitions in the development of a teacher’s strategic knowledge are signposted by episodes marked by emotions (chapter 3, part I, section C). In view of my findings, I am confident that, in programmes of professional development, the discussion of cases - such as prototypes, parables or anecdotes of teaching practice - with others would get teachers to reflect upon the socio-cultural and historical roots of their own personal values. As in Freire’s culture circles (chapter 2, section A), teachers may find educational propositions which are common to certain groups of colleagues and, therefore, stand out as indications of their shared ideology, regional origin, age, gender or other characteristics. Apart from enabling a teacher to classify groups of teachers, as it were, the very realization that educational propositions have cultural features should motivate the teacher to try and reflect on his/her own propositions and values.

On the other hand, despite the tensions between primary teachers and science education experts in terms of teaching knowledge, it is reasonable to assume that the values of primary teachers and of science educators do not differ significantly. These parties are likely to hold similar stands on moral, ethical, social and other grounds of this kind. The result is that the educational propositions of these parties are not dramatically different. Hence, the tensions between them within this realm may not be such that it becomes necessary to stress such tensions in professional development programmes for teachers.

However, academic research may find that the gap between a teacher’s rhetoric
and his/her practice is wide. This is, of course, a sensitive area. Values cannot be classified as ‘correct’ or ‘good’ except within well-defined moral, ethical or ideological canons, traditions or doctrines; in a word, except within a particular cultural frame of reference. Likewise, to assert that a particular set of values is not coherent, or that one’s actions are not consistent with one’s declared values, demands authority of a moral or ideological kind. This is the sort of authority which can only be claimed by religious or political leaders; otherwise it is attributed, not claimed.

The issue of values underpinning teachers’ educational propositions is thus a generative theme in its own right. In spite of the cultural tensions in question being small and it seeming perhaps unwise to point out a gap between an individual’s rhetoric and practice, both tensions and gaps exist and have some bearing on the quality of the relationship between these parties. Arguably, this is particularly the case when science educators and primary teachers combine their efforts to improve science teaching in primary schools. Therefore, the way this issue of educational values is transformed from a meaningful theme for teachers in general to a (generative) theme for debate in, say, an INSET programme, becomes the key focus of discussion.

Theme 5, ‘Thrust of Teaching’, concerns the distinct emphases that can be attributed to ‘understanding’, marking therefore the differences between primary and specialist teachers. Theme 6, ‘Children’s Diversity’, draws on a prototype case in which a teacher was struck by the realization that what he was doing contradicted his own beliefs. Theme 6 also illustrates the kind of debate and reflection the recognition of such differences and contradictions can generate. In that sense, ‘Children’s Diversity’ is a particularly useful approach to the discussion of the value of generating debate about and reflection on tensions both between and within groups of teachers.

As in the previous section, the Plowden Report (CACE, 1967) provides a good reference to illustrate the fairness of the proposal that these two themes are meaningful to teachers. Plowden’s considerations about the role of the teacher allows for inferences about the ‘primary ideology’, which here take the form of the themes ‘Thrust of Teaching’ and ‘Children’s diversity’. Note, for instance, these extracts:

Teachers must strive to make children feel that they matter, however little they are able to respond, and however unattractive they may appear to be (CACE, 1967, para. 873).“
Teachers have to select an environment which will encourage curiosity, to focus attention on enquiries which will lead to useful discovery, to collaborate with children, to lead from behind (para. 875).

The primary teacher is expected to be a good man [sic] and to influence children more by what he is than by what he knows or by his methods. Teachers cannot escape the knowledge that children will catch values and attitudes far more from what teachers do than what they say (para. 876).

My volunteers gave evidence that they endeavour to do precisely this; to build on pupils’ curiosity; to set up a secure environment; to be consistent in their response to pupils, and so on. Some of these points apply across the board to all teachers, some do not. This difference between teachers at different levels of education relates to differences between children at different ages. As we look at other points Plowden makes, this becomes clear:

Teachers must strive to serve as substitutes for parents... to care tenderly for individual children and yet retain sufficient detachment to assess what they are achieving and how they are developing (para. 873).

Teachers face the difficult task of assessing individual differences, appraising effort in relation to them and avoiding the twin pitfalls of demanding too much or expecting too little. Teachers must support apathetic children until they gain a momentum of their own. They must challenge and inspire children who are too readily satisfied and, on occasion, force independence on those children who wait to be prompted (para. 876).

Secondary teachers, and particularly teachers in post-sixteen education, are not expected to act as substitutes for parents, however deprived children may be emotionally, materially or intellectually. Yet these kinds of expectations suggested by Plowden, could be identified as applying to my study; primary teachers do see their role more or less in the terms described above. For example, the dilemma concerning the principle of fairness, equity and justice (theme 2, heading 1), clearly relates to the excerpt from paragraph 876 cited above. Girls may be as apathetic about science and technology, as boys can be about the arts or modern languages. The discussion of theme 6, ‘Children’s diversity’, has shown that to avoid the twin pitfalls of demanding too much of one group or expecting too little from the others, depends on striking a difficult balance; this balance is illustrated by an allegorical representation in my discussion of Freire’s principle of dialogicity (figure 3, page 73). The striking of such a balance, therefore, is not an endeavour peculiar to primary teachers. Indeed, the difficulty of attaining this equilibrium can
well be measured by the gulf between the rhetoric and the actions of teachers in
general; for even those who are conscious of the need to avoid the double pitfall in
question, may fail to exercise in practice what they express in words.

4. Generative Themes Relating to Communication

As stated in chapter 3 (part II, section D), my Thematic Investigation has consisted
of analyses of teachers’ discourse. My volunteers commented on patterns they
themselves had shown when comparing and grading particular episodes - episodes
related to their teaching of science which, at the beginning of this investigation,
they had been asked to associate with various emotions. When I asked the teachers
to make these comments, I attempted to problematize what they were saying. My
purpose was to obtain practical and theoretical propositions from the teachers.
The transcripts of these dialogues were analysed, thus revealing aspects of the
teachers’ strategic knowledge I had not noticed during the actual dialogues. In each
of the last three sections I have focused on one type of proposition. The themes
that correspond to these sections have concerned ideas about learning, about the
nature of science and about educational aims and values. Whatever the
perspective, my focus has been on whether or not there are gaps either between
what the teacher says and what he/she does, or between what my teacher
volunteers say and what science educators say. In this section, I would like to
discuss a special type of proposition; the kind of proposition I associate with
principles of communication and with semiology. In the previous chapter, I discuss
this type of proposition under two headings:

Theme 7: Elements of Communication in a Teaching Process

Theme 8: Schemes for the Articulation of Messages

Some propositions included there could equally well be classified as curricular
knowledge (Shulman, 1986b, p. 9-10) (see chapter 3, part II, subsection D.5) or as
instructional strategy - notion adopted, for instance, in the ORACLE project:

The instructional strategy corresponds to what is loosely called ‘teaching
method’ and may include lecturing, demonstrating, class or group discussion,
the use of work sheets or project work (Galton et al, 1980, p. 112).

It is important to note, however, that the issues discussed there did not concern
strategic decisions of other types. For example, they did not concern organizational
strategy; that is, how to manage the learning environment.

By making an analogy between science teaching and processes of communication, I
adopted semiology as analytical tool and rational principle of enquiry. This enables me to shed light on very important issues related to the teaching of science; for instance:

* what was communicated to children;
* what source was used for it to be communicated;
* which form of representing and formulating the subject of this communication was being adopted.

That is to say, as a rational principle of enquiry, the analogy between teaching and communication draws attention to the need to identify three elements of the process of communication: its object, its source and its media (Eco, 1974, p. 94). These elements need to be well meshed together; otherwise, the student at the receiving end does not register the message prepared at the transmitting end. For the communication to be effective, the choice of each of these three elements should be compatible with both the other elements. Such compatibility is not a simple matter to define, unless some general rule is accepted as parameter. Semiology provides precisely the necessary general rules.

So, themes 7 and 8 attempted to discuss whether or not object, source and media of communication seemed particularly suitable or well-chosen in the circumstances. During that discussion, it became apparent that communication was the component of the Tetrahedron of Principles (chapter 3, part II, section D) that made the connection between the other three components of this model: learning, nature of science and educational propositions. Besides, to judge by current debate in science education this is an increasingly important theme for discussion. Here, I refer to the debate about the use of analogies and metaphors (Duit, 1991; Lawson, 1993) and to discussions concerning the development of children’s understanding of theories produced by science and their associated consensus models (Gilbert et al, 1995), and also issues about communication in science in general (Bentley et al, 1992).

C. SCOPE AND LIMITATIONS OF FREIRE’S CONTRIBUTION TO TEACHER EDUCATION

A current criticism of teachers is that they do not expect from pupils as much as pupils can actually achieve (OFSTED, 1995, p. 7). This shows the pertinence of my assertion - made in the manner of Freire - about the necessity of a challenging ‘other’ in order that true reflection as well as innovative practice take place. As Pope and Scott (1983, p. 1) argue, teachers’ views may be highly resistant to
change. Of course, the tendency to seek contentment and avoid audacious behaviour is not a trait exclusive to teachers. In that sense, although the proposal to create needs or stimuli to encourage teachers to adopt audacious behaviour was backed up here by what Freire says about limit-situations, it could just as well have been backed up by the sayings of other scholars. The argument would find support, for example, in Vygotsky’s views on the importance of frustrations, and language development (Vygotsky, 1986); Kuhn’s on the shortcomings of prevalent theories, and scientific revolutions (Kuhn, 1970); Marx’s on conflicts between labour and capital, and social-political changes; Kelly’s on rival hypotheses, and anticipation of events (Kelly, 1963); or in Polanyi’s ideas, for example, when he says:

> to hit a problem is the first step to any discovery and indeed to any creative act. To use a problem is to see something hidden that may yet be accessible (Polanyi, 1969, p. 131).

The fact that these different ideas have elements in common with Freire’s theory is, in part, a sign that the scope of his work spreads beyond the realm of adult literacy and beyond the boundaries of backward countries and their peasantry. In this section, I shall consider the scope and limitations of Freire’s contribution to teacher education.

Thematic Investigation is a search for themes which reflect an epoch and a place in which particular teachers are living. This, in part, means that a new investigation is necessary for each particular group of teachers at each determined moment. Made-to-measure goods or services seem fairly anachronistic nowadays. Freire’s method has the air of a tailor-made programme of education; it is bound to the time, the space, the programme co-ordinator and the learners concerned. This can be considered a great limitation to the application of Freire’s proposals. Undoubtedly, it makes great demands in terms of time; but also the programme requires more than the usual amount of flexibility on the part of the co-ordinator. As time becomes a scarce and therefore expensive commodity within teacher education institutions, it seems unrealistic to consider that Freire’s method might be received with enthusiasm there. Besides, this approach entails the prospect of unpredictable discussions and a constant swing between theory and practice, which sounds yet more daunting.

Another limitation to the use of Freire’s methodological strategy relates to the previous experience of learners. It is necessary to emphasize here that Freire’s literacy method is geared to the education of adults. In his epistemology, therefore, the life experiences of the learners are of utmost importance. That means that his
method may not be applicable to initial teacher training. Even its adoption in programmes for professional development geared to inexperienced teachers may result somewhat unsatisfactory.

In a Thematic Investigation, the search is for themes that are meaningful to the learners concerned. Only then should the investigator consider whether the themes are relevant as regards the formalized ideas that he/she aims to convey. For that reason I find it necessary to identify the transitions of teachers from one stage of professional ability to the next. When teachers recall those moments of transition, the investigator has a greater chance of finding themes that are meaningful to them (see chapter 3, part I). It seems that an attempt to contravene this rule in adapting Freire’s method to work on initial teacher training would result in being limited to the technical aspects of what Freire proposes.

The question is: how would it be possible to get student-teachers to reflect on strategic knowledge in teaching, when they have no practice in teaching and their ideas about it are based only on their experience as students back in their own school days? The analogy with literacy seems valid, still: to train experienced teachers disregarding the experience they bring from their classroom practice seems as inappropriate as to use ‘primers’ with illiterate adults; but to train student-teachers through a dialogical process, as is proposed here, initially seems as bizarre as to have recourse to ‘culture circles’ to teach 6 or 7 year-olds to read. But, indeed, the question of whether a dialogical initial training of teachers is possible might certainly be an interesting one for anyone willing to pursue it. I certainly am.

Another question that remains open concerns the prospect of adopting Freire’s philosophical framework and conducting a Thematic Investigation on teachers’ science subject knowledge - an enquiry in preparation for a dialogical programme on content matter knowledge per se. Freire’s methodological strategy was originally devised for exploring people’s culture (not their cognitive world). However, the educational programme which follows the Thematic Investigation of people’s culture is intended, not only for literacy, but to an understanding of the mechanisms of phonetic combinations in Portuguese (Freire, 1974, p. 55).

My study of teachers’ strategic knowledge is a preamble to an educational programme on matters concerning ‘content knowledge in teaching’, in the sense used by Shulman (1986b). The lack of content knowledge per se in some teachers - as in the case of primary teachers - constitutes an added difficulty, since this ‘deficiency’ has to be addressed. As it stands at the present time, the
methodological strategy to gather the programme content for such courses does not aim at that aspect of teachers' professional knowledge. Consequently, the education programme envisaged at the moment for teachers concentrates basically on other matters, and excludes content knowledge. The belief that this programme will help to make the attitude of teachers towards science teaching altogether more positive is the only aspect of it related to the provision of content knowledge, and this is clearly a very indirect and subjective relation: the understanding is that once teachers' attitude is positive, they should be more open to learn the 'substantive structure of science' (Schwab, 1964a, p. 24 ff.). Whether or not this is so, and what modifications in the present Thematic Investigation would be necessary to address the problem are other questions that this study leaves open.

By being aware of the limitations of Freire's work, one begins to see possibilities for follow-ups to this present study, like those mentioned above. Other possibilities, however, are a consequence of Freire's ideas being particularly relevant to our time. Note, for instance, that he maintains that in designing a programme content of education we should focus on culture, on language, on the collective construction of knowledge. This lends his work a post-modern air. I have chosen not to discuss 'post-modern' theoretical perspectives in this study. However, one finds these perspectives currently being discussed in relation to critical teacher education (Kincheloe, 1993) and also in direct relation to Freire's work (McLaren, 1994). The interest shown by Kincheloe and McLaren is hardly surprising, since post-modern philosophy adopts a view whereby reality is socially constructed or semiotically posited (McLaren, 1994, p. 193), both characteristics being found in Freire's work, as discussed in chapter 2. A study that stands out as another possible follow-up to the present one is a consideration of whether or not Freire's ideas are subject to the criticism levelled by post-modern philosophers against current thought; and, regarding my use of this educational philosopher's proposals, whether or not this use is subject to the same criticisms.

D. PROPOSAL OF DIALOGICAL TEACHER PROFESSIONAL DEVELOPMENT

The emphasis in section B, earlier in this chapter, was on a description of teachers' strategic knowledge in relation to the formalized knowledge of educationists. It can be seen that primary teachers' experience of introducing the Science National Curriculum in England and Wales does provide timely support for an empirical study of teachers' strategic knowledge. By considering this specific case, however, I also wanted to look at more abstract and general issues. One of these is the problem of the development of professional knowledge in teaching.
In this section, I would like to turn to that issue and again try to strike a balance between theory and practice. By describing a concrete proposal for a professional development programme, I discuss further the question of gaps and bridges between theory and practice in teaching; I also discuss the question of similarities and differences between the discourses of practising teachers and educationists. In saying that I am going to discuss these questions I do not claim that I can resolve them. My purpose is to give a sense of the issues that lie at the forefront of the research. Here I would like to try and express the kinds of answer that it may be possible to provide to those questions from the perspective of this research.

The obvious point of reference for the design of an in-service teacher education programme based on Freire’s principle of dialogicity is the last phases of his literacy method (page 57). They are:

**Phase 4 The elaboration of agendas, which should serve as mere aids to the co-ordinators, never as a rigid schedules to be obeyed.**

**Phase 5 The preparation of cards with the breakdown of the phonemic families which correspond to the generative words** (Freire, 1974, p. 52).

