AN INVESTIGATION INTO THE NATURE AND CONSEQUENCES OF TEACHERS' IMPLICIT PHILOSOPHIES OF SCIENCE

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SUMMARY:

The aims of this study were to investigate the beliefs concerning the philosophy of science held by practising science teachers and to relate those beliefs to their pupils' understanding of the philosophy of science. Three philosophies of science, differing in the way they relate experimental work to other parts of the scientific enterprise, are described. By the use of questionnaire techniques, teachers of four extreme types were identified. These are: the H type or hypothetico-deductivist teacher, who sees experiments as potential falsifiers of hypotheses or of logical deductions from them; the I type or inductivist teacher, who regards experiments mainly as a way of increasing the range of observations available for recording before patterns are noted and inductive generalisation is carried out; the V type or verificationist teacher, who expects experiments to provide proof and to demonstrate the truth or accuracy of scientific statements; and the O type, who has no discernible philosophical beliefs about the nature of science or its methodology.

Following interviews of selected teachers to check their responses to the questionnaire and to determine their normal teaching methods, an experiment was organised in which parallel groups were given H, I and V type teaching in the normal school situation during most of one academic year. Using pre-test and post-test scores on a specially developed test of pupil understanding of the philosophy of science, it was shown that pupils were positively affected by their teacher's implied philosophy of science. There was also some indication that V type teaching improved marks obtained in school science examinations, but appeared to discourage the more able from continuing the study of science. Effects were also noted on vocabulary used by pupils to describe scientists and their activities.

Key Words: Philosophy of Science
Science Education
Teaching Methods

PREFACE

This work was carried out during a four year period beginning in October 1977. During this time the author was a part-time research student at the University of Aston in Birmingham and also working as a deputy headmaster of a 13-18 comprehensive school.

Thanks are due to Mr. N. Stears, Science Adviser for Gloucestershire, and Mr. K. Lambert, General Inspector responsible for Mathematics and Science in the Metropolitan Borough of Dudley, who arranged for access to teachers in their local authorities for the pilot questionnaire and the main survey respectively. I should like to thank three heads of department: Mr. M.J. Newbould and Mr. M.J. Powell for carrying out tests on the pupils in their schools during the development phase, and Mr. B.H.W. Hughes for allowing the teaching experiment to take place and for risking the disruption of his department. Many pupils must also be thanked for filling in test forms and some for enduring the styles of teaching to which they were exposed in the teaching experiment. I am most grateful to my wife for all her help and to Mr. A.B. Morris for pointing out many of the mistakes in the first draft of this thesis. Finally, I am particularly indebted to my supervisor, Dr. Peter Coxhead, for his continual guidance and support during the four years of this investigation.

I declare that this thesis is not, in whole or in part, substantially the same as one which has been submitted to any other university. Except where specifically stated, the work is original; some of the tests used were however modifications of ones produced originally by others and details of the test development is given in the main text.

David R. Dibbs.

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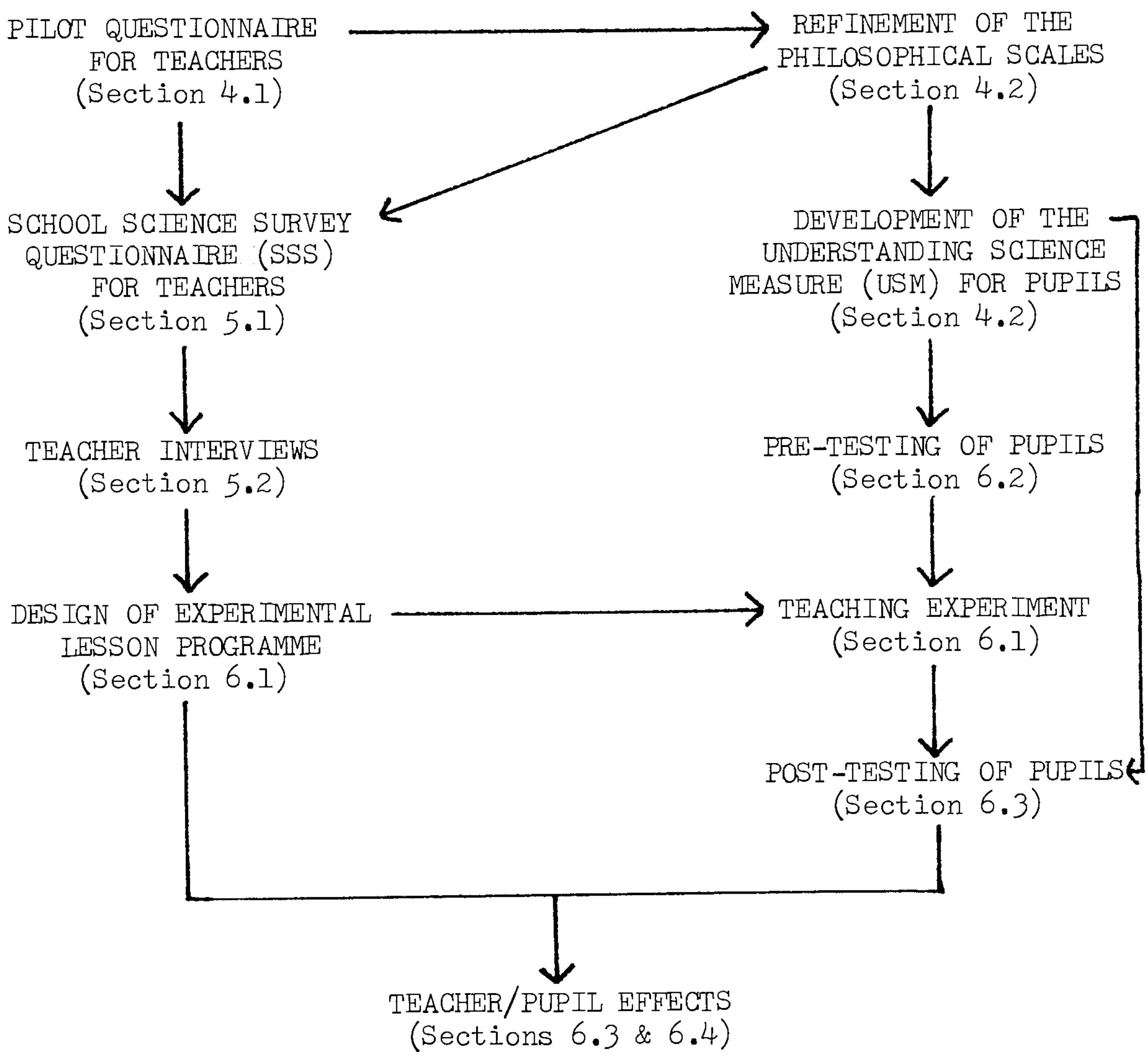
THE RESEARCH PLAN

As this study is made up of several interconnected strands, the following plan may be useful as an aid in understanding how the stages of the investigation described in various sections of Chapters 4, 5 and 6 relate to each other.