The whole design of the programme, which I will now elaborate, corresponds to Phase 4 above. So, let’s consider what would be Phase 5. The teacher development programme could start with the ‘breakdown’ of one of the generative themes proposed; by that I mean the discussion of it in a simple form in terms of its separate parts. Take, for example, theme 3 (‘Scientific Knowledge’) and theme 4 (‘Scientific Enterprise’). Both themes relate to the question of the nature of science. In other words, the topic ‘nature of science’ can be discussed in terms of these two separate aspects: the products and the processes of science. As I imagine myself coordinating such a discussion, I shall refer to the programme co-ordinator as male.

The discussion of the theme ‘Scientific Knowledge’ would start with the analysis of one ‘existential situation’, say, an anecdote or precedent. This could be recorded on video or audio-tape. For example, teacher A.W. recorded an activity she conducted before she did the Rep Test for this research. It was an activity about ‘gravity’, in which she asked children to predict which ball, taken from a given set, would "hit the ground first". Her conversation with pupils before and during the experiment that was involved (dropping balls simultaneously) could provide the existential situation to start a discussion with practising teachers about the nature of science and, more specifically, about scientific knowledge.
The group of teachers would discuss the problems they think pertain to that situation: A.W.'s content matter knowledge; truth; theory; children's ideas; scientific concepts; prediction, observation and empirical evidence; vocabulary, and many other aspects. As the group perceives the further implications of the episode as a problem situation, the co-ordinator of the debate could go on to present a transcript or a recording of his dialogue with teacher A.W. about that activity. Whichever type of register he chose, he should be selective and produce only particular excerpts of his conversation with the teacher. These excerpts would include certain aspects of the theme 'Scientific Knowledge' which the co-ordinator considers relevant for the teaching of science, and therefore necessary for science teachers to reflect. For example, the selection could include passages like the following, cited when I discussed theme 3 (heading 1) in chapter 4:

I see the theories as 'out there' as opposed to 'in here'. They are created, imagined by some one out there, someone much cleverer than me and I have to take their word for it that that was the truth. (AW3.314)

It could also include this passage (idem heading 2):

there is a lot of confusion in my own mind about this, because I think my secondary colleagues are too academically minded. They should be focusing more in the processes and looking at things more in a context, rather than saying: 'this is such and such's law and this is this person's rule'; not actually putting the whole scope of things and setting in a world context. It's just science, a little box just of science. I am not sure that we should be doing that and how appropriate is that for anybody to know these things. Isn't it more useful to have it applied? So I am totally in confusion about that. (AW3.192)

The process of selecting the passages is important in the breakdown of the generative theme in discussion. Moreover, it is also important to find passages where possible conflicts or confusions can be highlighted. I shall now discuss these two points. To avoid interrupting the account of my concrete proposal for a professional development programme, I will leave the illustration of the way some aspects concerning the nature of science could be discussed within such a programme to Appendix 5.

The distinction between truth and theory, for example, is certainly one aspect of scientific knowledge that needs to be discussed in a science teacher education programme. However, for science educators to lecture non-specialist teachers on their theories about science is certainly not going to do the relationship of science educators with teachers any good. Discussion of the theories developed by
philosophers of science can be a way out of this problem, but there seems to be little point in going into such theories in detail. The subject can seem too remote if it is considered only in terms of the philosophers and historians of science. Statements taken from the discourse of other teachers may provide the ingredients to save the discussion from philosophical digressions and yet go deep enough into the topic.

The other role for such selection of excerpts from dialogues concerns the discussion of conflicts and confusions, for instance between science expert and non-expert teachers. The second passage cited above contains explicit reference to such conflicts and would certainly trigger interesting discussion; and not only about science content matter and the different emphases given to its role in pupils' education by secondary and primary teachers. This excerpt could also raise a number of other issues for discussion: for instance, about the status of a scientific law; about the role of theories and models, as well as other ways in which scientific knowledge can be communicated; about the process of knowledge growth in science, and so on.

Once issues such as those relating to the nature of science and scientific knowledge have been seen in familiar contexts, it would be possible for teachers to discuss those issues out of such contexts. Other themes, such as 'Scientific Enterprise', for example, could then lead to discussions about the actual theories or formalized arguments concerned, such as epistemological debates about the nature and the process of knowledge growth in science. Having learned about one or two of these formalized arguments through an initial debate of familiar existential situations, teachers can then do the opposite exercise. They can be challenged to find an example, allegory, or prototype case of an activity where one teacher adopts a realist conception of science; another teacher, a relativist conception, and so on.

Having acquired some command of this ability to move from theory to practice in relation to more generative themes than 'Scientific Knowledge', teachers can then be challenged to move from practice to theory. Initially, they could be given passages from textbooks, the now old Science National Curriculum: Non-Statutory Guidance (NCC 1989, 1991), say, or any other proposal for teaching practice on a topic of science. Then, they would be asked to say which of the generative themes discussed could have a bearing on that activity and how. This could lead to extra discussion about particular aspects of some of the generative themes in question. The teachers would inevitably express their ideas and propositions concerning the endeavour and thus give the programme co-ordinator the opportunity to
problematize that. He could point out inconsistencies in the arguments of the teachers; for example, the inconsistencies between their rhetoric and the kinds of teaching practice they propose. Or else, he could simply clarify any point about a particular theory or explain some formalized argument that was missed earlier.

The theory-practice pendulum could swing at least once more. At the end of this dialogical in-service programme, teachers could be asked to plan an activity, or indeed, a whole teaching unit; that is, a series of activities. Certainly, the emphasis would not be on the establishment of targets, educational aims or anything of this sort. The exercise could be to discuss the strategic potential of a particular topic of the Science National Curriculum. This discussion would inevitably have to involve some ‘dress rehearsal’ on the part of the teachers. This would enable them to bring to light practical problems in the conducting of a smooth ‘performance’ in classroom, and therefore would allow them to ask for help or advice from the science education expert programme co-ordinator. Besides, the planning of an activity by teachers would help the co-ordinator who adopts a radical-democratic stance to strike the dialogical balance between reflection and action, on the one hand, and between teachers’ experience and knowledge and his own, on the other (see chapter 2, section C and figure 3).

A possible follow-up for this in-service programme could arguably be some form of action research. The teachers could put their plans into practice and reflect on the outcomes of the exercise, for example. They may eventually develop more self-confidence and become more knowledgeable about the various dimensions of science education, developing, perhaps, their own heuristic model of the area - their equivalent to my Tetrahedron of Principles. As this happens they will be aware of the sources of information and help on which they can draw to find their way out of difficulties, thus being able to be truly independent, reflective practitioners. Before this happens, though, the presence of a challenging ‘other’ seems advantageous. It is he who will spur the teacher on to make the most of opportunities - in educational terms - that a topic or activity offers. Different topics and, indeed, different types of teaching activities allow teachers to work dialogically with pupils. By working on these topics through these activities, teachers can encourage their pupils to develop in different ways and domains: content knowledge; the nature and purpose of scientific enterprise; reasoning, organization and communication skills; critical thinking, etc. Nevertheless, it seems unrealistic to expect teachers to reflect on and engage in innovative practice without a necessity (for example, when pupils show signs of boredom) or stimulus (such as evidence of ‘successful’ practice provided by colleagues or perspective of
captivating practice provided by other people).

As I end this description of a concrete proposal for a professional development programme, I can hardly emphasize enough that one should not get distracted by the purely technical aspects of the above procedure. These aspects are not difficult to assimilate. As Freire says "the difficulty lies rather in the creation of a new attitude - that of dialogue" (Freire, 1974, p. 52).

Dialogue, as conceived here, was almost certainly absent from the professional and academic upbringing of both teachers and teacher educators. So, there is a great temptation on the part of the programme co-ordinators to diverge into anti-dialogue. One common enticement here is the practice of placing a few teachers in a group to discuss their ideas and experiences about something. Teachers are likely to get angry if they are left to say constantly what they think is relevant in teaching or how they reckon something should be taught - especially if they are paying for the course in question.

Another pitfall is to lecture teachers about the problems of their common practices. Teachers are likely to get offended if it is suggested that they engage in apparent malpractices. The temptation to drift into anti-dialogue is also great when teachers reject 'too much' discussion, and instead request recipes for good practice and formulas for successful teaching. In this situation, the co-ordinator risks either giving the teachers what they ask for, or lecturing them - giving them what they may take to be abstruse empirical information or philosophical thoughts. In the latter case the teachers will certainly be greatly annoyed, saying that the co-ordinator does not know what real children and real schools are like. On the other hand, the problem with recipes and formulas is that they do not work; if they worked, the science teaching projects of the sixties and seventies would have been more successful and we would not talk about the era of teaching projects (see chapter 1, section A). None of these situations will ultimately encourage any effective reflection or meaningful change of practice on the part of the teachers. For this reason I adopt following passage as my motto:

I cannot think for others or without others, nor can others think for me. Even if the people's thinking is superstitious or naive, it is only as they rethink their assumptions in action that they can change. Producing an action upon their own ideas - not consuming those of others - must constitute that process (Freire, 1972, p. 100).
E. CONCLUSION

Based on the empirical evidence shown here, together with the additional arguments I have elaborated, I suggest that an enhanced teaching praxis in science depends upon teachers reaching a critical stage of consciousness as regards their strategic knowledge. This kind of knowledge does not replace knowledge of science subject matter, but cannot be replaced by it, either - at least, not if one aims at teaching for understanding, rather than for recitation of hollow words, or for mindless repetition of actions.

As I envisage it, this critical consciousness can be acquired if teachers reflect on their practice. However, because it is comfortable to remain at a level of naive consciousness, this reflection needs to happen not only on practice and in practice. For much though teachers may prefer to reflect on their own practice, and to test their assumptions and propositions in practice, solitary reflection does not result in critical consciousness, as discussed in chapter 2 (section D). Necessary though such reflection may be, it can become virtually circular unless an element of challenge leads the person on to higher stages of transitive consciousness.

My conclusion is that an element of challenge is more likely to make reflection dialectic. Hence, dialogue with an outsider (someone with a different point of view) presents a possibility for that. Solitary reflection just does not compare with a dialectic dialogue with an outsider. The interaction between teachers and teacher educators can be dialectic, in that sense. That will be the case if the interaction is dialogical; that is, based on dialogue and aimed at bridging the distances between the interlocutors - the gulf between their knowledge bases; the gulf between their areas of activity and realm of experience; and other such guls that amount to what can be described as cultural distances.

As an outsider, a teacher educator can enter into critical dialogue with teachers by problematizing their accounts of their own practice. Problematization involves providing teachers with the opportunity for setting their ideas - somewhat idiosyncratic and inarticulate as they will be - against equivalent formalized ideas: relevant theories and proposals for action.

Because formalized ideas are better articulated and have a wider range of validity, they have the potential to be powerful analytical tools, and in that sense foster dialectical reflection. However, due to that same generality and sophistication, formalized ideas might fail to be effectively challenging. This happens when they are presented out of context, or when they are allowed to gain the status of truths,
even though they are only theories - well thought out and soundly based on evidence, but nevertheless no more than propositions.

If teachers and experts were able to engage in dialectic dialogue, the gain would be mutual. The teachers could reflect on their practice and articulate their propositions while the expert challenged these. The expert, in turn, would have to be able to apply his/her theories in order to challenge the teachers in that way. To be able to apply theories means:

* to identify gaps in teachers’ praxis;
* to point out areas of conflict between the teachers’ propositions and principles of the science education community; and
* to show up any contradictory principles at play in the teachers’ practice.

So, the expert would have the chance to reflect on his/her relevant beliefs - beliefs underpinned by the formalized ideas which the area of science education supplies - just as teachers would draw on their main sources of anecdotes and allegories: past and vicarious experiences. Thus challenged to review his/her beliefs, the expert’s comprehension of practice would, in all likelihood, improve. The teachers, on the other hand, would be challenged to review their practice and thus improve their theories.

I would suggest that this is the spirit of authentically collaborative work, particularly as regards teacher professional development: mutual challenge. Dialogical collaboration is the type of work that follows an investigation such as this. Thematic Investigation may not, at first, seem collaborative. Investigator and teacher apparently do not work together in a Thematic Investigation. As this study illustrates, however, the teacher and researcher who wish to collaborate, may not act together but they still work for the same cause. Each party has its own say and can thus play a specific part in the joint effort of creating possibilities for the improvement of current practices.

Naturally, collaboration is not dialogical if some pretend not to have suggestions, or answers. Some may hide their knowledge and opinions, for at least one of two possible reasons. They may believe their interlocutors should think for themselves. Put another way, they may think that the other people need to make the effort and learn to reason. On the other hand, they may be more interested in what they can learn than in what they can contribute. Thus, collaboration fails to be dialogical either when a person is being patronizing with regard to the other people, or because the other people are given only the promise that something will be done in
return for their cooperation.

So, a person may not actually be willing to collaborate. But this is not the only obstacle to dialogical collaboration. A genuine willingness to work together is essential but not sufficient. Apart from this prerequisite there are others. To participate, one needs to be able to articulate one’s theories. Besides, one has to be capable of drawing on one’s experiences. Without these attributes one cannot:

* communicate one’s own theories and experiences to others;
* make sense of the theories and experiences of these other people; and, more importantly,
* couch one’s own questions, suggestions, criticisms about the theories and experiences of other people so that they can make sense of such doubts and opinions.

Science educators and teachers all need to be willing to collaborate in dialogue if the intention is to improve science teaching. However, the former have the greater responsibility in such an endeavour. This is so because science educators have a much more empirical and theoretical knowledge than teachers. This asset gives them greater power and much more room for manoeuvre. It is the science educators who have the obligation to shorten the distance between theory and practice. Moreover, it is their duty to inform practitioners about inconsistencies between the rhetoric and the actions evident in their discourse and in their practice. In addition, science educators are in the privileged position of being outside the classroom and having a range of analytical tools on which to draw in order to make sense of what is taking place there. This gives them a wider perspective than that of the practising teacher.

Enough has been said in this thesis to suggest that many of the issues in the professional development of teachers within science education are complex and contentious. Manifestly, any science educator working on teacher professional development has a considerable challenge to face. In attempting to face it, I have tried to fulfil the responsibility of a teacher educator. Clearly, though, the challenge that faces teachers is no smaller and is, indeed, of an altogether different nature. They have to send us educationists and science experts unequivocal signs of disapproval every time we forget that, knowledgeable though we may be about science and its teaching, we are not practising teachers. And even if we were once teachers ourselves, we have to accept that we will always have something to learn with those who attempt to put our theories into practice.
In concluding this thesis it is important to say that, as I delved into the subject of teachers’ feelings, I noticed two sets of feelings, suggesting two contrasting types of attitude towards science teaching. One type suggests teachers who want to distance themselves from the subject, and would also rather not teach it. The other, however, suggests teachers who want to close the gap separating them from science educators; who want to build upon pupils’ curiosity and interest in science-related matters; and who want to understand the logic of science that still escapes them. The tension between these opposing tendencies stands out as the source of energy for teacher educators to entice teachers away from an indifferent form of teaching, to another, critical and passionate. The process that teacher educators have to put into operation is that of conscientização. As can be inferred from the empirical data presented here, to raise teachers’ strategic knowledge beyond the first stage of transitive consciousness - the stage of naive consciousness - does require a great deal of energy. In addition, though, it requires that teacher educators should be very clear and firm about their own position. As I have said, their responsibility is the greater, and moreover, they have the power to decide which way to turn the whole process. The choice is: either take the initiative and start building the bridge across the gulf that separates non-specialists from experts and thus help teachers to move towards a critical and passionate education of pupils in science; or else retreat, wait to see which way the energy flows, and thus risk letting teachers take the comfortable option that will distance them from the practice of education as education should always be practiced: with love. I do not think there is any room left for compromise.
APPENDIX 1: Questions for Repertory Test Cards

As explained in chapter 3 (part III, section B), the conversations with each teacher happened in three meetings. These were preceded by an introductory meeting in which I introduced myself as well as my research aims, methodological assumptions, methodology steps and requirements. The text below was handed and afterwards a set of cards with questions marked on them (see specimen on figure 7, page 168). There has been small changes on these questions from the pilot phase. In the following pages I present the pilot and the final sets of questions on the cards. The teachers’ answers to these questions are charted on table 3 (page 185).

We would be very happy explaining you what are the aims of this interview, so ask us if you wish. Here, we want to state briefly what we expect now.