CHAPTER 1:

INTRODUCTION

The origin and development of a research project depends to some extent on the nature of the problem to be investigated, but it is also dependent on the background and personal experiences of the researcher. These may explain his interest in the topic and his reasons for approaching it in a particular way. This introduction is an attempt to outline the initial ideas and experiences which led to the present study.

Teachers of science subjects in schools may sometimes have the experience of hearing their non-science colleagues describe the sciences as 'factual' subjects. This may be taken to mean that science courses, at least at school level, are concerned with the transmission from teacher to taught of some factual information which is thought of as being 'scientific' in nature. This is, at least by implication, saying that science courses are distinguished from others by their content, but that they are similar to courses in, say, History or Religion in that the teacher disseminates factual material, the subject content, to pupils. In their turn pupils are expected to note, to learn and to be tested upon that subject content.

Although it is possible that some teachers of science also see their subject in this way, it is probable that some regard science as distinct from other areas of human knowledge in more than just its factual content. Even if a school science course is factual, it can be argued that the facts in which it consists are different not only in detail but also in the ways in which they have been established as part of the body of knowledge or in the ways in which they can be justified as accurate and truthful. Science may be distinguished from other areas of knowledge, or from other school subjects, not only by its factual content but also by reference to the methods adopted in arriving at and in supporting that content.

The question of how teachers and others view science interests the present author for several reasons. Since completing his science degree at university, the author has had some fifteen years experience of teaching science to pupils in the 11-18 age range, including seven years leading a team of science teachers in a large mixed comprehensive school in the Midlands. During this time he achieved some notoriety in the school staffroom by stating that the main aim of the science courses was to teach the pupils to 'understand how Mr. Dibbs's mind works'. It was intended that this should serve as an introduction to the methodology adopted by scientists. A background which includes study for a degree in philosophy and an involvement with the introduction of science curriculum projects may be a sufficient explanation for this extreme viewpoint. It may also explain the desire to investigate the nature and the extent of understanding of philosophies of science within the science teaching profession. Indeed a training in philosophy and experience in science teaching makes it possible to execute a classic 'pincer movement' upon a research problem in this field.

Although one would not want to dismiss as fruitless all attempts to produce curricular innovation that are based on exploiting content links between traditional school subjects, for some may be interesting and successful (e.g. Hall 1976, pp 268-274), an interest in curriculum changes having their origin in similarities of method was one of the starting points in the present study. Combined science and mathematics courses or those linking science with other subjects such as geography can be advocated on grounds of overlapping subject content. However, if one considers the intellectual processes involved, there could be more justification for suggesting closer cooperation between scientists and those teaching craft subjects. Ideas for the development of craft courses which aim to promote creativity in pupils by emphasizing the design process rather than the practical skills associated with the production of a finished product (Morris 1977) are examples of a similar line of thought affecting another area of the school curriculum. Indeed the design process is in some ways akin to one view of the methodology of science, that put forward by Karl Popper (1968, 1969, 1972).

Thus interests in the philosophy of science, in science education and in curriculum change served as triggers for this investigation. Initial and somewhat inexact questions were formulated to act as a basis for developing the research plan. These questions were:

1. Do teachers have an understanding of the philosophy of science?
2. Does this understanding affect their view of science itself and its place in the curriculum?
3. Is there a connection between a teacher's philosophy of science and his teaching style, particularly in relation to his use of practical work in lessons?
4. If there are different teaching styles, do these in turn influence the pupils' understanding of the philosophy of science?

This line of research reflects the belief, shared by many (e.g. Robinson 1969, Finch 1971), that teaching pupils about the nature of science and its methods is at least as important as imparting details of specific facts and theories. This view is shared by at least some teachers engaged in introducing science to younger pupils (Dark & Squires 1975).

The factors which influenced the choice of a research topic also had a great effect on the methods chosen to carry out the investigation. There is a paradox in the education system of this country. It appears to be dedicated to bringing students to the boundaries of human knowledge as a preparation for carrying out original research. Yet the majority of those maintaining the system, the schoolteachers, are suspicious of, and choose to ignore, the results of any research concerned with education itself. As one can hardly write with any honesty about science education unless one is prepared to use the methods of the scientist to investigate the educative process itself, interests in the philosophy of science and in its effects on science education are inevitably bound up with a belief that these things should be studied empirically.

Combining educational research with teaching has both advantages and disadvantages. It prevents the researcher inhabiting an ivory tower isolated from the realities faced by real teachers confronting living, breathing pupils in actual classrooms and school laboratories. However it does also prevent the use of certain techniques, such as extensive observation of teachers taking their classes in a variety of schools, because of the difficulties involved in deserting one's own classes. Thus the main research techniques eventually chosen were the use of posted questionnaires, the use of group-administered tests, the interviewing of teachers outside of normal school hours, and a relatively long-term teaching experiment conducted by the researcher in his own school.

SUMMARY OF CHAPTER 1:

Interests in the philosophy of science, in science teaching and in curriculum change led the author to choose this particular topic. This study sets out to investigate:

a) science teachers' understanding of the philosophy of science,

b) whether a teacher's philosophy affects his teaching style, and

c) what effects this may have on pupils in his classes.

CHAPTER 2:

CONTEXT OF THE STUDY

As a background to this project it is necessary to review three distinct areas. The first is the literature on the philosophy of science to which science teachers could have access and which may therefore influence their understanding in this field. The second area of interest concerns the history of the development of science as a component of the school curriculum, and the third consists in reports of research in related fields which could have some bearing on the design of this investigation.

2.1 The Philosophy of Science

2.1.1 Scientific Method

In this century the prestige of the natural sciences has undoubtedly been great. This prestige has been acquired because of the aid the sciences give to modern technology and because of their successful supplanting of ancient mythologies. The result of this very success has given rise to the belief that there is something special about science and its methods. To claim that something is 'scientific' is to imply that it has some special merit or reliability, yet we apply the term 'science' only to a small group of highly developed branches of knowledge. Nobody would claim that a railway timetable or a telephone directory is scientific in spite of the accuracy and truth of its contents (Cohen & Nagel 1963, p 191). It is not so much content as methodology which is used to separate science from non-science. Although the sciences differ in their subject matter, what remains constant in all sciences is the persistent search for truth and the ways in which the search is conducted.

The main concern of those interested in the philosophy of science has been to describe and analyse the logical foundations of scientific method and thereby to make it clear how science may be distinguished from other human activities. Although authors disagree about the precise criterion for demarcation, there is general agreement about the dependence of all true sciences on empirical evidence. The disagreement is about the nature of the relationship between the established and accepted knowledge and its associated evidence. There have been recent attempts to find a satisfactory description of the actual methods adopted by scientists (e.g. Kuhn 1970, Lakatos & Musgrave 1974) but for the purposes of this investigation it seemed more appropriate to take simpler views of scientific methodology as a starting point. Neither science teachers nor pupils are professional philosophers; nor are they practising scientists. Therefore they can be expected to have an understanding only of those philosophical issues concerning science which have become more firmly established as part of a more general cultural background.

For this reason, first consideration was given to the way in which scientific method is described in the kind of books which teachers read during their period of training. Even if such books do not affect how the teachers think, they reflect the level of understanding that is expected of those entering the teaching profession. A fairly typical account of scientific method can be found in some philosophy of education texts. For example O'Connor (1957) puts it thus:

> All the sciences started as branches of philosophy in the sense that the Greek word 'philosophia' was originally used in a very general sense to cover all investigations into the nature of man and of the universe. But in the sixteenth and seventeenth centuries a discovery was made about scientific method which seems to us nowadays trivial and obvious, perhaps because it is the unquestioned foundation of a civilization based on the achievements of natural science. This was the discovery that if you want to know what the world is like, you have to look and see. As a practical maxim, this was not always a commonplace. There have been long periods in the history of the world and no doubt there

> will be again, when people were discouraged from looking either by intellectual fashions of their time or because the prevailing religious or political outlook might conflict with what observation would tell them. And of course mere observation of the world was not enough to lay the foundations of science. The results of observation had to be refined by experiment and by measurement and the direction of observation controlled by hypothesis. But once man had learned the lesson of 'respect for fact', natural science started on that brilliant epoch of development which has marked off the last three hundred years from all other periods of history. ... with the systematic adoption of the experimental method and the transmission of natural laws into mathematical modes of expression, men were at last developing a large body of reliable and testable knowledge.
> (op.cit. pp19-20)

An analysis of passages such as this reveals three essential components in the scientific method described. The first point emphasized is the importance of <u>observation</u> as a basis for scientific knowledge. Second is the value of <u>hypothesis</u> for determining the direction of observation and as an aid in deciding on the types of experiment to be performed. Finally there is the respect for the <u>facts</u> that are discovered and established as true by the highly successful methods employed by the scientists.

It must be noted that these three are intended to be seen as equally important components of what distinguishes science from other fields. They are not to be regarded as alternative criteria of demarcation, in some way in competition with one another for primacy of position. However much of the controversy concerning the philosophy and methodology of science seems to be based on the premise that the three are in some sense rivals. Various authors seem to argue that one should be chosen in preference to the others as the line of demarcation. Such a disagreement can be seen as a matter of one's point of view. At a distance it may appear that all three are of equal importance but, as one approaches any one position more closely, the others recede into the background. An extreme viewpoint may be so close to one corner of the triangle that the other two are completely obscured.

For the purposes of this investigation it was decided therefore to classify a teacher's philosophy of science according to which of the three components seemed to dominate from his viewpoint. These viewpoints can be said to correspond to three alternative views on the philosophy of science which can be detected in the literature. These are termed the verificationist philosophy, the inductivist philosophy and the hypothetico-deductivist philosophy. Each is described below.

2.1.2 The Verificationist Philosophy

Chalmers (1976) begins his discussion on the nature of science by outlining what he considers to be the popular view of scientific knowledge: scientific knowledge is accepted as reliable knowledge because it has been objectively proved to be true. It is firmly based on facts derived from experiment and is independent of personal opinions, preferences or imaginings. In the extreme version of this view of science, the respect for the established 'facts' and their truth or reliability outweighs any consideration of the way in which the facts may have been established. What is important is that they can be proved to be true, and the place of experimental work consists in its ability to verify the facts of the case. From this point of view science is a factual study concerned with understanding the true nature of the physical world. Scientific facts are regarded as true because they have been in some sense verified by experiment, something which is conspicuously absent in the case of, say, religious 'facts'. For those who hold with this view, the criterion for demarcation of science is a criterion of verification not unlike that proposed by the logical positivists and perhaps derived from that tradition which has been a part of the intellectual climate of the educated man since 1936.

This was the year in which logical positivism was introduced to the English reader by the publication of Language, Truth and Logic. This book, written by A.J. Ayer, has become one of the most widely read introductory philosophical texts. Ayer (1971) outlines the principle of verification as follows:

> The criterion which we use to test the genuineness of apparent statements of fact is the criterion of verifiability. We say that a sentence is factually significant to any given person, if, and only if, he knows how to verify the proposition it purports to express - that is, if he knows what observations would lead him, under certain conditions, to accept the proposition as being true. (p 48)

For the logical positivists any statement about the world, if scientific, is supported by observation or demonstrable by experiment, and it is this support or demonstration which gives the statement its scientific respectability and acceptability. On the other hand, statements which cannot be demonstrated to be true by the use of such observations or experiments are excluded from the scientific domain. As Ayer remarks (op.cit. p 49) 'one cannot conceive of an observation which would enable one to determine whether the Absolute did, or did not, enter into evolution and progress'. Although statements of this kind could be taught to, and learned by, pupils they should find no place in a science course. This tradition of basing science upon what can be proved by our sense data has a respectable history in Britain and is derived from the philosophy of Locke, Berkeley, Hume and Russell. It is by no means a useless way of distinguishing scientific truths from metaphysical statements. Ayer asserts that 'philosophy must develop into the logic of science' (op.cit. p 202) and he presumably intended that his work should serve in some ways to fulfil that aim.

Ayer later modified his views about the principle of verification, not because he regarded it as misconceived, but because he was still unable to find an entirely adequate way of formulating it. However Ayer's subsequent willingness to accept a watering down of the verification principle is unimportant here. For the last couple of generations, educated non-philosophers have thought of contemporary philosophy as logical positivism. Talking some thirty five years after the publication of the first edition of the book, Ayer (in Magee 1971) explained how this had come about:

> I suppose it is partly just because of the success of Language, Truth and Logic. This is a book more widely read than most philosophical books, and one that I suppose has been pretty influential on what has happened since. (p 59)

Throughout this study it is not the views of philosophers themselves that are called into question. What is being considered is the influence these have had on the beliefs of educated non-philosophers.

Science teachers are not professional philosophers and, in many cases, any philosophy they have been taught as a part of their training would have been presented to them by non-philosophers. If their teaching methods and the picture of science they communicate to their pupils are affected by their philosophy of science, then this philosophy, to a philosopher, would be considered to be out of date or to be based on oversimplifications or misunderstandings of the original philosophical doctrines.

It is not being suggested here that logical positivists have a one-sided or necessarily inadequate view of science. However their insistence that any non-analytic statement must be susceptible of proof to escape classification as nonsense can be seen as an excuse for others to believe that any accepted scientific statement has been so verified that its truth can be accepted as beyond all reasonable doubt. Once this step has been taken, respect for the 'facts' and reliance upon them could be so great that the methods used to bring about their discovery pale into insignificance. Then the relevance of experiments, especially so in the educational context, lies in their ability to demonstrate the truth of established scientific doctrines to anyone who has doubts.

This view of science, with its emphasis on respect for facts, lacks a real understanding of the methodology of science and the relationship between experimentation and scientific thinking. It appears to use a misunderstanding of the positivist philosophy to justify the common sense view of science as simply a well verified collection of facts. It will therefore be apparent why it was decided to term this view of science the verificationist position. This is to be regarded as the simplest and least sophisticated of the three extreme viewpoints.