What we are going to try and do is get you to talk about the teaching you do, you wish to do or even you would never do if you could. We will try to do that in a way that is hopefully your language and not my language. And the way in which this is done is to start by asking you to read the set of cards apart. They were designed to help you bring into mind some passages of your experience as a teacher. See if it is possible to fill them all with something that makes sense to you. It doesn’t matter if it didn’t happen to you. The point is, it has to be of relevance for yourself. Please, don’t mind how it looks. What you are going to write will be used by yourself on the next step. There is no hurry. Take your time.
In the pilot phase each card starts the same: "Try to remember a classroom situation you would classify as". These are the contents of each card:

1. Try to remember a classroom situation you would classify as One that gave happy outcomes
2. Try to remember a classroom situation you would classify as One you are proud of
3. Try to remember a classroom situation you would classify as One disappointing
4. Try to remember a classroom situation you would classify as One imposed and not welcome
5. Try to remember a classroom situation you would classify as One surprising
6. Try to remember a classroom situation you would classify as One joyful for your students only
7. Try to remember a classroom situation you would classify as One quite reasonable
8. Try to remember a classroom situation you would classify as One remarkable
9. Try to remember a classroom situation you would classify as One that happens some times
10. Try to remember a classroom situation you would classify as One awkward
11. Try to remember a classroom situation you would classify as One unexpected
12. Try to remember a classroom situation you would classify as One you wish would happen again
13. Try to remember a classroom situation you would classify as One welcome, although imposed
14. Try to remember a classroom situation you would classify as One you are ashamed of
15. Try to remember a classroom situation you would classify as One you feel sorry at its absence
16. Try to remember a classroom situation you would classify as One funny
17. Try to remember a classroom situation you would classify as One that gave sad outcomes
18. Try to remember a classroom situation you would classify as One that was only trendy
19. Try to remember a classroom situation you would classify as One that is less frequent this days
20. Try to remember a classroom situation you would classify as One non-sense
21. Try to remember a classroom situation you would classify as One normal
22. Try to remember a classroom situation you would classify as One joyful both for you and students
The questions below are in the final form. Each card starts the same: "With respect to physics teaching, what would you remember as something". These are the contents of each card:

1. What would you remember as something that GAVE HAPPY OUTCOMES ?
2. What would you remember as something that gave you PERSONAL SATISFACTION ?
3. What would you remember as something DISAPPOINTING ?
4. What would you remember as something EXCITING ?
5. What would you remember as something IMPOSED AND NOT WELCOMED ?
6. What would you remember as something SURPRISING ?
7. What would you remember as something JOYFUL FOR THE PUPILS BUT NOT FOR YOU ?
8. What would you remember as something REASONABLE ?
9. What would you remember as something REMARKABLE ?
10. What would you remember as something that STILL HAPPENS SOMETIMES ?
11. What would you remember as something AWKWARD ?
12. What would you remember as something UNEXPECTED ?
13. What would you remember as something YOU LOOK FORWARD TO ?
14. What would you remember as something WELCOME, ALTHOUGH IMPOSED ?
15. What would you remember as something SHAMEFUL ?
16. What would you remember as something YOU MISS ?
17. What would you remember as something FUNNY ?
18. What would you remember as something UNACCEPTABLE ?
19. What would you remember as something TRENDY ?
20. What would you remember as something FORTUNATELY LESS FREQUENT NOWADAYS ?
21. What would you remember as something ABSURD ?
22. What would you remember as something NORMAL ?
23. What would you remember as something JOYFUL FOR YOU AND PUPILS ?
APPENDIX 2: Results of the Repertory Test FOCUS Grid Analysis

As soon as the teachers answered the questions shown in Appendix 1, I returned the cards to them without the portion with the question (see figure 7, page 168). In the final stage of this study, I asked teachers to choose nine of these cards to be used as ‘elements’ in the Rep Test. In the pilot phase, the teachers were not asked to make such selection, hence the different number of elements in the computer generated (RepGrid, 1991) diagrams in the following pages; the number of elements in a particular grid is marked in its heading. The elements are listed at the bottom of the diagram and correspond to the columns of the grid. The number preceding each element refer to the question that prompted the teacher to provide that particular situation or proposition as an instance of his/her strategic knowledge. The sign ( (+), (-) or (N) ) marked with each element refer to my own classification of the questions. As I explained in chapter 3 (part III, section B), the questions were intended to make teachers recall episodes they associate with particular feelings. Some questions could be said to refer to ‘positive feelings’, as they ask the teachers to recall something exciting, for example (there are ten such questions: 1, 2, 4, 9, 10, 13, 14, 16, 17 and 23). Nine questions (3, 5, 7, 11, 15, 18, 19, 20, 21) refer to ‘negative feelings’, since they request, for instance, something disappointing. Finally, four questions (6, 8, 12, 22) could be classified as ‘neutral’: question 6, for example, refers to something surprising.

Hence, my RepGrid diagrams show the way the teachers used bipolar criteria to compare their answers on the element-cards. Each pole of a criterion is marked on one side of the actual grid filled with numbers. In the diagram headings, the word ‘constructs’ refers to these criteria. The numbers in the grid correspond to the scores the teachers attributed to element-cards according to such criteria. The scores range from 1 to 5. The smaller the score, closer is the association of the card with the pole of the criterion on the left. The shading of the grid cells help to visualize this association.

The scales and ‘trees’ on the right side of diagrams show, at the bottom, the way the element-cards compare with each other as far as the scores are concerned. The same applies to bipolar criteria, if we look at the trees at the top (see chapter 3, part II, section C). The patterns of these trees were the initial motivation for the
FOCUS: Rep-Grid_JC
Elements: 9, Constructs: 6, Range: 1 to 5, Context: Primary school teaching of physics

An exciting discovery by a child
Not facts. Doing.
making sth for a 'reason' to be used
Exciting for the children
Children excited to do
I interest the children

I'm limited in thinking of activities
A fact - Knowledge
Giving Knowledge
Group not particularly stimulated
Children Told
I let the children down

23 Range of fuels (Boring) (-)
24 Earth, sun, moon in sky (Difficult)(-)
10 Group work. A group without same input (+)
18 Tell chdn what magnets attract (-)
1 Putting electricity into young chdn's house(+)
17 Mirrors [the novelty of the experience](+).
13 Making an electric switch (+)
9 Nicola & the car moving (+)
12 Making instrums after orchestra visit (N)

challenges and problematizations in the last two meetings with teachers (see data collection flow chart in figure 10, 179). The order of grids is that of teachers' names.
FOCUS: REP-GRID_DH.
Elements: 9, Constructs: B, Range: 1 to 5, Context: Primary school teaching of physics

Children enjoying science
Teaching style rather than content
Children's reaction
Teaching style accessible to kids
Workshop allows pupils develop own level of ability
Subject can be accessible to all pupils
Subject's access to all pupils by being practical
Overcoming uncertainty in teacher's ability

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<th>6</th>
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<th>7</th>
<th>22</th>
<th>9</th>
<th>17</th>
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<td>New but now normal</td>
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<tr>
<td>The unthinkable becoming norm</td>
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<td>Professional development</td>
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<td>Teacher development issue</td>
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<td>The reliance of qualitative resources</td>
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<tr>
<td>Frustation in doing less than professional lesson</td>
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</tbody>
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8. Resources lacking to complete task (N)
6. It was less daunting once undertaking (N)
14. Being expected to teach sthg avoided (+)
17. Children's delight, 'Magic of magnet, (+)
9. 'Grasp of electricity by young pupils (+)
12. Issues of ability, Chris Alcock (N)
13. Where chdn develop learnng by applyng knowldg (+)
2. Class Museum w/ 7-8yr (+)
FOCUS: REP-GRID_MK
Elements: 9, Constructs: 8, Range: 1 to 5, Context: Primary school teaching of physics

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<th>Dialogue</th>
<th>Need to know</th>
<th>Focus on learning</th>
<th>More analytical</th>
<th>Accountability</th>
<th>Quality environment</th>
<th>Encourage expression of ideas</th>
<th>Non threatening learning</th>
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<td>1</td>
<td>2</td>
<td>1</td>
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<td>1</td>
</tr>
</tbody>
</table>

Monologue

Why are we doing this?

No application (no continuity)

No purpose

Autonomous

Sink or swim

Show no interest in children's ideas

Isolated/not supported

Learning for its own sake or for a purpose? .... (N)

Anecdotal stories help my relationship w class (+)

Don't focus question on chdn who lack confidence (+)

Hope chdn felt successful tackling sci work (-)

Appraisal: hope to improve through help w/ rsch(-)

Informal chat w small groups: back up learning (N)

Talk back: chdn reflect on what they've learned (+)

How to apply knowledge gained ......... (N)

Felt familiar to teaching practice ...... (-)
FOCUS: REP-GRID_CP
Elements: 9, Constructs: 7, Range: 1 to 5, Context: Primary school teaching of physics

<table>
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<th>Constructs</th>
<th>Scores</th>
<th>Notes</th>
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<tr>
<td>Tchr attitude towards tcgh Sc</td>
<td>3</td>
<td>Young ch 1st contact w Sc-v.exctd</td>
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<tr>
<td>My enjoyment of tcgh science</td>
<td>4</td>
<td>Ch excitement from the activity</td>
</tr>
<tr>
<td>Knowlg aspect,Telling ch wt is correct</td>
<td>1</td>
<td>Practical</td>
</tr>
<tr>
<td>Ch ideas</td>
<td>2</td>
<td>Practical science enjoyment</td>
</tr>
<tr>
<td>Skills children should develop</td>
<td>2</td>
<td>Children excitement</td>
</tr>
<tr>
<td>Knowlg side-Tc affraid of AT4-Wt shd I get out of it?</td>
<td>2 1 1 2</td>
<td>How Sc is taught-the approach story</td>
</tr>
<tr>
<td>Skills</td>
<td>1 4 4 3 5 5 5</td>
<td>Knowledge</td>
</tr>
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16 Very young introduction science ........(+)  
2 Chd get excitement out of tuning fork ......(+)  
4 4yr old mixing paints 'magic'-her face ....(+)  
25 Echo work rely on story to demonstrate it (N)  
24 Chdn own ideas must be challenged............(N)  
15 Lack of knowlg, Tchrs ask what Kn to teach (-)  
20 Tchr expanding repertoire not afraid AT4 (-)  
11 Prism work;Not relaying correctly to chdn (-)  
1 Prediction skill developed (faulty bulb)....(+)}
FOCUS: REP-GRID_LP
Elements: 9, Constructs: 7, Range: 1 to 5, Context: Primary school teaching of physics

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<th>Structure</th>
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<td>Planning strategies</td>
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<td>I'd use how much chd know from experience to assess&amp;plan</td>
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<td>Ability quantitative measures</td>
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- Observation
- Child centred assessment
- Independent learning
- Using experiences to assess & plan
- Way chd learn become investigative&inquiring
- Attitude qualitative measures
- Response from children

100 90 80 70 60

22 Chdn're inquisitive/Phycs=experiment (N)
23 Working together & "finding out" (+)
2 Observing chdn's independence in learn (+)
1 Encouraged by chdn ability to investigate (+)
10 Joy when an activity goes well (+)
17 Chdn's comments eg:God did everyth (+)
9 Chdn's ability to recall difficult facts (+)
6 How much chdn already know fr expernc (N)
14 NC gives scl a framewk & emphasis (+)
### APPENDIX 2

**Teacher S.S.**

**FOCUS:** REP-GRID SS  
**Elements:** 16, **Constructs:** 10, **Range:** 1 to 5, **Context:** Primary school teaching of physics

<table>
<thead>
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<th>Easy</th>
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<td>Happy with planning</td>
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<td>Doesn't make demand on me</td>
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- **Difficult**
- **Children like**
- **Pessimism**
- **Insecurity**
- **Dread**
- **Desapointment**
- **Means**
- **Not happy with planning**
- **Want to achieve**
- **Make demand on me**

16 Miss having a wide range of practical ideas (+)
12 Something happens & I can't explain (N)
15 Feeling inhibited by own lack of expertise (-)
5 Not confident w/ Electricity or Forces (-)
11 Issues I am not confident (forces) (-)
7 Looking at toys & explain how they work (-)
3 Chdn+properties x descriptions of materials (-)
13 I'd like to teach colour and light (+)
8 My resources at home I draw upon (N)
2 Float & Sink: being observed + careful plan (+)
1 Incredible thought into bridge building (+)
14 NC science-chdn's exper > my generation's (+)
6 How now children happily hypothesize (N)
9 Children's natural curiosity (+)
17 Perceptions chdn already have at Syold (+)
10 Chdn practical activities x passive learn (+)
FOCUS: REP-GRID_A.W.
Elements: 9, Constructs: 7, Range: 1 to 5, Context: Teaching of physics in primary school

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<tr>
<th>Introduction of new vocabulary</th>
<th>Discovery</th>
<th>Motivated</th>
<th>High personal motivation</th>
<th>Successful</th>
<th>Unexpected Outcomes-phenomena</th>
<th>Boys &amp; Girls work together</th>
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</tbody>
</table>

Try introduce mean Sci correct Teacher Directed Unmotivated
Low personal motivation Unsuccessful
Expected outcomes on phenomena Boys take over

15 Class demonstration(melting) & chdn bored (-)
11 Being asked Qs I can't answer (-)
14 Chdn demanding certain topics (+)
3 Floatg/Sinkg ch didn't learn concepts (-)
12-Gravity: I expected balls fall together (N)
23 Electric circuits: learning has taken place (+)
8 Chdn've found triang good for bridges (N)
2-Ryan explains why ear muffs work (+)
6 Paper airplanes: experiments w/ = weights (N)
APPENDIX 3: Transcripts of Interviews with Two Teachers

This is a sample of the conversations that followed the Rep Test. I present here transcripts of my dialogues with two teachers: A.W. and L.P.. The criterion to choose them was basically their professional experience. A.W. is the least and L.P. the most experienced of my volunteers. They were interviewed respectively in March 1992 and July 1993. These transcripts correspond to the second meeting with each teacher - the meeting that succeeded the Rep Test FOCUS Grid analysis (see data collection flow chart in figure 10, page 179). I transcribed the conversation with A.W. myself, whilst the one with L.P. was transcribed by a third person. During these transcriptions some symbols were used. They are:

{xxx} Transcribed under some doubt
[xxx] Commentaries
[...] Silence
* Parts hard to be heard

I. CONVERSATION WITH TEACHER A.W.

2.1 Arnaldo: I suppose you know roughly what we are doing. These methodology asks you things from a kind of parallel perspective; from your inner self. So using things like activities you've done I tried to tackle your tenets or, using the correct word, constructs; the ideas you have about the world or the way you organize the world in this particular issue. This data now will be discussed because I did some analysis of it and the outcome of this analysis will be the main thing that will be discussed. So in a way this is the hardest interview, because it is more about you analysing my analysis and see if the picture I've got looks like you or if there is something missing, mistaken.

2.2 A.W.: Ok.

2.3 Arnaldo: This is just that... you've done. So you used this criteria to analyse this elements. I reorganised them. You can see the order here is not the same, neither here nor here. Why did I do this? If you look to the figures... They are similar. I tried to put similar figures close to each other. So if we look to something like [this, ] more graphical, every five is a black, every four [etc]

2.4 A.W.: I quite like that graphic representation.

2.5 Arnaldo: They are both the same
Let's have a look at this here [...] Very close on your right hand side are Electrical Circuits, Triangles Bridges, Ear Muffs and Paper Airplanes. They are in this side. [*leaving some untranscribed*]
The first question is: seeing... this pattern of those four together, do you see any reason why they would be close, from what you remember from those situations?

[pause]

2.6 A.W.: They are all situations I would describe immediately as successful. While those are the ones that are unsuccessful for me personally.

2.7 Arnaldo: Right. [picking up original grid] You used this very word, successful and you said these were successful, was it?

2.8 A.W.: [laughs of surprise] yeah.

2.9 Arnaldo: That's it, you used the word successful in all them. When you did it. You called them successful yourself, at that time. But you also said they were also Unexpected Outcomes and High Personal Motivation.

2.10 A.W.: That's interesting.

2.11 Arnaldo: Yeah. Would you say that something successful is always something of High Personal Motivation?

2.12 A.W.: Yeah

2.13 Arnaldo: And what about the other way round? Every time you are highly motivated the activity is successful?

2.14 A.W.: Yes, it's that way round, isn't it. If I'm motivated to do something, generally it's successful.

2.15 Arnaldo: Is that a criteria you use to analyse your...

2.16 A.W.: No, I'd not took it like that before. Because I teaching. When you're teaching, you try to teach everything with equal motivation. But obviously I'm more motivated in other areas, certain areas.

2.17 Arnaldo: Do you remember [pointing to Unexpected outcomes]?

2.18 A.W.: That's interesting, isn't it, the Unexpected Outcomes...

2.19 Arnaldo: Do you remember what were you referring to when you said Unexpected Outcomes.

2.20 A.W.: Yes, ah ...

2.21 Arnaldo: About the taps and ...

2.22 A.W.: Yes phenomena... Phenomenum

2.23 Arnaldo: And what about this other side? Although you said those are successful, the other elements [pointing them], you said they are all unsuccessful. But to the pattern here. Well the pattern is only on your right hand side, the lack of pattern... How would you interpret it?

2.24 A.W.: Seems like a clear cut, doesn't it?

2.25 Arnaldo: Yeah, on your right, yes.

2.26 A.W.: I don't know... I guess that this areas must be... I have quite definite ideas on, I have quite strong feelings about them. Ah... Once this I'm a bit higgledy piggledy I'm not to sure about myself, am I? I'm all over the place. It's difficult because of things like this, Being Asked Questions. That doesn't seem to fit in quite so easily, 'cause this are all topics, aren't they? Areas. And this, Children demands, is slightly different. That... Yeah... quite similar pattern...

2.27 Arnaldo: Yes. You are quite right. I think... The kind of analysis I did was, as I said, a kind of statistical... I tried to match, well first I counted the fives etc, them I tried to put together those which were similar, like [pointing]. Then I tried to see, comparing them the difference between the scores you've given on *. Doing this I built this tree which tells us something like the agreement of, not the agreement but the coincidence between the scores to those elements. So... to your right *

So let's have a look here. If I go moving [mask] this way less agreement between them. You used, see? this J here. Those two, they are very, very close on the scores you've used. Can you see any reason why it happened? Can you see why...?

2.28 A.W.: Structures and Bridges...

2.29 Arnaldo: Do you know what these structures are about? Do you think they are near to each other? *
2.30 A.W.: Yes, I do.
2.31 Arnaldo: In which ways?
2.32 A.W.: Because they are both examples of times * things have come from the children. They are both very investigative and they are times when I tried to hold back the teacher and observe the children rather than doing a more teacher directed thing which is important to me. I .i. happy; if the children are discovering for themselves. So in that respect they are both similar.
2.33 Arnaldo: How do you usually feel in these * when you manage to put them to discover?
2.34 A.W.: How do I feel?
2.35 Arnaldo: In preparing these activities, in doing them... Sorry, how do you prepare them, what do you expect when preparing yourself *
2.36 A.W.: When preparing something like those, the main thing for me are the concepts involved, ordering the concepts involved and the resourcing it.
2.37 Arnaldo: In terms of material?
2.38 A.W.: Yeah. Ah... Yeah.
2.39 Arnaldo: And how do you usually feel during the process, when they are discovering? How do you usually approach them?
2.40 A.W.: To begin with I’d try to get them motivated, through my own motivation.
2.41 Arnaldo: How do you manage to do this?
2.42 A.W.: Say, like, if you’re doing the ear muffs I try to get them to ask me questions that I want to ask them. If you see what I mean. For example, try to get them to be aware of the phenomena of sound. Where does it go when you can’t hear it any more. And trying to get them to ask me about that.
2.43 Arnaldo: Why do you think it’s important for them to ask you?
2.44 A.W.: Because then it’s theirs. It’s their own problem. And it’s not me telling them what to do. And in that way they are motivated to find out the answer to the problem. If I just say, 'where does the sound go' they would just... 'I don’t know'. But if they say to me: 'Yeah, where does it go? Where’s it gone, Miss?' You know, And then, they are really interested and they want to sort that problem and they are determined to solve it.
2.45 Arnaldo: Is there any particular way when you manage to do this? When you manage to make them to ask questions?
2.46 A.W.: Ah... What do you mean, any particular area? Or the way that I’ll do it?
2.47 Arnaldo: The way you do it. For instance you gave an example, You then from the picture of it * design questions.
2.48 A.W.: Usually, it might take * questions. I would be a kind of "Have you noticed?" question, or "did you see?", rather than "What do you think?". Not... Not asking them questions to which I know the answers. You see what I mean?
2.49 Arnaldo: Yeah.
2.50 A.W.: Not asking them questions when I’ve got the answers fixed in my head. Just getting them to look and observe things. Not necessarily their eyes, but just observe generally. In order they can pick up, and what’s I’m trying to get at.
2.51 Arnaldo: What’s the reason you prefer to ask questions you don’t have the answers on your mind?
2.52 A.W.: Because I think it’s silly for me to sit here and ask children questions when I already know the answer.
2.53 Arnaldo: Why is that?
2.54 A.W.: Because then they can say to me... [smiling, she turned to me] That’s a silly question for you to ask me. Don’t you make that yet?
2.55 Arnaldo: So, you are not saying they are questions you don’t have the answers, but they know you have the answer. You may have it but you
A.W.: No.
I’m asking questions to help them to observe the phenomena I want
them to observe. So I’ll be directing and focusing their attention onto
what is the one key, you know, at that time. Ah . . . And I wouldn’t ask
questions directly about concepts, because it’s not appropriate at that
time; it’s not fair. Make them ordinary questions and they answer them.

Arnaldo: Ok. Right, let’s see how it progresses moving it to a lower [level].
Can you see there a cluster.

A.W.: Yeah.

Arnaldo: So you have four...

A.W.: Quite similar.

Arnaldo: Quite similar. Do you still keep that together? Do you think The
similarity is the same?

A.W.: Ah [pause] This two, as your graph shows, this two are the most
similar. Then this tree [bottom tree] and then that one, just as you’ve
done it!

Arnaldo: In which way those tree... are similar?

A.W.: This two, the Bridge and the Ear Muff are most similar. And then
the airplane one are the closest of those two. And them that one
[Electrical Circuits], slightly..., slightly different because of the nature of
the subject.

Arnaldo: So, in all this cases you... you try to prepare materials and
resources, concepts and use the questions in such a way that the issue
will be open?

A.W.: This tree [bottom] definitely. That one too, to certain extent, but
not quite as much.

Arnaldo: What’s particular about electrical circuits?

A.W.: Ah... I think... [whispering: What’s the phrase?] I think it’s because
of the concepts the children have already got on their heads about
electricity.

Arnaldo: In which way?

A.W.: They already know what it does. They know it’s a power source and
there is energy in there. They know There are travels around the wires.
They know a lot about it already and some of them might know things
that aren’t necessarily right. They don’t know it has to travel in a circuit
maybe. So that’s slightly different, ’cause you’re working with quite a lot
of knowledge already they’ve might got. Some of it might not be right.
This two * not quite so much in that. With that one very little can
thought about it. That one they have prior knowledge, but * it’s fun.

Arnaldo: Being fun, does it make any difference?

A.W.: To them, yes. ’Cause they’ve already got motivated. They felt
familiar with it. They’ve done it before, you have to do it.

A.W.: Is it a sort of rule?

A.W.: [long pause] What’s the rule?

Arnaldo: Well, when it’s fun they enjoy it more, they learn.

A.W.: Oh Yeah.

Arnaldo: Why is that?

A.W.: Because they want to learn, they want to know more. Because it
comes from them.

Arnaldo: And what about having fun just for fun?

A.W.: What do you mean?

Arnaldo: Without any aim apart from enjoying themselves. Like you said
once when it turns into a chaos.

A.W.: Oh I see. That kind of fun [laugh followed by loud laughters] That’s
not fun.

Arnaldo: Not for you {you should say}

A.W.: Ah... I forgot the question now. That kind of fun...
A.W.: They learn more because of the fun or they learn quicker.

A.W.: [pause]

They are not learning as much, they might be learning. They are learning but they are not learning what they are intended to learn. They are learning more spontaneously.

A.W.: Is that the same with the other tree?


A.W.: In different levels or...

A.W.: Yes, in different extents. That one was the most highly motivated for them and that one and that one and that one.

A.W.: Because it's great fun to make a bulb light up. And to make buzzers go off and... You know, motors and all that kind of things.

A.W.: I'm finding those two very difficult. Because they are... Let's say different from the rest {which makes hard me to compare them} Ah...

A.W.: Are they among themselves similar?

A.W.: Yeah.

A.W.: In which way?

A.W.: 'Cause they are things that are out of my control. Things that haven't occurred to me. Surprises. Shocks.

A.W.: Yeah. And being out of your control, does it puzzle you? Does it...

A.W.: First of all it makes me think I should had thought of that. Then I feel obliged to carry out. Ah... maybe I don't know how to do that.

A.W.: Because I try to take the learning from them. They want to find out something, I think I should try to help them in that and follow that up rather than just say 'Look we are not doing that we are doing electricity. We are not doing that'. As a teacher I should respond to them. And even though it may not be * them at all, whatever they do there's some obligation for me to do that. Try to help them do that.

A.W.: I wouldn't say more obliged. Ah...

A.W.: Oh, yes in there I can follow up much more easily. There it's really out of blue. It's really something I don't know how to find out. I can't say 'Oh, Ok we'll find out. We'll do an experiment. We'll discover.' You know. Much simply I don't know anything about it. So I have to learn through research myself or ask some else.

A.W.: I wouldn't say more obliged. Ah...

A.W.: In different kind of obligation?

A.W.: They were talking about time zones. Well it's not really phys...

A.W.: Ah... They were talking about time zones. Well it's not really phys...

A.W.: They were talking about the speed of light, the speed of sound, and somebody said, they heard this somewhere, If you travel at the speed of light, times slows down. And I cannot get my head on that... It's like time is a constant, how can it slows down. Just because you go faster why does it go... I cannot understand that. And I'm sure that the kid is right.

A.W.: And I don't know what to said... What to say... How to answer that.

A.W.: In this situation there do you said... ah... that there are some
things that make them think, and one of them is * you should had thought. Is this question one you think you should had thought before?

2.110 A.W.: No. Because that was completely... ah... spontaneous question... We were just having a chat, you know, a discussion on the carpet. And the discussion * all over the place. And I’m not controlling it, it’s just them coming up with their theories and ideas and...

2.111 Arnaldo: And this is different from the questions they ask here [?] ?

2.112 A.W.: Yeah.

2.113 Arnaldo: In which way are they different?

2.114 A.W.: Because then I should had thought it before.

2.115 Arnaldo: So, in a way you would know the answers already.

2.116 A.W.: Not necessarily know the answers, but know how to find out.

2.117 Arnaldo: You remember that here you said that you try to make them to ask you questions; preferably questions you don’t know the answers. And you said now the same, just remarking that here you would be able to find the answer although here you wouldn’t. How do you define a boundary between these two questions? How far can you put... You mentioned this shrinking of time you wouldn’t know how to start...

2.118 A.W.: All I could do with that is to go and try to find some book and even then there’s no garantee that it’s going to explain it to me in such a way that I can understand; or in such a way that I can do something in the classroom so child can understand it. So... I don’t know what to do about that situation either than stand up and saying, you know, ‘You look in a book, I look in a book. We’ll see what we can find out’ Nothing {ever} really {is} resolved. 'Cause it’s not the kind of thing we can do in the classroom. It’s higher level concept.

2.119 Arnaldo: And why do you feel that you should had thought before?

2.120 A.W.: In that one?

2.121 Arnaldo: Yes. Those {kinds of pressures}. How these are different of...

2.122 A.W.: Well I couldn’t possibly had thought of that one before.

2.123 Arnaldo: Yes. Definitely

2.124 A.W.: I don’t really... I suppose... I don’t really had to have thought of that one before of those. But I should had of these. [pause] Is that topical related? They are related with what I’m doing. Those are questions that are more on top of their heads {kind of questions}. It might be about something like this, but it’s just at such a higher level that I haven’t gone that far. I don’t know.

2.125 Arnaldo: And how do they negotiate their fun or interest here in your inability?

2.126 A.W.: [long pause] Well, it’s just as you said. It’s a matter of negotiation.

2.127 Arnaldo: How do you {do this}?

2.128 A.W.: Through discussion, ah... if it’s possible to do something; to carry out some investigation, then we will do that. But if not, then it’s just for me to say ‘We don’t know the answers to that question.’ That’s it.

2.129 Arnaldo: {That’s the farthest you can go.}

2.130 A.W.: Or we might say ‘Perhaps we should ask a scientist. But we don’t know any scientists.’ We take it into a certain level. We can look in the books. See if there is anything we could do. And if there isn’t then I cannot persist in that because of the demands in curriculum.

2.131 Arnaldo: Is there any criteria you use to know how far you can go?

2.132 A.W.: No because each situation is different.

2.133 Arnaldo: Don’t you have any standard?

2.134 A.W.: Not really, because it depends... It depends totally on what the question is, how many resources I have available; largely on the resources. If I haven’t got it here I can’t do it.

2.135 Arnaldo: When you say {‘it’s a matter of'} resources’, what kind of resources do you mean?

2.136 A.W.: It might be some electrical equipment to measure ah... sound
frequency or... strength of the sound? Do you know what I mean? We haven't got anything like that. To {make a good} distance that the sound travels, that kind of thing. Or it might be a computer equipment.

2.137 Arnaldo: When * of this example, the time when it shrunk.

2.138 A.W.: Ah!

2.139 Arnaldo: Would this be a situation when you say 'well, let's ask a {scientist}.

2.140 A.W.: In that situation what was completely stan*ed, I didn’t know what to do. Ah... I went home that night, I looked in my encyclopaedias, any books I think of that would have anything to do with that. And I couldn’t find out anything about it, really. What I did read made no sense. It was using vocabulary I don’t know. There was no understanding in there.

2.141 Arnaldo: And you went so far because you felt obliged?

2.142 A.W.: And also because of me. I wanted to know, 'is that right'? You know, [sound laughter] It was for myself, that.

2.143 Arnaldo: And if it was something like, let's say, the Ozone Layer? Your attitude, would had been the same? Or if there is some news about nuclear power station leak, would you approach in the same way you did this time?

2.144 A.W.: Ah... You mean what I {pursue} it?

2.145 Arnaldo: Let put another question: if the child's question was nothing about timing or whatever, but... ah... something more linked to the environment, like energy or... Would you approach on the same way?

2.146 A.W.: No because I would have had more knowledge myself to drop on. I would watch it on TV or I might go to the resource library. There is more you can do. It’s not abstract. It happens.

2.147 Arnaldo: Ok. Let’s see how it follows. Very far is the next link. The next one is here. Do you really feel that they are similar?

2.148 A.W.: In terms of success, yes. Ah... They are out of my own capabilities. They are both... For me they are both dodgy areas. I’m not convinced that I know what’s right or what’s scientifically accepted. So they are subjects that I will teach but I’ll be worried while I was doing.

2.149 Arnaldo: Why do you worry?

2.150 A.W.: In case I’m giving the wrong ideas. And in that case I'll try not to give any ideas [laughs] in case they are wrong. Ah... I know what I think, but I don't know if it's right; about Forces and all the rest of that.

2.151 Arnaldo: And do you think it’s important to have it right.

2.152 A.W.: I think it is important to know how to get it right. It doesn’t have to be right at the start but you have to know, to see if you can get the answer. 'Cause otherwise you're teaching them one thing they will have to unlearn and learn *

2.153 Arnaldo: How would you think, how is this procedure to get it right if you don’t have the answer?

2.154 A.W.: Well, again it will be in terms of some kind of investigation, or reading; research in terms of reading. So that I can get the answer.

2.155 Arnaldo: Do you distinguish reading from investigation?

2.156 A.W.: I do for the children, 'cause lots of them can’t read the kind of books they have to in order to be able to do that.

2.157 Arnaldo: Which kind of issues would that be?

*[some reference to the grid]

2.158 A.W.: That’s very difficult, 'cause I found the results are not the phenomena I expected to occur. Like the gravity, the Floating and Sinking. I think that object float for X, Y and Z reasons and it doesn’t. Is that because I’m making a mistake or am I right or...

2.159 Arnaldo: This examples there... ah... the kind of investigation is always experiments, or...?

2.160 A.W.: For me doing?

2.161 Arnaldo: Yes. Would you have another kind of investigation to know the
answer?

2.162 A.W.: For myself?! All it would be would be reading; and asking colleagues.

2.163 Arnaldo: and for them?

2.164 A.W.: [pause] For them? [pause]

2.165 Arnaldo: Do they have to wait till...

2.166 A.W.: They would have to... Well I have to... [pause] simplify... what I know... into an investigation... without distorting it.