2.1.3 The Inductivist Philosophy

The second of the three philosophical stances is the one that puts its emphasis on the primacy of observation. Historically it is derived from the thinking of Francis Bacon, published in his Novum Organum of 1620. Bacon outlined two ways of seeking and finding the truth. First he suggested that the mind may proceed from sense perceptions to the most general of axioms and from these deduce less general propositions. Secondly he held it is possible to build immediately obtainable axioms on sensory data and the perception of particular instances and then move gradually and patiently to more general statements and laws which describe nature. Bacon regarded the first way as an unsatisfactory method of obtaining truth because it involves a jump from an insuffiecient basis of experience to general conclusions. It could lead to rash and premature generalizations. For Bacon, the second was the true way: the mind moving gradually from a careful and patient examination of particulars to the more general interpretation of nature.

Although not a scientist, Bacon must receive the credit for realizing that a 'new organ' was needed. This was a new logical method based on induction, instead of the traditional deductive logic of Aristotle. The essence of the Baconian method lies in drawing up lists, recording positive and negative instances of the phenomena under investigation and then making careful comparisons looking for patterns of uniformity.

Much of Bacon's work anticipated that of John Stuart Mill, who is usually regarded as the philosopher who has given the most complete account of the new inductive logic as applied to the empirical sciences. Bacon's recommendations were elaborated by Mill and became his 'methods of experimental enquiry'. The drawing up of lists while searching for the causes of phenomena is transformed into the methods of agreement, disagreement, concomitant variations and residues (Mill 1961). In the method of agreement, one collects details of conditions present in all positive instances of the phenomenon being studied, for its cause must be present every time the phenomenon occurs. In the method of differences, one notes similar circumstances with and without the phenomenon under study, for nothing can be the cause unless the phenomenon always occurs when it is present. In the method of concomitant variation, one is required to note things which vary in a similar way to the phenomenon, for only things changing at the same time are likely to be causally related. The method of residues advises the subtraction of already known causal connections, in the hope of isolating those which might influence the unexplained phenomenon.

Mill's methods of induction have been accepted as one of the standard descriptions of scientific procedures. A common view of scientists is that they slowly and patiently collect data by observation, keeping careful and objective records of their findings.

Application of the new inductive logic leads gradually to a better understanding of the universe. Joad (1963) remarks

> ...the fact that what has been found out is small in comparison with what remains, does not imply that it is not, therefore, true, nor does it suggest that the method which has been followed is mistaken. This method is the slow and patient accumulation of evidence collected in a spirit of impartial acceptance of objective fact. The study of this evidence has been conducted in a mood of impersonal disinterestedness and freedom from utilitarian preoccupations, which is not alien to the spirit of the great religions. It is by such methods and in such a spirit that the triumphs of science have been won. (p 266)

This philosophical viewpoint with its insistence on the priority of observation was termed the inductivist position. From this viewpoint science is an observational activity. The scientist is seen as collecting and recording with infinite care large numbers of factual observations concerned with phenomena which attract his attention. After or during the period of collection, certain patterns or regularities may become discernible and lead him to propound a generalization or law which describes the occurrences in a coherent way. Science is seen as an activity which establishes general laws of nature on the basis of large amounts of supporting evidence. This view of science even receives some support from descriptions of their work by famous scientists such as Newton or Darwin. It has been incorporated in many standard books concerned with describing and clarifying what is characteristic in scientific progress.

For example, Harre (1960, p 178) suggests that science needs to establish certain things if it is to achieve its aims. Scientists require:

> (i) A complete system of rules for making predictions. That these should be fully satisfactory for their purpose can be ensured only by basing them upon a complete system of well-grounded generalizations in which the world is accurately described.
> (ii) A fully coherent system of laws. The generalization-prediction rules which are the laws of nature should be expressed in a system where all are the logical consequences

of a small number of principles.

To many people science does seem to consist in a number of laws of nature which summarize an otherwise bewildering array of individual happenings. Therefore it seems reasonable to argue that scientific activities are those which lead to the establishment of such laws. As these laws are based on many individual instances, scientists in training need to be given experience in observation, data collecting and the making of inductive generalizations on the basis of the collected evidence. That inductive logic is regarded as the cornerstone of the scientific edifice is borne out by the frequency with which authors of philosophical texts attempt to criticize or justify the method (e.g. Hume 1939, Pt. 3; Russell 1912, Ch. 6; Cohen 1970; Stove 1973; Swinburne 1974).

2.1.4 The Hypothetico-deductivist Philosophy

One answer to the problem of induction discussed in many philosophy books is startlingly simple: this is the doctrine that there is no such process as induction; the notion does not describe what scientists actually do, nor is it the rationale of what they do.

In 1934 Karl Popper published his first book, Logik der Forschung (literally 'The Logic of Research'), which outlined his very different view of the methodology of the sciences. Unfortunately the book did not appear in an English translation, under the title The Logic of Scientific Discovery, until a quarter of a century later. In this book Popper proposed a criterion of falsifiability as the solution to the problem of what distinguishes science from other activities. A theory or statement is scientific only if it is capable of being refuted by experience. On this view, no laws of nature are certain or verified. They are hypotheses which, so far, have not been refuted in spite of concerted attempts to do so. They may be falsified or modified at any time and are therefore subject to continual experimental test, but their origin is unimportant. Whether they arise from inductive generalization or from armchair dreaming is irrelevant; what makes them scientific is their susceptibility to testing and their continued, even if temporary, survival.

In a radio discussion of his philosophy, Popper put it like this:

> On the pre-scientific level we hate the very idea that we may be mistaken. So we cling dogmatically to our conjectures, as long as possible. On the scientific level we systematically search for our mistakes, for our errors. This is the great thing: we are consciously critical in order to detect our errors. Thus on the pre-scientific level we are often ourselves destroyed, eliminated, with our false theories; we perish with our false theories. On the scientific level, we systematically try to eliminate our false theories - we try to let our false theories die in our stead. This is the <u>critical method of error elimination</u>. It is the method of science. It presupposes that we can look at our theories critically - as something outside ourselves. They are not any longer our subjective beliefs - they are our objective conjectures. Thus the general picture of science is: we choose some interesting problem. We propose a bold theory as a tentative solution. We try our very best to criticize the theory; and this means that we try to refute it. If we succeed in our refutation, then we try to produce a new theory, which we shall again criticize; and so on. In this way, even if we do not succeed in producing a satisfactory theory, we shall have learned a great deal: we shall have learned something about the problem. We shall know where its difficulties lie. The whole procedure can be summed up by the words: bold conjectures, controlled by severe criticism which includes severe tests. And criticism, and tests, are attempted refutations. (Magee 1971, p 73)

Unlike philosophers who follow the inductivist tradition, Popper does not see observation and data collection as having either logical or temporal priority in the scheme of things. It is the formation of the hypothesis, the bold conjecture, which takes priority. Observation and experiment occur in the second stage, the testing of tentative theories to eliminate errors. As Popper says later in the discussion quoted above:

> According to my view, observation and experiment are essentially <u>ways of testing out theories</u>. They may thus be

regarded as belonging to the critical discussion of the theories. (op.cit. p 73)

The growth of science would then consist in the identification of problems, the proposal of possible solutions, an attempt at error elimination by criticism and experiment, leading to a solution (possibly) and more problems (probably). This is expressed schematically by Popper (1972, p 287) as follows:

$$P_1 \longrightarrow TT \longrightarrow EE \longrightarrow P_2$$

Here 'P' stands for a problem; 'TT' stands for tentative theory; and 'EE' stands for attempted error elimination. Often in practice several hypotheses or tentative theories will suggest themselves as possible solutions to a particular problem and this may also be represented schematically:

$$P_1 \begin{array}{l} \nearrow TT_a \longrightarrow EE_a \longrightarrow P_{2a} \\ \longrightarrow TT_b \longrightarrow EE_b \longrightarrow P_{2b} \\ \searrow TT_n \longrightarrow EE_n \longrightarrow P_{2n} \end{array}$$

(op.cit. p 287)

The crucial stage in this scheme is not how one arrives at tentative theories but how they are tested, although the ability to engage in creative thought leading to hypotheses is a necessary precursor to all deductions of testable conclusions. Formulation of hypotheses is central to this view of scientific method and must take place before criticism and before the design of experimental tests.

Strictly one should call Popper's view of science a falsificationist position for it is the attempt at refutation which characterizes his method, but, as his scheme lays great emphasis on proposing hypotheses from which experimentally testable conclusions can be deduced, the philosophical position derived from his doctrines was termed the hypothetico-deductivist position. This is the third of the three extreme viewpoints of science to be investigated in this study and, like the other two, it gives rise to certain expectations of an elementary science course. For a hypothetico-deductivist, the training of future scientists needs to include practice in problem solving, that is practice in formulating and testing hypotheses, as well as information about which theories are currently held by the scientific community.

Although there are other accounts of the ways in which scientists conduct their affairs (e.g. Kuhn 1970) which suggest that the Popperian doctrines cover only a limited part of what has contributed to scientific advance, it is the hypothetico-deductivist position which has gained the support of practising scientists (e.g. Medawar 1967 & 1969) and which has become the current orthodoxy (e.g. Donnelly 1979; Ziman 1980, pp 63-64).

This view of science, together with the verificationist and inductivist views described above, has become part of our general cultural heritage. One does not need to be a philosopher or even to have read widely to have encountered some or all of these views of scientific method. Even if none of these is entirely accurate in describing the true practices of research workers, they all have a great measure of accessibility. It would not therefore be surprising if these philosophies have influenced those who teach science in our schools and those who plan courses for others to teach.

2.2 A Brief History of Science Education in Schools

2.2.1 The Introduction of Science

The inclusion of science as part of the curriculum in British schools is of relatively recent origin. One of the earliest attempts at science teaching was made at the City of London School when a part-time appointment was made to teach chemistry and natural philosophy in 1839. By 1847 the school boasted a full-time chemistry master who included practical demonstrations in his lessons. Arnold introduced physics at Rugby in 1837. In 1859 a science lecture room and laboratory were built there, when Temple was headmaster and James Maurice Wilson science master. This was the first purpose-built science building in a public school (Brock 1977a) and Wilson taught all the boys in the 14-16 age range for two hours per week. However only the most proficient and trustworthy boys were allowed into the small laboratory which could accommodate only six pupils at a time. With the help of his colleague, F.E. Kitchener, Wilson introduced botany into the curriculum at Rugby in 1865.

Despite such efforts there were few openings for science teachers in the middle of the last century (Tasker 1977) although some trade schools taught science and the publication of elementary science textbooks by writers such as John Charles Buckmaster supplied a growing need from 1870 onwards when science became accepted as an elementary school subject. No doubt the introduction of science into schools was encouraged by the universities of Cambridge and Oxford starting science degree courses in 1851 and 1853 respectively. A faculty of science was established in the University of London in 1860, although science teaching in the university was in practice well supported before that date (IAAM & SMA 1958).

By 1895 the Sixth Report of the Royal Commission on Scientific Instruction and the Advancement of Science (known as the Devonshire Commission) was recommending that in all public and endowed schools a substantial portion of the pupils' study time should be devoted to natural science. The Commission recommended not less than six hours per week for this purpose and advocated the construction of school laboratories to supply accommodation for practical work. All those concerned with the introduction of science into schools recognized the need for practical facilities to enable teachers to demonstrate and pupils to experiment for themselves.

The importance of practical work was stressed by Professor Henry Armstrong of the Central Technical College, City and Guilds of London Institute (Armstrong 1910). His heuristic or discovery method aimed at placing the pupil in the position of the original investigator and facing him with the problems of those who carry out original scientific research. Armstrong whole-heartedly committed himself to promulgating the notion that understanding comes through doing. Precisely what was learned (information) was less important, at least in the early stages, than the method (process) involved in learning, thinking or finding out about something (Brock 1977b). In a report he made to the Education Section of the British Association for the Advancement of Science in 1902, Armstrong was able to point to over a thousand science laboratories in British schools due in large measure to his campaigning.

In practice a child, with a child's background knowledge and experience, could never in the time available discover enough for him to reach the point where he could make real contributions to the advancement of science and so the heuristic method came to be regarded as supplementary to class teaching rather than as a substitute for it.

However Armstrong's publications are usually seen as a turning point in the development of science education by historians of education. For example Curtis (1967) says:

> The heuristic method sounded the death-knell of the old object lesson and emphasised that the teaching of science is an affair of the laboratory and workshop rather than the classroom. The teaching of elementary science became more practical, and oral lessons and demonstrations were superseded by laboratory work in which the pupils handled apparatus, carried out experiments, and drew their own conclusions from the observations and experiments they had made. (p 296)

In fact disagreement about the aims and methods of science teaching were present from its first introduction (Layton 1973). By about 1850 Henry Moseley, the first HMI to have a background in science and mathematics, was encouraging the teaching of science for utilitarian reasons. Scientific knowledge was something to be understood and used, so the purpose of 'experiments' was merely to make lessons more vivid than verbal accounts alone. In contrast John Stevens Henslow, the professor of botany at Cambridge and friend of Darwin and Huxley, saw the educational value of science primarily in being exposed to the process of scientific enquiry. Individual experimental work was absolutely necessary if science education was to have any real value. For over a hundred years this issue has divided those concerned with teaching science. The utilitarian viewpoint had the greatest influence in the first half of this century and what has happened more recently may be seen as a reaction to this.

In spite of the encouragement of educators such as Henslow or Armstrong, the teaching of science during the period 1900-1960 was essentially elitist in that it was viewed as a precursor of university education for those who might be considering careers in science, engineering or medicine. Science was not valued in itself as a contribution to the cultural background of all future citizens. In such a climate it was natural to favour teaching methods which ensured the passing on of factual content and general principles. Demonstrations were often preferred to individual practical work by pupils.