2.167 Arnaldo: Alright... Let's have a look... Those two you said are different they are linking together to these two. How do you interpret it? Do you think they should cluster together?

2.168 A.W.: Oh... I think that's form ah... strong link. Those two strongly and these two... I'm not sure about those.

2.169 Arnaldo: Do you the bottom four here, they have stronger relation than this two?

2.170 A.W.: Yeah [not too positive].

2.171 Arnaldo: Why?

2.172 A.W.: Because that, that... that's {not definite things} It might happen, might not. Those are actual things I've done. Those are...

2.173 Arnaldo: So you have a very clear idea about those. While these...

2.174 A.W.: My own knowledge is not sufficient to...

2.175 Arnaldo: Yes.

2.176 A.W.:*

2.177 Arnaldo: And without noticing, you've grade them, these two similar grades to these two. Do you find it's just a coincidence?

2.178 A.W.: No... It's... It's... That's me [laughter].

2.179 Arnaldo: Is it?

2.180 A.W.: Yes. Because all those are the things I... the areas of doubt, self doubt for me.

2.181 Arnaldo: And how do you usually manage this?

2.182 A.W.: [laughing] Not very successfully. Ah...

2.183 Arnaldo: What's the criteria you use to say that?

2.184 A.W.: Because

2.185 Arnaldo: What's the parameter you have for success?

2.186 A.W.: I have done both those things before and I'm still not happy by doing them. All those things I can do happily again and enjoy them again. These two... [pause] Because it's not clear in my mind I have to go through all the reading again and sort out my own concepts and... the same with that. I mean I have to do all the research again. It's not... it's not my own concept it's somebody else's that I have to take on board.

2.187 Arnaldo: Did you see any improvement since the first time you did this... {you've gone through those} situations?

2.188 A.W.: No. It's just got more complex.

2.189 Arnaldo: In all means, in all ways? I mean: for you to prepare, for the children to handle... to live the situation?

2.190 A.W.: No... my preparation was probably a little improved because I had collected more things. So it was better than {worst}. But in doing different kinds of experiments... the concepts just became more confused to me.

2.191 Arnaldo: When you live a situation like this, you try to study to... improve your own knowledge and professional approach on this issues and you still feel that you didn't know? Or worst still, as you are saying, instead of improving did it stay the same?

2.192 A.W.: It got worst.

2.193 Arnaldo: It got worst?

2.194 A.W.: Because each time you go in at a different level, getting deeper and deeper into the problem. And all wo*ling around in your head, and you can't clearly classify things any more. Nothing seems to clear.
A.W.: Well with the Floating and Sinking, [laughs] I avoid it, I won't do it again for a while. With the Gravity... I do that again... but having done once... I would... I think I would talk to my colleagues more and see what they think of that of. And I will look through all the packs that we've got, and see if I can understand it. But even then, even when my own understanding is clear the results may not confirm the accepted theories. So then, I'm left thinking one thing and the children are left thinking something else. And that's not the way I want it.

A.W.: The problem with the Gravity is just that we need something, design something that make sure that all balls hit the ground at the same time. That was the fundamental problem. And unless I come up with (or the children come up with) some way of doing that... That experiment will not be successful.

A.W.: That they would realize that... ah... when you drop the balls the weight of them is irrelevant. Because in space, it doesn't matter how heavy things are. That's my understanding, and I hope that that's right. And I wanted them to, firstly, notice the phenomena and then try to suggest ways why... reasons, hypothesis for why that might be. If they are wrong it doesn't matter but the results have to be right.

A.W.: Not much, no. I think the processes, the way we do things is more important than a final outcome.

A.W.: Because I think that's the most important part to the children at this age.

A.W.: Because I think that I can teach them all about gravity and weight, all about that, just by writing down on the black board, them coping it down, and they would recite me that 50 times. Then they would all "know" [that all] in order to do that. But they wouldn't understand any of...
it. They'd know it but wouldn't... they wouldn't be their own. They wouldn't understand it.

2.219 Arnaldo: Would you do this? Would you write on the black board?
2.220 A.W.: No. No. 'Cause it's so pointless. There is no learning taking place. It's just a log* of knowledge. And that isn't what I think my role is.
2.221 Arnaldo: But they would {pass the exams}.
2.222 A.W.: Yes, they would. But that's not what I'm about. I think maybe secondary schools do that. [laughs]
2.223 Arnaldo: From now [showing lower levels of congruence] what we have is... is fairly apart from the two clusters here. you see? Because further away that this [Melting Chocolate] join this cluster [Gravity etc]. So you could say that this is a cluster. Is it a cluster or is this something apart?
2.224 A.W.: I would say it's more a cluster with those, because it wasn't a very good... a very successful... I don't think it's something separate; on its own.
2.225 Arnaldo: Does it fit on the criteria you used to classify those {four}.
2.226 A.W.: Not for the same reasons, no.
2.227 Arnaldo: What's the difference there ?
2.228 A.W.: The difference there was ah... the organization in terms of classroom behaviour and control. That was the problem there.
2.229 Arnaldo: Wasn't it anything about content?
2.230 A.W.: I don't think so, no.
2.231 Arnaldo: Or... the way they answer *
2.232 A.W.: Because of the organization, the lack of it.
2.233 Arnaldo: What lacked?
2.234 A.W.: It was a new experience for them, because of... It was a kind of organization they never had before. Ah... It was organized; from my point of view, but {for} their point of view it was new and they didn't like it.
2.235 Arnaldo: Is it something they would overcome after a while?
2.236 A.W.: Yeah. I mean, if I come to do that again, it will be completely different.
2.237 Arnaldo: And the organization, would be the same?
2.238 A.W.: No, completely different.
2.239 Arnaldo: In which way would you do it?
2.240 A.W.: Ah... On a more small group ah... kind of organization, rather than a whole class thing. It would be groups {acting}...
2.241 Arnaldo: Do you feel that there is another subject... you would use demonstration through?...
2.242 A.W.: I didn't understand the question, sorry.
2.243 Arnaldo: You did a demonstration, didn't you?
2.244 A.W.: Yeah.
2.245 Arnaldo: Is there any other thing you could do a demonstration * which is effective?
2.246 A.W.: No, it goes against my own theories, really. I shouldn't have done it in the first place.
2.247 Arnaldo: Why did you try then?
2.248 A.W.: I don't know, I just... [pause] I think I did that because it was a danger... It's dangerous to have flames in the classroom. And I wanted to make sure that I would be the one in control. And I was the one doing the burning. Well it *grant against everything I believe, because of course, it's a demonstration. and I don't agree with that. So, the reason that it happened is, is primarily of safety.
2.249 Arnaldo: So you think that is impossible to... make a demonstration in the same way you would do the Electrical Circuits, the Paper Airplanes? You think it's impossible!?
2.250 A.W.: That's not impossible but... to what end? What is it purposed?
2.251 Arnaldo: Well you said that you ask questions.
A.W.: Yeah.

A.W.: Or you make them to ask questions. Is it possible to do the same with a demonstration?

A.W.: It's possible... but I wouldn't do it. Because... I'd want them to do their own demonstrations. They wouldn't have to... each child to do it. But in groups they would have to do their own little demonstrations to make them learn from their own experience or successes. Rather than me showing them something. Because you don't know anything about it, unless you do yourself. You can learn more from doing than watching.

A.W.: That's the way we are [laughs]

A.W.: Is that a general rule? Everything is like that?

A.W.: Yes. We learn by doing. Froebel said that. [sound laughter] I'm a Froebel student.

A.W.: Let me show you. Those are the words I used [as role titles for the initial card filling in process]. Now you understand these trees, don't you?

A.W.: Yes. [long pause] It all fit in quite well, doesn't it? It's an accurate description of me, the way I feel about this things.

A.W.: Would you say that... Is there any other feelings you would like to add there?

A.W.: What, generally?

A.W.: Yes. Thinking about physics.

A.W.: Ah... [pause] I just wish that I felt more confident personally ah... while teaching physics. Because... as I said, I'm... I'm... I understand my own concepts and why things happen. But don't you if that's what you'd understand. It probably not. So therefore should I not teach them? I could teach 28 children wrong things.

A.W.: Yes I should teach them because it's better than no putting any physics at all. At least they are going through processes, if not learning the necessary content. As I said that isn't my priority, as they learn correct content...

A.W.: Is that your choice?

A.W.: Yes I should teach them because it's better than no putting any physics at all. At least they are going through processes, if not learning the necessary content. As I said that isn't my priority, as they learn correct content...

A.W.: They go through processes, the scientific processes in order to learn whatever it is they are going to learn.

A.W.: {Is there any} reason why {choose} processes rather than content?

A.W.: Because I think it's... It requires a lot more thinking. It's a lot hard to do.

A.W.: Is it possible to gain content without {procedures}

A.W.: It's possible to know. But I'm not convinced the understanding will be ah...

A.W.: Oh, yes. You can have some content but it might be ah... total misconception. Or it might be just a very early stage. And because it's such an early stage it might be distorted such as an extent that it's no longer true. Do you see what I mean? Like a secondary school teacher might counsel 'oh! you might not tell them that, that's not right'. But it might be right for them because it's just such an early stage of development. And they got lots of stages to go through yet. So they might actually get to the secondary type of understanding eventually.

A.W.: Would you be able to work with them without any content.

A.W.: Oh, yes.

A.W.: Only processes, procedures?


A.W.: How would you do?

A.W.: Ah... By asking them to design investigations or experiments. Ah...
Say to... [long pause]
Well it doesn’t matter. You would{n’t} necessarily have to learn the
content. You mean... you’d have to find the stimulus but it might not
necessarily be what I would describe as content. Might just be a stimulus.
2.281 Arnaldo: So you would choose things like Electrical Circuits, Airplanes,…
I suppose. Is it right? To do this process thing of enquire, etc.
2.283 Arnaldo: Is there anything particular about this... well, physical...
2.284 A.W.: Ah... [long pause]
2.285 Arnaldo: Is there anything particular about physics?
2.286 A.W.: What in these particular areas?
2.287 Arnaldo: Yes.
2.288 A.W.: I think it’s because in those areas, through the child’s own
investigation, it’s more likely they will discover the right concepts than
say Floating and Sinking. Chances are in Floating and Sinking they will
discover something which is not true. Like ‘all the heavy things sink’.
2.289 Arnaldo: There is any reason you see for this pattern?
2.290 A.W.: [pause] Well it’s difficult because they are all actual physical things,
that you can do and touch and...
I think that if anybody is going to do Floating and Sinking, this is a very,
very complex area. I’m quite certain that most adults don’t understand it.
And I think it’s ridiculous we should accept a seven or eight year-old
child to grasp everything ah... when most of the teachers don’t.
2.291 Arnaldo: You then talk about... ah... a different content. It’s not complex
in terms of material resources.
2.292 A.W.: No, no. In terms of the conflicting evidence that we get. And there’s
just... there are so many variables.
2.293 Arnaldo: This conflicting... that kind of thing... give me an example of
conflicting...
2.294 A.W.: Say you have... say you have something that’s very heavy and it
sinks. You make a boat and that will float. Why? You know, for a child
who is just classifying into ‘oh that’s sinking because it’s heavy’. And then
if you put it in a plasticine boat or you make some kind of structure, you
can make it float. But it’s still heavy. From the child’s point of view it’s
too conflicting. Those two things can’t be reconciled within the child.
2.295 Arnaldo: Doesn’t it happen with the Electrical Circuits, then?
2.296 A.W.: Yes, but there are not... You can differ... there are tests to sort that
out.
2.297 Arnaldo: Wouldn’t you be able to fill it out, they be able to do further
investigations in Floating and Sinking and come out with a rule to...
2.298 A.W.: Yes. Yes. They could do that but still my getting into more complex
situations rather than making it easier. You might... you might from your
rule that you initially thought that heavy things float... heavy things
sink and you make them float. You might find out that ‘Oh! No. It’s all
big things that sink.’ And you get a different ah... a different classification
coming in. Or things that have holes in them will always sink. And it’s too
many different things going on, all at once. While with the electrical
circuits, you can test things out quite easily, without bringing in new
things all the time.
2.299 Arnaldo: What’s your criteria to... to... ah... Paper Airplanes?
2.300 A.W.: Very similar. Similar to the electrical Circuits.
2.301 Arnaldo: What would be the aim there?
2.302 A.W.: What? The aim in me teaching that?
2.303 Arnaldo: Yes.
2.304 A.W.: Ah... The last time I did that was to sort out the idea of airfoils
and... ah... the distribution of the weight and the importance it takes on
the paper airplane {before} it travels. And other things came in *. Like
the wind, ah... the air. But mainly it was to do with the shapes and the

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weight.
2.305 Arnaldo: Is it to different from boats, airplanes?
2.306 A.W.: In terms of phenomena, no.

II. CONVERSATION WITH TEACHER L.P.
2.1 Arnaldo: So, perhaps we could start...before we...we...we look at the things you...you wrote on the cards, we could start by me asking you...you had two activities they were the same activity with two different groups. How was it like having had...well in a short... period of time of just one week having two groups which, I suppose, is it something you usually have?
2.2 L.P.: Yes. It's kind of on a rolling programme. I've done it again this Monday, you see.
2.3 Arnaldo: Oh, right.
2.4 L.P.: Because I'm getting through thirty five children, and having a group at a time.
2.5 Arnaldo: How many each time?
2.6 L.P.: Er, well, a third of the class.
2.7 Arnaldo: Right.
2.8 L.P.: So that's, what, about twelve, eleven or twelve.
2.9 Arnaldo: Mmm.
2.10 L.P.: Um...so by the time, I was quite...confident in what I was trying to get to the children and...in fact was able to lead them on a little bit further.
2.11 Arnaldo: Mmm.
2.12 L.P.: The first time I wasn't quite sure how, you know, if I was pitching it at the right level, if it was too easy or too difficult. They are of the same age, but of course, they're very different in their progress and development within that age group. There are some that are very bright, some are average, some are...you know, slower learners. Um...and so the second time, it was... um... I knew where my aims and objectives were... a little bit more, because having done it the first time, this week it was... we sort of rattled through it because um... you know, I was far more confident and... I think... they're fantastic because they come in and say 'Are we doing experiments?' and thus associate, you know, Monday afternoons, 'we're doing experiments' so they really think that they're...scientists and, you know, learning all these different things, and, so they go about it in a very purposeful way, I think. And they've heard from the other children, you know, the sort of things... 'ooh, it's your turn this week to go and *
2.13 Arnaldo: You said you had your aims and targets more clear. Can you talk about them?
2.14 L.P.: Um, I knew exactly...more exactly what I wanted out of the children < i knew that I wanted to get out of them the vocabulary... the words 'pushing' and 'pulling', and maybe 'energy' and 'forces'. Couldn't take it too far...um... and so I knew that I... how to gear the discussion a little bit more to get those sort of words coming, and how to perhaps structure the activity to allow... I, I, I altered the activity just a little bit...um... so that it was more of a forces... had more implication for all the forces that-
2.15 Arnaldo: Mmm
2.16 L.P.: ...they would have to employ to... to move the objects. Um... so I suppose I just sharpened the edges a bit of, of the presentation of the lesson. So really it... it was, really just to focus on what makes things move.
2.17 Arnaldo: Right.
2.18 L.P.: And I was far more clear in my mind when... I did it the second and third time that that was my objective, just to get the children to look at different ways of moving things, and to introduce the vocabulary, the appropriate vocabulary.

2.19 Arnaldo: Er...and... and is there anything behind it, apart from the, the actual words and concepts of 'pushing' and 'pulling'. Is there anything like a hidden agenda, anything parallel to, to the concepts, you... you try to {pull} from them?

2.20 L.P.: [pause] Only to give them um... the opportunity to investigate... to have experience of being independent learners.

2.21 Arnaldo: Mmm.

2.22 L.P.: I would think that it was kind of Attainment Target One... you know, investigation and observation, and...giving them an opportunity to talk about... we're not actually getting them to acquire knowledge...

2.23 Arnaldo: Mmm...

2.24 L.P.: ...what I'm trying to get them to do is to be inquisitive...

2.25 Arnaldo: Right...

2.26 L.P.: ...and to find out about things.

2.27 Arnaldo: Mmm. And you, you mentioned um...being more structured along these...three sessions. {Which} are the, the dimensions which are the components of this structure...what do you bear in mind when you try to structure the activity...?