> An individual experiment may be spoilt at one stage owing to lack of skill or knowledge, but in a demonstration the teacher prevents such failures by anticipating difficulties. Alternatively, the teacher can show definitely how one unexpected factor adversely influences the result.
> (Newbury 1958, p 139)

In his book Newbury advocates a balance between pupil practical work and teacher demonstration, but it is clear from the above passage that the pupils must always obtain the 'right results' and an appropriate teaching approach employed to ensure that this is indeed the case.

In the mid-sixties a 'wind of change' swept through education. Prior to comprehensive reorganisation there was a realization that science should be part of the curriculum for all pupils. The Newsom Report (1963) had the following to say about science teaching:

> The pupils are living and will live in a world which is permeated with scientific reference. It is not a mere side issue that science at school should help them to deal with this situation ...
> Much scientific knowledge, even of science teachers, is hearsay; someone trustworthy is being believed. The pupils ... talk about atoms, molecules, electrons and they may read about a large number of other so called particles. Could they not discuss the credibility of what they read? ... They might be stirred by the thought that all our theories represent temporary resting places in an unending quest ... Might not Newton's famous words about being on the seashore with the whole ocean of truth undiscovered before him make an appeal to ordinary boys and girls as much as to the sixth former? (p 146)

Not only was this suggesting that science should be available to all as a component part of the normal school curriculum, but that science courses should be revised in the interests of the majority who would never be members of the science sixth form or consider scientific careers. The report advocated science courses which not only question the basis of scientific knowledge but also attempt to relate that knowledge to the everyday experiences of the pupils and to the moral and social problems faced by today's citizens, aspects which were severely neglected in the traditional academically orientated courses then offered in most schools.

In the same year a small book was published in which Bassey (1963) outlined the results he had obtained in an investigation of scientific knowledge and attitudes of non-science university undergraduates. Only 11% of his sample were able to describe scientific method correctly (sic) including the testing of hypotheses and most reported their school science courses to have been a catalogue of facts to be memorized for examinations. Bassey's conclusion was that science courses were not meeting the needs of the academic non-scientists let alone those of the less able majority.

At the same time as many local authorities were implementing their schemes for comprehensive reorganisation, a number of curriculum projects, perhaps inspired by the American experience with BSCS, CHEM Study, CBA and PSSC, were published and became available to science teachers generally after a period of restricted trials. These projects, sponsored by the Schools Council and/or the Nuffield Foundation, have had a widespread effect which is out of all proportion to the number of pupils following the schemes as written. Although less than 20% of candidates at O and A level are entered for Nuffield examinations (Booth 1975), most examination boards have revised their normal syllabuses to bring them to a compromise position between their former style and that of the Nuffield projects. The late sixties can be seen as an important turning point in the history of science education because of the influence of what is sometimes termed the curriculum reform movement.

2.2.2 The Curriculum Reform Movement

The curriculum reform movement in science education can be seen as a reaction to the views quoted by Bassey (1963). There was a strong feeling among science educators that a move should be made from teaching fact-laden courses towards providing ones planned to emphasize the processes of scientific enquiry (e.g. Jevons 1969, p 80). New curriculum projects were concerned with showing science as a process for generating knowledge (e.g. BSCS 1965, p 6) rather than as a parcel of established fact. It is often thought that the Schools Council and Nuffield schemes introduced between 1962 and 1973 (see Table 2.1) sought to increase the amount of practical work in school science courses, but this was not quite the case. They were as much concerned with changing the type of practical work as with altering the absolute amount because

> ... practical work which only asks a pupil to verify some law that has already been verified thousands of times before is hardly an experiment worthy of the name. But, put another way, if the class is working as a whole to test some hypothesis under the guidance of the teacher a question can be asked which leads all pupils to the same conclusion.
>
> (Peterson 1965, p 88)

Thus the curriculum reform movement can be regarded as making a contribution to the long standing disagreement about whether school science should be more concerned with the utilitarian aspects of knowledge or with the challenges of problem solving. Certainly the Nuffield O level schemes were planned to introduce experimental work not simply to illustrate theoretical points made in earlier lessons but to promote genuine testing of hypotheses put forward by pupils or by the teacher. It is tempting to see this debate in terms of the traditional verificationist approach and a newer Nuffield hypothetico-deductivist one.

As each curriculum project had its own organisers and team

Table 2.1 Major Science Curriculum Projects, 1962-73.

Project	Age Range	Ability	Published
Nuffield Junior Science	(5)7-11	All	1967
Science 5/13	5-13	All	1972
Nuffield Combined Science	11-13	All	1970
SCISP (Patterns)	13-16	Top 20%	1973-4
Nuffield O Level - Biology	11-16	Top 20%	1966-7
Chemistry	11-16	Top 20%	1966-7
Physics	11-16	Top 20%	1966-7
Nuffield Secondary Science	13-16	Less Able	1971
Science for General Education	12-16	All	1969
Scottish Alternative - Physics	12-16	Top 40%	1962
Chemistry	12-16	Top 40%	1962
Project Technology	Secondary	All	1972-3
Nuffield A Level - Biological Science	16-18	Pre-univ.	1971
Chemistry	16-18	Pre-univ.	1970
Physics	16-18	Pre-univ.	1971
Physical Science	16-18	Pre-univ.	1973
Scottish Certificate of Education Exam. Board: Certificate in Sixth Year Studies - Chemistry	17-18	Top 10%	1968-9
Physics	17-18	Top 10%	1968-9

Notes: 1. Science 5/13, SCISP (Patterns) and Project Technology were Schools Council Projects.

2. The Scottish scheme, Science for General Education, was developed for all abilities in the 12-14 age range and the less able 14-16 age group.

3. The Scottish Alternative Chemistry and Physics Syllabuses were published by the Scottish Education Department.

members, it is an oversimplification to talk of a 'Nuffield approach' or a 'Nuffield philosophy'. However it is possible to detect a certain amount of agreement between the various writers on project aims. Fairly typical of the aims of a curriculum project are those of the Scottish scheme, Science for General Education, which hoped that pupils would acquire:

1. some knowledge of the empirical world around them.
2. a little of the vocabulary and grammar of science.
3. an ability to observe objectively.
4. an ability to solve problem situations and think

scientifically, and

5. an awareness of the culture which is science.

(Mee, Boyd & Richie 1971, p 4)

To achieve these aims, particularly the last three, 'discovery' methods were recommended as essential. To benefit from the course pupils 'must be active participators and not passive receptors' (op. cit. p 5).

The first Nuffield schemes to be published were the O level courses and these were intended to foster the investigational approach. Even the biology team, the only one which found it necessary to produce pupil textbooks for each year of the course, was criticized for including too little factual information on some topics (Barnard 1968). At least the publication of pupil texts means that children can read about the aims of the course for themselves rather than having to depend on their teachers telling them what they may have read in the teachers' guides. In the Nuffield Biology scheme, each pupil text has a 'Preface - To the Pupil' which states:

> Experiments are not intended to prove things you already know; they are to investigate whether something does or does not happen so that you can form hypotheses which, themselves, can be tested by further experiments. Thus, a negative result may be as important as a positive one. We have also tried to indicate how you should use the results you get; how you should test them further and how you should relate them to the questions you posed yourselves.

Obviously if such a scheme could be put into practice as its authors seemed to intend, it would answer completely criticisms of school science of the type advanced by Tawney (1974) when he says:

> ... pupils come to believe that science provides no opportunity for the expression of differences of opinion, for imagination, and for creative work ... The scientist is seen to be entirely objective: he makes his observations and deduces generalizations from them ... Pupils come to think that experimental results 'prove' that theories are right; for example they will say that a demonstration of Brownian Motion 'proves' the existence of molecules.

Tawney goes on to say that the blame for misconceptions about science, held even by scientists, lies not with the way scientists write up their research reports as suggested by Medawar (1963) but with the way in which we, scientists and non-scientists alike, are introduced to science in schools.

The Nuffield Chemistry team members were clearly aware of criticisms that had been made of school science. They were keen to spell out the need for seeing science in schools as an exciting investigation. In their Handbook for Teachers (1967) we find:

> From the beginning, progress should thus be made by means of investigations in which pupils and teachers are jointly involved ... The problems may arise from suggestions made by the pupils or provided by the teacher. Everyone will discuss possible methods of solution before work at the bench begins.

They put their views even more clearly at the beginning of the Introduction and Guide (1966) to the course. They were determined that

> Pupils should gain an understanding ... of what it means to approach a problem scientifically. They should be taught to be aware of what scientists are doing and can do. This has little to do with the short-lived remembering of dictated information. Therefore science should be presented to pupils as a way in which they can conduct an inquiry into the nature of things as well as a body of information built up by the inquiries of other people.

Both the Nuffield Chemistry and the Nuffield Biology scheme explicitly adopted the hypothetico-deductivist philosophy of science proposed by Popper (1968, 1969, 1972). By doing this the authors hoped to influence the way in which science was presented to pupils. It was not intended that teachers should merely use some of the experiments suggested in the courses to increase the amount of class practical work in their lessons. Rather it was hoped that they would absorb and be affected by the philosophy of science embodied in the projects even if they chose not to use the course material on some topics. Through the change in teaching methods it was hoped to present science as an on-going process in which pupils could be involved in formulating hypotheses and then in designing experiments to test and refine their own ideas. The tenor of the Chemistry Project was well set by the quotation, from the discoverer of the structure of the benzene molecule, printed at the beginning of the <u>Introduction and Guide</u> (1966):

> Let us learn to dream, gentlemen, and we may perhaps find the truth, but let us beware of publishing our dreams before they have been tested by a discerning mind that is wide awake.
> F.A. Kekule (1890)

In some ways the O level physics course is the weakest of the three Nuffield schemes. It had nowhere a clear outline of the project team's philosophy of science. They wrote of it being 'important to discuss several rival answers to a question and learn that there may be more than one "right answer"' (<u>Teachers Guide 1</u>, 1966). They wanted pupils to 'devise their own experiments, meeting difficulties as well as successes' and emphasized the importance of being 'a scientist for a day', but what comes across to the reader is the feeling that doing a large amount of practical work is enough in the early stages and that it is only later, 'towards the end of the course' (op.cit. p 3), that pupils should be encouraged 'to look <u>at</u> their evidence as well as looking <u>for</u> it'.

In spite of the differences in quality of the Nuffield O level projects, there can be no doubt that interest in them was very high at the time of their publication. The time was one of great interest in science education generally - one notices the number of journals concerned with science education, both in this country and in America, that began publication in the same period. One new journal at this time carried details of American curriculum changes (Cane 1965) and followed this with the first pronouncements of the corresponding Nuffield team (Coulson & Nyholm 1966).

Reactions to the Nuffield schemes were mixed. Some regretted changes or thought parts of the schemes unsound (e.g. Bradley 1967); others, particularly those who had been involved in the trials, were enthusiastic (Jackson 1967). More informed assessments (Shayer 1970, 1972, 1974, 1976; Ingle & Shayer 1971), which considered the suitability of the material for the age and ability range for which it was intended, were, with some reservations, complimentary.

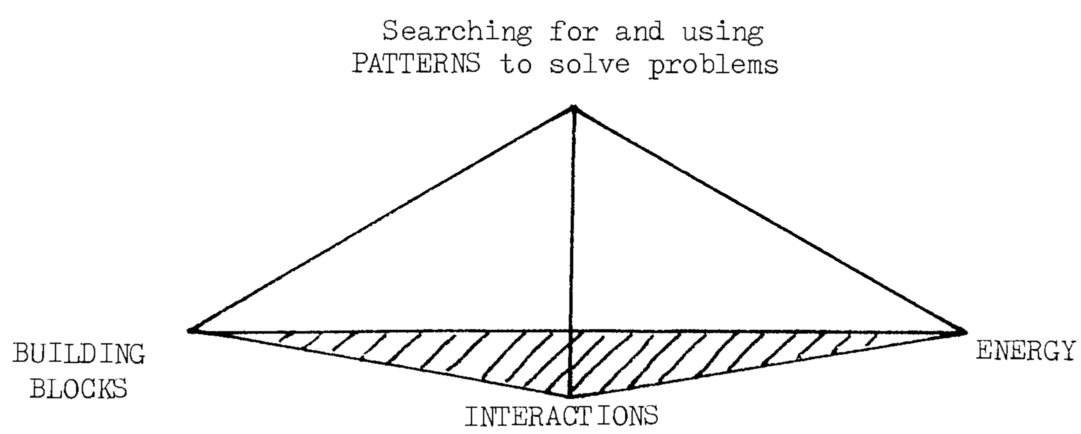
On balance the introduction of the Nuffield schemes had a beneficial influence even if they served only for focus attention on school science teaching and the need to finance it adequately. However in the light of the comprehensive reorganisation that was taking place at the time, two criticisms have remained. The first is that, in spite of references in introductions to 'science for all', the schemes were intended only for grammar school pupils and there was considerable suspicion that the projects would work only with able pupils. Nuffield projects are not the only ones which can be queried on these grounds (Dickson 1972). The second criticism is that the teams should have coordinated their efforts to produce a view of science as a whole to the pupils, rather than working in relative isolation. Indeed it can be argued that there are good reasons for integration (Brown 1977) and that it was a mistake to produce three separate schemes, at least for the first two or three years of the secondary course.

Those sponsored by the Nuffield Foundation were aware of these criticisms and, with the subsequent introduction of the Secondary Science Project for the less able 13-16 age group and Combined Science for younger pupils, they soon provided a better coverage of the full secondary age and ability ranges. The Combined Science scheme stated that the 'individual sciences should be seen to constitute a unified whole, based on a common philosophy, with similar aimes and methods' (Teachers' Guide 1, 1970, p xi). The philosophy and methodology of science were seen as the unifying bases of the combined course. The course was seen by the authors as a source into which teachers could dip to find suitable problems to present to their pupils. They were therefore disappointed when it became clear that some teachers were content to use the material but not to adopt the philosophy that this was intended to illustrate (Elwell, M.J. & Wild, K. 1970, personal communication).