2.28 L.P.: Which are the what, sorry?

2.29 Arnaldo: The dimensions or components, you, you try to bear in mind, which is actually there?

2.30 L.P.: Com-?

2.31 Arnaldo: Components. The...

2.32 L.P.: Components

2.33 Arnaldo: Components, sorry

2.34 L.P.: Sorry, yes. Which are the...?

2.35 Arnaldo: Because you mentioned...getting more structured, 'having my aims more clear', you said, 'and my structure more clear' as well. Which are the components of...the structure?

2.36 L.P.: Just really, the way I gear the discussion, I suppose...[pause]

2.37 Arnaldo: For instance...?

2.38 L.P.: [pause] I suppose the questions I asked, and the focus that I... I...er...used, I suppose, because I knew from the first time I did it, that perhaps some questions - I can't remember in particular what questions... that I asked - didn't elicit the sort of responses that I wanted them to, to have... so I kind of... gave them perhaps more cues... to... to answer and to get out the sort of vocabulary I wanted to get out, but I suppose it was the way I... presented the material and the way I presented the discussion.

2.39 Arnaldo: Mmm. Thinking back now on the questions you asked. Um, which kind of questions were you actually asking them? *

2.40 L.P.: Well, I would {certainly} say, first of all the first question was, you know, 'there are lots of activities on the table. I want you to go and find out how these things move.' Or, 'make'... 'find different ways of making them move.' And then I went round to the children individually, and...um... because we had... we have to do observations on what the children say, I have to record what they say, so that I've got evidence to tick off the appropriate attainment target... so that if... when we're doing, um... SATS assessment - you know what SATS are?

2.41 Arnaldo: OK, yeah...

2.42 L.P.: ...SATS assessment, um... it...we've got evidence to say 'yes, that child did understand at that point in time, you know, pushing and pulling, Attainment Target 1B, Attainment Target 4 or whatever.' Um, so I was going round talking to the children...um... to find out what they... knew

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and I suppose I was asking leading questions: 'well, how did you make
that move?', then: 'what did you do? What made it move?', and they'd
say, 'I did.' 'Well, what part of you did?' And I was really, sort of, moving
them on all the time by questioning them,... for them to say 'it was me,
my...' I don't think they would have used the word 'energy' but I *
introduced the word 'energy'. 'It was me pushing them,' or 'it was my feet
doing it,' or 'it was my hand doing it.' Um, and then we got onto - because
I put some balloons and straws out, and they, they soon began to blow -
and I said 'well what are you doing.' 'We're blowing.' 'Well, what's
happening?' 'Oh, it's the air that's pushing them.' 'But who's making the
air move?' 'Me.' You know, and so we were going onto that, and then um...
delightful ones. I said, 'Well, what about an aeroplane, then? How does
that move?' Because that's...we moved on a little bit this week with this
third group. So they... so one child said, [laughs], 'The pilot puts his feet
through the hole and pedals!' [laughs] It was wonderful!

2.43 Amaldo: Wonderful.
2.44 L.P.: Because can you imagine him running up the runway, you know, and
it was ages... and then they, they kind of got to petrol, and they said
'Well, what do you put it in?' and it was, like 'In the hole.' 'Well, what's
the hole?' And eventually some bright spark said 'engine', you know, and
we got there, and I said 'Well, there you are, that's the power that pushes
that', but I thought that was a delightful image of this pilot. So, I mean,
that's the way the questioning went.

2.45 Amaldo: On the first, um... you gave me two tapes. The first one was the
first session, I suppose, and was just a fifteen minutes, which was very
important because when the, the discussion was getting hotter *
2.46 L.P.: ...{ran out} didn't it...
2.47 Amaldo: ...exactly...
2.48 L.P.: ... And I didn't really have time to turn it over, in fact I wasn't quite
sure whether there was anything on the other side, it might've just been a
five minute or fifteen minute tape.
2.49 Amaldo: Um... well, no problem, because you actually had another one.
The kind of questions you were asking were usually 'what'.
2.50 L.P.: Direct.
2.51 Amaldo: No, 'what'.
2.52 L.P.: Oh, I...this is what I was saying...
2.53 Amaldo: ... 'what' something...
2.54 L.P.: Yeah.
2.55 Amaldo: 'What are you actually doing?', 'what, um, what was she doing',
'what was he doing', er... and just once in a while you asked 'how?' And I
{hold} those two tapes and I just noticed once you asking 'why?' Um, is
there any reason for you...?
2.56 L.P.: No, I can't really think. I suppose really because it's more like the
blind leading the blind, do you understand that statement?
2.57 Amaldo: Mmm.
2.58 L.P.: ...'cause I'm not very sure of these things, so {it's kind of}, we're
finding out together more or less, so that might be the way I...I'm
thinking in my mind, you know, 'what they doing, why are they doing it?',
it's probably the way I'm thinking.
2.59 Amaldo: Uh huh.
2.60 L.P.: ...that's why the questions are coming out like that.
2.61 Amaldo: Would the question 'why?' catch different things from a question
'what'??
2.62 L.P.: [pause] Yes, I think it's far more... it, it requires a far more depth of
thought [pause] because you can visually see what a child's doing. The
other children can visually see what the children are doing, and say what
they're doing, but it requires that lower level of thought for them to, sort
of, think about why somebody's doing it. So, I think 'why?' would be a far

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more difficult question for them to answer than 'what?',... so maybe that’s
why at this level I, I think it’s more appropriate to say 'what are they
doing?' and then 'how did that happen?' and then maybe, if I’ve
perceived that they could, you know,...handle it, I would say 'why?'

2.63 Arnaldo: Mmm. And, and you mentioned, visually, so you think 'what?'
goes to visual aspects...?

2.64 L.P.: Because they can say, 'what is he doing?' and they can say 'pushing
the bike.' 'How's he doing it?' 'With his feet.'

2.65 Arnaldo: Right.

2.66 L.P.: But 'why?' is a bit difficult in that context, isn’t it?

2.67 Arnaldo: Mmm. Well, that’s...

2.68 L.P.: Why’s he doing it? Because I’ve asked him to do it.

2.69 Arnaldo: Yeah, but, why the ball is moving...

2.70 L.P.: Yes. I...

2.71 Arnaldo: For instance...

2.72 L.P.: ...I don’t, I think it would... you know, you can kind of look at their
faces sometimes, and think, that’s enough...for now.

2.73 Arnaldo: From their faces?

2.74 L.P.: Yeah. You know, I...I respond to their... if they start fidgeting a bit,
or if they go a bit blank or if I start getting, er... responses like 'my cat’s
had three kittens', I know I’m on to a loser, and I might as well forget it
then and, and they’ve had enough, you know, cut-off point. And then if
you, that’s where you get your continuity and progression, because the
next...year up, you might start asking the why’s a bit more.

2.75 Arnaldo: Right. So, but, but from your answers, now, um...I gather that
you were not quite conscious of the difference between them at that
stage...

2.76 L.P.: Not particularly, no.

2.77 Arnaldo: Right.

2.78 L.P.: But I mean, now you’re saying it, I can now see the reasoning why.

It’s difficult, isn’t it, when the children aren’t there... for me to know why
I’m, how I’ve, um, phrased things... but I suppose because I’m responding
to what the children,... the signals the children are giving to me, if I can
see them really concentrating and answering appropriately, then I know
I’m on the right level. But as soon as I start pushing it too far, in the way
I’m asking questions, then they... I can tell by the way they start, turning
round, looking at a book, or fiddling with somebody’s hair, or, I think,
OK, they, you know, I’ve lost them at that point, that they...they’re still
sitting there nice and quietly, but they’re not actually absorbing anything.

2.79 Arnaldo: Mmm. Does the National Curriculum help you to structure?

2.80 L.P.: Yes. Oh, yes, definitely.

2.81 Arnaldo: In these activities, for instance. You had it run three times. Did
you go back...what’s the process of using the National Curriculum... on
this particular one, how was it?

2.82 L.P.: Well, because you asked me to do that one.

2.83 Arnaldo: Yeah, but, you...you did it once.

2.84 L.P.: Yes.

2.85 Arnaldo: Er...to do it, did you use the National Curriculum attainment
targets and such?

2.86 L.P.: Yes, yes, yes, yes.

2.87 Arnaldo: How, how do you usually work with the National Curriculum?

2.88 L.P.: Well, usually, for instance, that teacher’s doing a topic on toys. So
you’re asking me to do the pushing and pulling was very appropriate,
because she was going to do that.

2.89 Arnaldo: Right.

2.90 L.P.: Because that was part of her toy...um... the *, but last term, she was
doing weather, and um...something else... and it was appropriate for me
to look at materials... weatherproof, waterproof, that sort of thing. So we
usually try and tie in... to make it more meaningful, we usually try and look at the topic and then tie in... the scientific aspect of it, the historic aspect, the geography. [pause] But, because there's so much in the scie...in the National Curriculum, you do have to sometimes contrive to put things in, or have one-off lessons... if you're really *... I mean, last year, the Year One teacher said, '{I can see there's a gap here}, they haven't done pushing and pulling,' and just as an activity did pushing and pulling... but it wasn't actually... within the plan of the topic...

2.91 Arnaldo: Right...

2.92 L.P.: ...because you can be...you can either, I think the danger of the topics is you either contrive too much, do you know what I mean by that?

2.93 Arnaldo: Mmm. I do, yes...

2.94 L.P.: ... and ... go off at great tangents, or you just don't cover something thoroughly. You just kind of pay lip service to it, so... all the time we're changing our strategies, you know, as the...all these National Curriculum subjects have come on...um...on line... you're having to sort of reassess how you fit them in. I mean sometimes history...just doesn't lend itself to some sort of... um... topic that you're doing, so you might do a mini-series of history lessons, the same with science. If you're...some topics, for instance... are focused on history, like the Saxons or something, and if you find that that's going to be too difficult to, to fit the science in, then that would be treated... perhaps rather separately, you'd try and find some sort of links so it's meaningful to the children's learning, but... sometimes you just have to think, 'well, I'm just going to do that in science', you know, and... you've gotta in the end of the day, tick boxes...to say that you've covered the curriculum.

2.95 Arnaldo: Mmm. And, and ... concerning just * you said 'the blind leading another blind', um...does the text of the science Attainment Target 4 in that case...helped you, or gave you any hint... that was particularly useful...

2.96 L.P.: No, I think it was horrible, I can't stand it, I thought it was really boring. I don't now, because I quite enjoyed doing...pushing and pulling, but it...I'd go for the sound and the light and all that sort of...aspect, but... I haven't taught that attainment... I must've, I've kind of avoided that one before, because I just don't like it, didn't like it, couldn't see... where I'd go with it...

2.97 Arnaldo: Mmm...

2.98 L.P.: ...so I kind of thought, well, I know the next teacher will pick that up, which she did. So, yeah, I mean some of the things * just don't turn me on at all, I mean I'm not... I'm not very keen on science because I didn't have a very good science education myself...um... and I suppose I'm a bit wary of what I'm... of say-, of saying the wrong thing. Um... and of course you've got to be au fait with the subject yourself before you can feel confident. And most of... my level is stuff we did all the time anyhow, the light, the sound, and... the magnets and all those sort of things we've always done as good infant practice.

2.99 Arnaldo: Right.

2.100 L.P.: Now, it's just...it's just sort of, formalised, isn't it?

2.101 Arnaldo: Uh huh...

2.102 L.P.: ...and you've got, but I mean, some things, as I've said, I'm not...very happy about, and so I've tended to avoid them, and knowing the next teacher would pick it up.

2.103 Arnaldo: Right.

2.104 L.P.: * I've always been reception, I suppose.

2.105 Arnaldo: Yeah. Which brings us to...to your cards. * {I'm glad we studied this} because I was going to say that you, you, you seem not to be very happy...with perhaps the whole process of being interviewed * with working with Attainment Target 4. I...I got it from, from some hints you
gave me by actually filling the card spaces, um... {them actually look forward to} teaching Attainment Target 4, which was more clear *, and now, so, you did not mention any specific topic Attainment Target 4, most things were very general...

2.106 L.P.: Yes, yes...
2.107 Arnaldo: ...and now so...
2.108 L.P.: ...I avoided that particular one... that, that one... the pushing and pulling one, you know, you've made me do it...really. I wasn't happy about it at all. I just couldn't see... it just seems, sort of, apropos nothing, you know, suddenly in the middle of it, you've got to start... to introduce this pushing and pulling and, and, it never really, you know, never really, um...made me feel that I wanted to do it. But I will in future.

2.110 L.P.: Well, you made me do it. You, I did it for a purpose, because you wanted me to do it, and so I said to the nurs- er, to the reception teacher, 'I'll do pushing and pulling.' I knew that the other teacher had done it, I said 'What did you do for pushing and pulling?' She said, 'You do this, this and this, and you make *', and I said, 'Right, I'll do that.' But I really needed somebody to say this is how they did it, you know, to present it to me in a... in a... practical way.

2.111 Arnaldo: Right. Yeah, ah, you make some comments about the way you did it...if you, if you...*, um, but if we could carry on with {these} questions. And, also you said, {here, it's a shame that} you'd never been taught these subjects. So, you, you did not, um... mention any... topic very clear {activity} apart from when you take temperature - when they take temperature every day, and they are always looking forward to seeing it higher, which was, I found interesting.

2.112 L.P.: They all shout, you see, {they'll go} 'hooray!' when it's high. {When you bring it, if you didn't say to them, they go 'hooray!'} and we all clap and go- I don't know why, because they're all hot and bothered.

2.113 Arnaldo: Have you been doing... it {this week}?
2.114 L.P.: Well, I did it because, um, the reception teacher was away, and she'd been doing weather, and I've been joining in, and whenever I've done a topic on weather, we've, that was a part of it, taking the temperature, and the children would take the temp- the thermometer out in the morning and put it in a sunny spot and then after, and then they'd keep on and on, 'Let me go and get the thermometer'. And then, of course, they'd bring it in -and this was at my other school, and it was a really hot summer, and one it got up to something like ninety - I think they'd put it on somebody's car boot or something - and it got to ninety, and we all went 'hooray!'. You know, I don't know why. And then when they started to do it here, I went 'hooray!', and they all went 'hooray' because it was hot and it was sunny and everything, and when the teacher came back, I heard her say, 'What thermometer?', and they'd gone and done it themselves, you see, and they'd brought it in, and she'd said, 'Oh, it's eighty degrees', and they all went 'hooray!', and I heard her say, 'Don't say that, children', and they said, 'But Mrs Palmer said we could say "hooray"' [laughs]. So, er, it * was just something to make it a bit more exciting, you know. I do like the topic of weather, I thought, I, I, I've often gone into that in quite a big way, um...

2.115 Arnaldo: Yeah. Well, well, apart from, from saying that it was exciting seeing the, the children doing it... you did not mention any other aspect of, of weather... any other thing that usually happened, or you think when you do these activities. Er, do you think that cards did not *, or did not make you remember any particular aspect of *.

2.116 L.P.: Well, I think I was really referring to the aspect of that one that I've been doing for you...
2.117 Arnaldo: ...Right...
L.P.: ... the pushing and pulling. I never really thought about the weather one when I was asking that one...

Amlando: Mmm...

L.P.: ...answering that one, because I do enjoy doing the weather, um... projects, because of, you know, there's a lot that you can do with it. There's a lot of aspects, like the rainbow, and all the different seasons, and the, the date and the times of year and all that sort of thing, and, er, it lends itself very much to, um, art activities...um... songs and all that sort of thing, so I think you can get so much out of that as a project, that's always been one of my favourite projects, but I don't think I was referring to that particularly... I always had in mind this pushing and pulling one... when I was talking about {these}.

Amlando: Yeah. * not seen, well, different things and... also different... well, topics of, of... physics being mentioned...

L.P.: Yes, when you keep saying 'physics' it puts me off.

Amlando: I know that, but... I thought that because you ha-, we had the first conversation when I said what I meant by physics, already, oh, I don't know, I, I...

L.P.: You see, weather now is in geography really...

Amlando: But it's...OK...

L.P.: ...You see, because when we try and tick off the targets, weather is actually in the geography curriculum.

Amlando: And what about the movement of the sun in the sky * you find it, sort of, um [absurd]?

L.P.: Because for the children that I teach, it is very difficult concept for them to - I think it's a difficult concept {anyhow} - for children to understand...

Amlando: Even, even to *...

L.P.: I think it is myself, {that it is a} difficult concept.

Amlando: How do you regard it *. * me what is difficult about it, or what's the sense you make of...

L.P.: Just getting them to understand that we are moving round the sun, I mean that, you know, I've done, we've got a little thing, um, the teacher of science has got a little... bulb thing for the sun, and, and she's got a rod with a ball on it - it's specially * - to show them how it rotates and everything, but I think it's just a very, sort of, intangible... idea, really, that, you know, that we are - I mean, because children only think of themselves... as being, you know... as being here, they can't, I don't think that they can really see us in the context of the Universe. I can't see it either, so I mean, I find it very difficult for children to understand that. Um, they can understand about the night and day. I've told, I told you about that, you know, when I've got... um... a big yellow ball and...

Amlando: ...Mmm...

L.P.: ...and they understand that Australia's the other side of the world. That's about as far-, but then my experience of teaching's only up with, you know, five- and six-year-olds, and really that... I mean, I forget which Attainment Target that is...

Amlando: What, the...sun? Attainment Target 4

L.P.: Yes, I know, but which level?

Amlando: Can be Level 1. But that's the thing, because you are, you are mentioning... some aspects of, of... the sun moving in the sky, but already putting the, the... sun as the sun at the centre of the Universe, or... anyway, understanding that we are a planet, like a separate object, rather than seeing the sky as that thing, that blue thing over there, and asking them to just notice what the difference it makes during the year, or during that day, ah, on the position of the sun, and they're shadow on the ground, or something, which it seems to me is what the, um, National Curriculum Attainment Target 4 suggests for Level 1.
ARNALDO: You see, you-, what I'm just, because you put it here, and because you had mentioned... * in our discussions, it seemed strange that you find it so absurd... because it could be just that, just by them, um...

L.P.: I think it was the passage of the sun bit that, I mean, I can, I, I, I still think that it's a very difficult concept for, to expect five-year-olds to, to understand.

ARNALDO: But it just said that you, you do not want them to... um... to get the {content}, you, you, you phrase it very nicely, um, you do not want to * them some content, some knowledge, you want them to be inquisitive.

L.P.: That's right, to find out for themselves. On the other hand... um... you can't expect them to keep reinventing the wheel... you know, you can't expect them to... if the knowledge is there, and somebody has slaved away for thousands of years to find out about it, you can't expect them to, sort of, go and do a... you know, Pythagoras or something, you, you've got to give them the, the knowledge, but at this age, I think for science, I was turned off science, obviously. I don't... I, I, I mean, I, I'm fascinated by lots of aspects, but as... you know, I never, I wouldn't do 'O' Level or anything *, I wasn't even taught science at school. Um, so it's obviously been presented to me as a thoroughly boring subject, which I know it's not... um... so I don't want to turn children off...

ARNALDO: ...Mmm...

L.P.: ...so I would rather give them the experience of finding out things, at this level, and just opening up the horizon, if you know what I mean, so that the... 'Ooh, I wonder what happened there?', or 'I wonder why...?', I mean, as a child I was always asking, 'I wonder how a camera works?' and everything, but... we didn't, sort of, do that, you know, in school, it was all a rotten old Bunsen burner and... you know, boiling up a few... chemicals or something that you, that the teacher did and you're at the back of the class and you don't what the heck's going on... and, er... and then that was about... the amount of science work, I suppose, that I did. I don't want that to happen to children, I'd rather have them have a hands-on experience, and know that they're capable of finding things out for themselves. So it's a balance, isn't it, between {imparting} knowledge and giving them the idea that they can find {those} things out for themselves.

ARNALDO: So you wanted to get {off the stream} of people who just say things and {give them} * hands-on, and... and... on a subject like, the, the sun and the sky, can't you put them, their hands-on?

L.P.: Not a lot, no. Not the sun in the sky, no! [laughs]
L.P.: You did this on the computer?

Amando: Yeah, this... should, should look nice, um... and also to help us to see some things. Number five and four, yeah, five and four, are dark grey, number three is light grey and one and two are white, OK?...So it's easier * that's here, alright, just the, these numbers, ah, just remember {them in order} * are here, number *, number nine, number one and, and, and so it goes. One thing that struck me, well... two actually... to start with one... These [in there], they received on all these pairs of categories you, you, you use these criteria you used to analyse the, those...um... events or aspects of, of teaching. You grade them almost exactly the same, um... apart from these two...um, almost all of them.

[pause]

L.P.: So what does that mean, then?

Amando: Looking at them now, could you find...er... one pair of criteria, looking only at these two...I have the, the card with me if you want to... perhaps... read your own writing. Could you find, er, a criteria that put them on opposite sides, rather than tying them together...

L.P.: What, number one and number two?

Amando: Yeah.

L.P.: [pause] {You won't show this} to Mike Watts, will you?

Amando: No, he never sees it. And if I wanted him to see it, *

L.P.: * says everything's fine, and I think, it can't be because I write such rubbish [laughs]

Amando: [laughs] [pause] See, everything, it seems that they are... pretty much the same kind of...um... I don't know, it's not exactly an activity, but...

L.P.: '{pieces of} National Curriculum have given a framework to science, and give emphasis to the import- gives emphasis to the importance', don't know what I mean by that.

Amando: Sorry, this, um {whole thing, I should} * giving you number one.

L.P.: [pause] Right, you want me to put these at a different *

Amando: ...If you could find something...

L.P.: ...{categoriseit}...

Amando: Yeah, exactly. If you could find...

L.P.: '* {motivational terms} in their teaming, I was encouraged by their *, observing children's independence in teaming.' So what have I- [pause] I'm still not quite clear what you want me to do. [pause]

Amando: What you, you gave me there, for instance, on number two, you were talking about a particular child, that was very... um... you mentioned she being *, and you thought that you, you were pleased to see that perhaps you had structured, on a right way, *. So, um, this independence in learning... was something you found, um... using all these criteria, the same you found when you look at number one, which is autonomous *, um, you were, you were encouraged by their {beliefs} in that...

L.P.: Mmm.

Amando: So, they seem to be different ways of describing the same feeling, or the same aspect of your teaching. If they are not, are you able to show me that. Are you able to... to phrase a criteria like those... criteria(s) which are {bipolar}, um, that put them, on different... {grounds}?

L.P.: [pause] And this is {number}, way children learn, become investigative and inquiring.

Amando: Right, so you are using... here. Which one? But you see, you gave both the same way children become investigative and inquiring to this one as well. [pause] Do you think that's more...

L.P.: I think that's more independent learning. [pause]

Amando: Do you? [pause] That's fine, if you, if you think that way... now. Just that you thought... differently the other time. Number one is more to your left hand, number... five is to your right hand, so number two would
be here.

2.182 L.P.: I still think these go together.
2.183 Arnaldo: Do you think...[pause]
2.184 L.P.: I mean, 'autonomous' and 'independent'
2.185 Arnaldo: Mmm. [pause] The question I, I, I aim to ask here, is that... if you are talking about the same thing... {being} autonomous, I mean, regarding their learning, the way they learn, autonomously, and...um...observing independence, children's independence in learning... Is there a role you play there?

2.186 L.P.: Mmm.
2.187 Arnaldo: That is something special about the way you deal with their independence, their...
2.188 L.P.: Facilitating, I'm sort of facilitating their learning...
2.189 Arnaldo: And how you work with their... different ways of doing it, *?
2.190 L.P.: You providing the... resources, and you're guiding them by the way you're speaking to them, what you're talking to them about, aren't you?
2.191 Arnaldo: Right. And how you-
2.192 L.P.: -and you're questioning them, *... leading them on, assessing where they're up to, and then moving them on... and you're priming them, stuff like that.
2.193 Arnaldo: And what about your... in a way, fear of being blind and leading someone who is not that blind? Because you mentioned, er...
2.194 L.P.: I don't think, at this age, that they would ever... I would get to that point, when... their... I mean, in a way I think it's quite good that it's, that, that I'm not particularly sure of it, because I think I'd be more thorough in the way I'd present it... and... you know, we are leaning these things together... and so therefore, I kind of, my naivete... I haven't got any preconceptions, and I'm not inhibiting them. It's like art, I'm not very good at art, I'm no good at art, I'm hopeless at art, and often I get really nice pictures from kids... whereas the teacher who's good at art... might come along and say, 'Ooh, why don't you do this?', or 'Why don't you do that?'. Now, my husband is a PhD in science, he, he, I don't think he could tolerate teaching children this age, because... their naivete would probably irritate him thoroughly, and he'd have to get the facts right. You know, he'd have to say, 'No, you're wrong', or, 'This isn't how it works', and go off at a complete tangent. Well, I haven't got the ability to do that...
2.195 Arnaldo: ...Mmm...
2.196 L.P.: ...so I'm not saying to these children, 'No, you're wrong.' I'm saying, 'This is what you think, um, you know, let's, let's have another look at that.' So, I'm, you know, I, I don't feel I inhibit them in their learning in something like science... I might perhaps in history, you see, because I'm interested in history, I enjoy teaching history. Um, and maybe I would do that because I'd know that they were wrong or right, because I've got more knowledge and understanding myself. With something like science or art... I'm not learning with the children, but, um, I feel I'm able to let them... go a little bit in their learning, and find out by mistakes, because I'll say to them, 'Did that work?', and they'll say, 'No', I mean, rather than being judgmental.

2.197 Arnaldo: Mmm.
2.198 L.P.: I want to go on a developmental...
2.199 Arnaldo: What about the question, um, that sometimes you don't know the answer...?
2.200 L.P.: We'll find out together, you know, I'll have to admit I don't know the answer, we'll go and have a look at, look it up in the book, or let's see what this book says about it.
2.201 Arnaldo: Right.
L.P.: Well, I mean I just smiled, because, and then they smiled, and I said, 'Do you really think that?', and they said, 'Yes', and I said, so, I might have said something like, 'It's a lovely idea' or something like that, and I said, 'Well, actually, it doesn't actually happen like that.' I will then correct them if it's something so obviously wrong, {what I should think was great} what they said; and they kind of, thought it through themselves, and thought, 'No I can't actually see the pilot's legs', you know [laughs], as they take off, but I mean it's great to know that they're, these complete misconceptions about... everything, you know. And you just build on that, then, don't you. You say, '{Well, what, how...}', you know, I mean, I might have said - I didn't - 'Well, where do they -', you know ' - when they're up in the air, where do their legs go?', you know what I mean, just keep questioning them until they kind of see, well actually, that couldn't possibly happen... rather than saying, 'Don't be so stupid,' you know, 'that couldn't possibly...'. If somebody really loves science and, and it... it would probably irritate them like mad to have some sort of crass statement, you know.

L.P.: By talking to them, or saying to the other children, 'Do you think that happens?', evaluate it, you know. 'Do, do you think that happens?', and the other will say... 'Well no, not really, because...' you know, and then come out with the reason, but never put the child down that's said it.

L.P.: They began to question that... the, like, the momentum part of it, but I didn't introduce that sort of, but they... but... what we did, sort of, go on to say, if we tilt, like, I had a ramp...

L.P.: ...had a bit of guttering and a... couple of balls, and they soon realised that it, you know, they... they could sort of, put the ball at the top and then let go, and it went on its own. But that's as far as we got. You know, or if they tilted it at different angles it would go faster, and...

L.P.: ...and, 'how could we stop it?', and, you know, we began to talk about things like that... but that was as much as they wanted to do. They weren't... that was enough... at that point.

L.P.: No I didn't do... you know, it's like everything with children you, you take it up to as far as they want to go, it's no good then saying, 'Well actually, so-and-so's theory of whatsis and whatsis says such-and-such,' I mean, it would be a complete turn-off for me and them.

L.P.: And, you wouldn't go {shooting} up to the point when it's vertical, so it's just free-falling?

L.P.: Um, we didn't do that, no, I hadn't, sort of, thought of doing that, no. I mean, I... I can see what you're saying, but, er... I think that would have been a little bit beyond them. Might just, sort of, give them something to think about. I mean, I, I suppose you would then go on to, sort of, bouncing balls and, you know, all that kind of stuff, wouldn't you?

L.P.: I can't know the answer to everything, they know that.

Araldo: And, and, and you, you {blocked} when you mentioned the suggestion of *the* aeroplane. How do you handle not, well, doing the, the actual situation with the children. How do you handle that?

Araldo: Uhuh.

Araldo: And, and, and you, you {blocked} when you mentioned the suggestion of *the* aeroplane. How do you handle not, well, doing the, the actual situation with the children. How do you handle that?

Araldo: And, and how do you make them see that it doesn't actually happen, rather than...
What makes something fall? Which is a way of moving.

2.222 L.P.: Mmm. But... maybe if somebody had come up with that we'd have investigated that.

2.223 Arnaldo: Right...{there are other} coincidences. One is, uh {that one is between four and, er...} I'm going to show you these in a moment, and, and seventeen {these two}, and seventeen {pause} So, here {you can} grade them the same, but number four here...mmm...* if I show you the other one... This is more complicated...

2.224 L.P.: Are you going to put all this in your PhD, would you put these in? These, these are going to be your, kind of, charts {and things}?  

2.225 Arnaldo: Mmm. Look, one and two, right. As they are very similar on the grades you gave them, they can be joined together... so one and two appear together... and have these - if you look to these as a kind of tree, these branch here, it's very high, well, higher than others, uh... and there is actually a number to show... what's the difference between them. So... these means that... you grade them very closely...uh... because sometimes it's * we should invert the pair, which... you make more sense on putting things on one side, rather than... having {one, two} like... some of them who, who change it. The structure and observation, it seems that structure, it's more, um... * it's closely related to those rather than to others, would be on the other side... before. So number five instead of number one, but just because it's the opposite, just because in fact it... but the other one that is very close... the other two... would be these ones.

2.226 L.P.: Mmm.

2.227 Arnaldo: Again, um... just remember which one I gave... um... Do you actually see any... similarity between... the things you wrote on these cards... {joy} * one child is {fond, that can't eat everything}.

2.228 L.P.: Just that, the, the humour of it coming through, you know, the child centredness of it coming through.

2.229 Arnaldo: Humour.

2.230 L.P.: And the child-centredness of it.

2.231 Arnaldo: Mmm...mmm

2.232 L.P.: Seeing it from the child's point of view.

2.233 Arnaldo: Is this... when you, when you mentioned 'humour', is just because, well, it was perhaps laughable, or... because it, it...

2.234 L.P.: No, not laughable in that you're laughing at the child, but with the child and, um [pause] having an empathy with the children, I suppose, and their learning. Just the human side of...

2.235 Arnaldo: ...Mmm...

2.236 L.P.: The thing is, the person who wrote those, wrote that...

2.237 Arnaldo: Thing...

2.238 L.P.: Thing, um... possibly hadn't been near a child for a while...

2.239 Arnaldo: ...Right...

2.240 L.P.: ...possibly hadn't taught young children... I'm not saying it's bad, because a, a lot of it's very good, and it's a lot of what we did anyhow...

2.241 Arnaldo: Uuhh...

2.242 L.P.: But you sometimes wonder, you know, if they kind of, sit in a * somewhere and, you know, the children haven't actually... been around them for a, for long. Don't you, really, when you read all of these things, you think... 'I don't reckon that person's ever been a child, or been near a child', you know, I mean, they didn't invite teachers to say, 'Well, actually that's not going to work, because what they're going to do is such-and-such', you know. So we're kind of inheriting something that somebody else has... fixed up for us, you know... and, er, you've got to make the best of it. You've got to make it available to the children...

2.243 Arnaldo: ...Mmm...

2.244 L.P.: ...in the best possible way that you know they're going to benefit from it.
Arnaldo: Yeah. Well, going on, on that direction, then. You... er... you have all these * and you, you would make {sets} of them, using these comments you, you just made now, or any others... um...

L.P.: Realism is the word I’m looking for...

Arnaldo: Ah, realism. Good word. Can you-

L.P.: -Ideolog-

Arnaldo: -Can you-

L.P.: -Ideology versus realism. Ideal, this is what would happen. In real-

realistically it doesn’t happen, because they go off target and talk about...

the cats and the, you know, things that aren’t actually relevant, because...

what you’re trying to do, obviously, is not relevant to them, is it? You

know, it isn’t actually always relevant to all children, how the sun passes

across the sky, I don’t suppose they could give a tinker’s cuss how it

passes across, they... it not... hasn’t actually, sort of... I mean, I didn’t start

thinking about things like that until... I was well into my teens. In fact,

when I first met my husband I, because I knew he knew a lot of things,

then I thought, I’ll ask him about science and... and I remember, you

know, thinking, 'he’s somebody who knows a lot, and I’ll ask him how a

camera works', but I was only about fourteen or fifteen, and I didn’t

really want to know how a camera worked until then, and I probably

haven’t got, I’m not very inquisitive about those sort of things, but now,

often, now, I will suddenly think, 'I wonder...', I mean I remember one
day saying to my husband, 'What’s a molecule, then? What d’you, what
d’you mean about these molecules? What d’you mean about cells, I don’t

understand, well...', and then I picked up a bit of paper, 'What’s that

made of, then?' and then I was amazed when he was telling me about

molecules and cells and, you know, nucleus and all that, that amazed me,

but I must have been about twenty three at the time.

Arnaldo: But, do, do you actually think that these, well * realistic, asking *

L.P.: Idealistic.

Arnaldo: You think. Well, are you putting 'idealistic' as opposite to

'realistic'?

L.P.: Not opposite, I don’t think you can say it's... I mean, it's good to have

an ideal, isn't it, it's good to have a framework...

Arnaldo: ...Mmm...

L.P.: ...Um... but I suppose I deal with it in a realistic way, that I know that

if I’m going to do something, like the, the moon... then sun’s passage

across the sky, out of thirty five, myself and perhaps two others will {get}
it. Others will, sort of, begin to think, 'Mmm, what’s she on about?', you

know, um, 'could be something in this', and the third at the end of the

natural curve are going to be fiddling with their shoe laces. So you’ve,

you’ve got to differentiate all the time, but I mean you can start off, I

suppose, with talking, I mean, it’s quite nice to have some children who

have got a grasp of these things, to initiate the conversation and, and

bring up the level of discussion...

Arnaldo: ...Mmmm...

L.P.: ...um... but sometimes you just realise that you’re on, you’re not going
to win here, you know, that they’re not really, you just cannot get out of
them what you want to, and that, you’re going to have to pitch it lower,

and start again, you know.

Arnaldo: So when you open the National Curriculum science...

L.P.: ...we all screamed, and said 'unbeliev-'

Arnaldo: [laughs]

L.P.: ...did you see it before it was cut down?

Arnaldo: {With the}, the fourteen...

L.P.: ...fourteen, with all those...

Arnaldo: ...seventeen...

L.P.: I mean, it was, it was a joke, you know, I mean, it was just hilarious,
you know, that, er... but I mean some things, like, 'teach children not to look directly at the sun', you can do, I can do that in assembly, you know, I can say, 'Put your hand up if you think it's-', you know, '-if it's a good idea to look directly at the sun.' And then, somebody'll say, 'No it isn't.' 'Well, why not?' 'Because you could, you know, really damage your eyes, because it's made of fire.' Right, they can all tick off that they've understood that. I mean, most people can understand that, even the little ones. But, other concepts are very hard to grasp, but, you know, I mean... it's all good stuff, we all know that, but I mean, some of it isn't quite appropriate where it should be... and the thing with science is, it's not like, um, maths, which is, you know, you can build upon different concepts... it's not like that, is it? It's kind of, not... you, you're not able to vertically go through it, it's kind of, it jumps from different levels... of understanding, I think, and that's where it's very difficult.

2.267 Arnaldo: Right. What I was going to ask you, if you, if you think you-, whether or not that topic is realistic...?

2.268 L.P.: Which one?

2.269 Arnaldo: Well, for instance, pushing and pulling?

2.270 L.P.: Yes, I mean, I do, I do think it is because it's-

2.271 Arnaldo: No, not asking if you, you think it's {easy} now because you did it, but when you were, are going to start, to set up a new...um... activity with children, er, do you, do you have a look on the National Curriculum and think whether or not what they propose is realistic?

2.272 L.P.: I don't think you're able to do that, you've got to teach it... you've got to, it's statutory.

2.273 Arnaldo: I know that, but, there are suggestion there, so I suppose some things you just...

2.274 L.P.: You've got to teach it all, there's not a suggestion you can leave a bit out. There are suggestions of approach, {it's} programmes of study, and all that sort of thing...

2.275 Arnaldo: ...Exactly, yes...

2.276 L.P.: But...

2.277 Arnaldo: The topics {how should be} dealt with.

2.278 L.P.: Each one, each one's got to be dealt with, otherwise when it comes to the SATS, they don't achieve the level.

2.279 Arnaldo: But when you say that, um, the sun and the sky...

2.280 L.P.: Well, maybe that could be, you know, it's not appropriate for five-year-olds, but it isn't, but when they get to be six or seven, then they can understand it, and have more of a concept of it.

2.281 Arnaldo: That is what I am asking, just to say, well, perhaps the other teacher will do these.

2.282 L.P.: Yeah, because I was a reception teacher, and thought, 'These kids aren't ready for this', but I know that, you know, they'll look at my records and see, 'Ah, she hasn't covered pushing and pulling', so therefore they'll thing, 'This is an area we've got to develop.' That's where your continuity and progression comes in, that if I think, you're not going to teach the whole of, um, Level One in reception, it's, it's a two year programme, isn't it? So I know there are some things that I don't think is appropriate for a reception * teach children, and I think that you... are {fostering} an idea and investigating and exploring, and um... getting interested in the subject is the foundation, because then the... other teachers to build on... when you're doing things that are perhaps a little bit {contextually} more difficult.

2.283 Arnaldo: Mmm. Right. {what do you think} Um, what I was going to ask you was for you to see if you, if you can separate them in sets, how many *

2.284 L.P.: Separate them into sets?

2.285 Arnaldo: Yes.
2.286 L.P.: Of my own criteria.
2.287 Arnaldo: Yes.
2.288 L.P.: How many sets?
2.289 Arnaldo: From one to nine. I mean, you can have just one set or nine sets.
2.290 L.P.: Or two or three or whatever. [pause] *
2.291 Arnaldo: Now, would you like to talk about any of these sets?
2.292 L.P.: Well, I think this is...
2.293 Arnaldo: And justify why...
2.294 L.P.: ...from my, sort of, way of assessing, planning, teaching, they’re kind of my, tools if you like.
2.295 Arnaldo: Right. OK.
2.296 L.P.: This is the kind of realistic side of what really happens, you know, the human side, the emotional side...
2.297 Arnaldo: ...Mmm.
2.298 L.P.: Team building, that kind of thing, * them together, and this is, how children learn.
2.299 Arnaldo: Right. Even when I ask * because, when seeing how you created using the different criteria, you... end up, er... splitting them into groups, two big groups. Um, those three, the bottom three and the top six, kind of nicely split into *
2.300 L.P.: I see, yeah, I’m with you.
2.301 Arnaldo: Alright? Um, So I was just having a look if you had them together, so number one, six and nine, they are not together now because number one isn’t here. And er, emotional, I think.
2.302 L.P.: Mmm. No, this was all, sort of, emotional sort of...
2.303 Arnaldo: {Are proposals still} realistic. Ah well, never mind...
2.304 L.P.: It is, realistic, but the, also the kind of, the human, emo-, yeah, you know, aspect of the whole thing. What really happens.
2.305 Arnaldo: Mmm. And these one and twenty-two, so I missed what you said.
2.306 L.P.: Um, that’s the way children learn, I think, really.
2.307 Arnaldo: But you didn’t put six and nine there, which were together here.
2.308 L.P.: Uuhh. Wh-, so what are you saying, what’s the...
2.309 Arnaldo: I was asking, I was going to ask, um, in a way I ask it already, so you, you’ve classified these nine things in different groups, you know, what I was going to do is just ask you, um, why do you think these two... gathered together and these three gathered together?
2.310 L.P.: Because they’re things that I look at to find out what children know and how they learn, so that I can plan... what to do with them.
2.311 Arnaldo: Right.
2.312 L.P.: They’re kind of indicators to me.
2.313 Arnaldo: Indicators of what?
2.314 L.P.: Of what the children know.
2.315 Arnaldo: And how do you use... what the children already know? How do you take it on board?
2.316 L.P.: Um, well I mean it’s difficult, because you’ve got to differentiate, haven’t you, all the, you know, some children know more than others, but I mean, I suppose then you, you think of working... when you kind of do some work with children, you might all start off together, but the follow-up work would be differentiated, you’d make some a little more difficult than others, and some would just merely colour in a picture of the moon, and the sun, others you, you would expect a bit more from, for them to put in bits, or use words, or you know, just something a little bit more... er... to progress them a bit more, so really you’re looking for differentiation of, of um, teaching strategies.
2.317 Arnaldo: Right. Mmmm. And if you had to list these teaching strategies, which, what would be the top one in terms of... um, these topics or topics like pushing and pulling?
2.318 L.P.: Finding out. Discussing it from, an, er you know, making
assumptions, get them to test out the theories, well, I mean it all sounds a bit too, sort of... um... idealistic, but I mean they've got their own ideas of what happens about things...

2.319 Arnaldo: How do you make?
2.320 L.P.: Well, they'll say, 'That'll do such-and-such' and you go, 'Well, test it out then, go and find out.' You know, they'll say, um, can't think of an instance, um... can't, I can't think of it, but I mean, that's sort of, the way they learn, is that they'll make an assumption... that something will happen if they do something, and you say, 'Well go and do it' and then come back, 'Were you right or were you wrong?', You know, and what happened. Um, I did a lot about work with water... capacity, um, volume, and they made assumptions as, sort of, you know... 'That container holds as much as that container.' 'Why?' 'Because it's fat and that one's fat' and, what have you. 'Well, test it out. How are you going to test it out?' And get them to find out how to test it out, you know; I'll put that one in there and if it spills over it's more, and, what have you, so setting up those sort of strategies for children to test out their own theories.

2.321 Arnaldo: Mmm. Right. I'm a bit worried about your time, to be...
2.322 L.P.: Yes, I've got parents coming in twenty five minutes, and I need to, have a rest, so, shall we continue next Tuesday, I've got down. Is that alright?
2.323 Arnaldo: Yes, no problem.
2.324 L.P.: Is this any good to you, all this?
2.325 Arnaldo: * there is no right or wrong, successful or unsuccessful, so in the next meeting I'm going to ask you whether or not some things I may conclude from these discussions... uh... if there are, well which * things you think...
2.326 L.P.: OK. Right.
APPENDIX 4: Discussion of One Interview

In our conversations, teacher A.W. repeated she was unhappy with her activities on 'gravity' and 'floating and sinking'. Our conversation could thus be used to generate reflection on a teacher education programme, as discussed in chapter 5 (section C). In this appendix, I would like to illustrate how I could take my dialogue with A.W. as material to discuss the theme 'Scientific Knowledge' and 'Scientific Enterprise' with other teachers.

Discussion

Apart from complaining that she was unhappy with her activities on 'gravity' and 'floating and sinking', teacher A.W. also said that, although the preparation for such activities improved with practice, "the concepts just became more confused" (AW2.190). Asked how she planned to go further, she replied that she would avoid doing any floating and sinking activity. On the other hand, she affirmed that she was still keen on 'getting the gravity activity right'. Prepared to study more about gravity, A.W. seemed convinced that the lack of success with this activity had nothing to do with her understanding of the topic, but was connected with the equipment available for conducting the relevant experiment in the classroom. Her remark on the matter is noteworthy. She said:

The problem with the Gravity is just that we need something, design something that make sure that all balls hit the ground at the same time. That was the fundamental problem. And unless I come up with (or the children come up with) some way of doing that... That experiment will not be successful (AW2.200).

The experiment in question resembles Galileo's Tower of Pisa experiment: two balls are dropped simultaneously into free fall. The discussion of these episodes takes on a new meaning when we look at the different positions A.W. took regarding two 'dodgy areas', as she calls 'gravity' and 'floating and sinking'. Her lack of success in the conducting these activities put her in an apparent conflict. She is in favour of inductive teaching and believes, according to her 'philosophy', that this approach is applicable across the board. But in the process of conducting
A.W. lacks knowledge of content in some areas of science and, apparently, also lacks knowledge of the structure of scientific knowledge (Schwab, 1964b). She is not as conscious of the latter deficiency as she is of the former. The case of the experiment on gravity illustrates the following: that A.W. says that "when you drop the balls the weight of them is irrelevant"; that this is her understanding; and that she hopes that is right (AW2.204). She seems content with her understanding of the matter, and unhappy about what happens to the balls when she actually drops them. Because she feels this way, she does not ask herself how she is using the scientific knowledge in question. It strikes me that she applies her knowledge of the law of gravity in, what seems to me, a rather uncritical, almost dogmatic, fashion. It is arguable that teacher A.W. behaves as she does because she does not have a very good understanding of the gravity law. However, had she earlier taken part on a discussion about the syntax of science (Schwab, 1964b, p. 31), she would probably have wondered whether or not the law applies in the circumstances.

It seems sensible to assume the discussion about the syntax of science would have made a difference, particularly after analysing the recording of the activity on gravity which A.W. conducted. The heavier (and smaller) ball consistently came first; no surprise about that. But, A.W. did not question her understanding of the gravity law - as she could had done, in view of such consistent empirical evidence. Instead, she raised doubts about the conducting of the experiment. The pupils, with their seven-year-old wit, pointed out that holes in the objects would probably make a difference to the way the air was passing through them. Not even the logic of such arguments persuaded A.W. to question her understanding; she continued to say that the balls should hit the ground together.

I questioned A.W. about her worries about this activity, asking whether it had really been a complete failure. This is the dialogue that took place:

A.V.: Well... The results weren't right, but was it a complete failure?
Teacher: No.
A.V.: In which ways was it positive?
Teacher: It was positive because it got the children thinking. It got them to look at their own hypothesis, their own theories, they thought about 'gravity...
zones', and 'small air holes', and 'air passing through the ball'... They know quite a lot. In that way it wasn't a failure because they still went through the science processes correctly. And they came with very interesting ideas. But in terms of content... I'm not sure whether progress took part.

A.V.: Why are you so concerned with the content?

Teacher: Because that's what I have to do? That's what the National Curriculum ask me to do. There's a certain amount of content I have to teach in certain amount of time. If I fail, then the children will fail.

A.V.: Is there incompatibilities between them? Between your goals and what you think is the National Curriculum...

Teacher: Not much, no. I think the processes, the way we do things is more important than a final outcome (AW2.205-16).

Analysing this passage it seems that teacher A.W. has not actually realized that the values she holds - of child centredness, of discovery learning, of 'the way things are done being more important than the final outcome' - are all being apparently forgotten or swamped by her concern with 'getting the experiment right'. In other words, she is not conscious of the conflict of principles involved in the practical problem she encountered. For her, there is nothing in the episode that constitutes a dilemma. Even when I point this out, she does not seem to see any significant conflict. I assume she does not see any conflict there because those events are not capable of challenging her.

The fact that A.W. is not conscious of conflicts in her praxis is particularly worth noting, since this teacher gave up teaching 'floating and sinking' in the face of empirical difficulties with this activity. So, even though A.W. does reflect on her practice, her analysis is not critical enough.

Conclusion

By listening to my dialogue with A.W., other teachers would perceive that their understanding of the term scientific process does not necessarily correspond to the scientists' understanding of the term. They would naturally sympathize with A.W., but from their privileged standpoint of external observers they would have the advantage of a distinct perspective and insight into the matter.

If this strategy fails, teachers should be explicitly shown the difference in the use of terms and application of concepts. This does not mean that they would be told about these differences, but that episodes of their own praxis would now be used as
topics for discussion, rather than their abstract conceptions and understandings. Their use of words and expressions - concepts and ideas, therefore - would then be contrasted with the use of them by science experts.

In the case of teacher A.W., although she says otherwise, she relies on knowledge of the products of science (content). That is the reason why she gave up teaching ‘floating and sinking’ and is reluctant to give up teaching ‘gravity’. She thinks she understands the law of gravity, therefore intends to carry on trying to ‘get the results right’. On the other hand, she recognizes that she does not understand the laws of hydrostatics, therefore does not see any point in trying to teach it.

This case also shows ‘science process’ being taken as synonymous with ‘practical activity’. The reasoning necessary to conduct empirical experiments, as well as to determine which claim has the greater authority when a given phenomenon gives rise to competing claims, are also important processes in science. When a teacher’s understanding of these processes is somewhat limited, two reactions are likely. One is to say that ‘anything goes’. This seems to be what A.W. suggests when she refers to children’s hypotheses about the rules objects obey when they are put in water. The other is to deny the value of the actual experiment, attributing, say, the failure of an object to ‘obey the natural laws’ to factors such as inadequate equipment, limitations of the observer and the like.


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