The Nuffield Foundation then began funding those giving attention to sixth form science courses. Although there was a Nuffield Advanced Physical Science Project, which would allow a sixth former to study Biological Science, Physical Science and Mathematics and thus obtain a broadly based science course, the working out of a unified approach to science for the more able 13-16 age group was left to the Schools Council. The project which resulted, the Schools Council Integrated Science Project (SCISP) or Patterns, appears on the surface to be the one which was most carefully thought out in terms of aims, objectives, philosophy and teaching method. The authors' approach to the course is very clear from their publications (Hall 1972; Hall, Mowl & Bausor 1973) and it is therefore worth considering this in some detail.

The SCISP project model is a tetrahedron showing the course content based on three fundemental concepts: building blocks, energy and interactions. The important integrating theme is the search for, and use of patterns. The building blocks in the scheme are: galaxies,

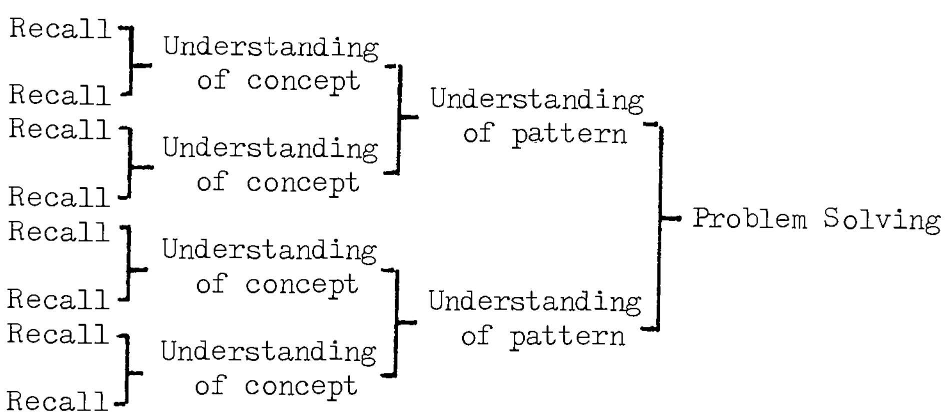
Table 2.2 SCISP Project Model



planets, communities, populations, organisms, cells, giant structures (sic), molecules, atoms, ions and electrons. In the study of energy, the emphasis is on the transfer of energy rather than on different 'forms' of energy. If A and B are two building blocks and one affects the other, this is termed an interaction.

As well as this attempt to integrate the subject content, SCISP incorporated a learning model based on the three highest levels in Gagne's (1966, 1970) hierarchy of learning. The original eight levels were: signal learning, stimulus-response learning, chaining, verbal association, discrimination learning, concept learning, rule learning and problem solving. In SCISP the seventh level, rule learning, is replaced by 'patterns'.

Table 2.3 SCISP Learning Model

a) 

b) Investigation ⟶ Concept ⟶ Pattern ⟶ Problem Solving

Gagne (1966) equates learning a concept with being able to identify an object class. This can come about by the study of positive and negative instances or by definition. One could almost equate understanding of concepts with ability to use a scientific vocabulary and the symbols of mathematics. 'Force', 'acid' and '+' are concepts. Understanding rules, or patterns, which are composed of two or more concepts having an ordered relationship with each other, depends on understanding the concepts used. Thus to understand the rule concerning work done (work = force x distance), one must first understand the concepts 'force', 'distance', 'x' and '='.

SCISP modifies Gagne's scheme into that shown in Table 2.3a above. Recall of previous evidence leads to an understanding of concepts (scientific terms) which are combined to produce patterns (generalizations). These in turn must be learned and understood before they can be applied to solving problems. Thus the pattern (!) of scientific method advocated and used in SCISP is that given in Table 2.3b. It is the use of this concept-pattern-problem solving structure which distinguishes SCISP from other courses rather than its subject content.

Most of the Nuffield projects, with the exception of the O level physics course, had adopted a Popperian hypothetico-deductivist philosophy. Certainly the only major science project being developed in the late seventies, the Nuffield 16+ Project, is explicitly hypothetico-deductivist in its approach (Wild 1977). In contrast the SCISP approach seemed to commit all its teachers to a view of scientific method more akin to Baconian induction. Investigation leads through understanding of the interactions between concepts to the establishment of a pattern. Once the pattern is established by generalization, it is not to be questioned but it is used to solve problems, increasing one's faith in its truth. Nowhere are pupils encouraged to question a proposed pattern - to treat it as a hypothesis and to test it by logic or by experiment. Hall, the main author of the project, maintained this criticism was unimportant for it was simply emphasizing the other side of the same coin and he refused to change the SCISP material before publication. Although Nuffield Combined

Science proved very acceptable to teachers (Charles 1976), SCISP has been severely criticized for its approach (Chapman 1976) and it may be that the uneasiness the scheme seemed to provoke in some is one reason for its lack of adoption by schools. For a teacher who has used the Combined Science material as intended with younger pupils, the difference in approach should be immediately obvious.

There may be other reasons why SCISP has been the least successful of the projects discussed above. General and integrated science courses could not hope to flourish while specialised science courses served a pre-professional function (Jenkins 1979, p 99). The separate sciences are so well established in the curriculum of most secondary schools that even authors in favour of broad based science courses may feel constrained to treat biology, chemistry and physics separately (e.g. Whitfield 1971). However recent trends have been towards encouraging integration in the science area (DES 1981, Schools Council 1981) and one can only pose the question of whether the small use of SCISP is after all due in some measure to its philosophical stance.

2.2.3 Philosophy of Science and Science Education

The history of science education in this country shows a continuing concern for imparting a view of scientific method and philosophy to pupils. Even the early pioneers of science education such as Dawes, Moseley and Henslow disagreed on this issue (Layton 1973) and Armstrong, writing at the turn of the century (see van Pragh 1973), complained about 'the absence of any proper distinction between what is commonly called science - i.e. facts pertaining to science - and the teaching of scientific method'. Even as late as 1967 the A.S.E. seemed to see practical work in terms of 'to prove', 'to show' or 'to demonstrate', but this verificationist view of science did at last seem to be in retreat.

Instead of a few isolated critics, there was an increasing awareness (Bigge 1964, p 331; Kuslan & Stone 1968, p 121; Tisher, Power & Endean 1972, p 51) that pupils need to be taught the philosophy and methodology of science if they are to appreciate the difference between science and other disciplines. As Bruner (1972, p 108) says, a science such as physics is not something that one 'knows about' but is, rather, something that one 'knows how to'. Gradually the realisation dawned that understanding of the philosophy of science is not the inevitable by-product of factual instruction and some (e.g. Lewis 1965) advocated that such objectives should be taught for directly.

It was at this time of increased awareness that the curriculum projects from the Nuffield Foundation and from the Schools Council became available and provided material that could have revolutionized science teaching in this country. That the revolution did not occur is evidence that many teachers missed the philosophical implications of the new schemes in spite of sometimes using the published course material with enthusiasm.

Even in a post-Nuffield era it is possible for an author (Donnelly 1979) to write:

> What is Science?
> Is this question relevant to the teacher of science?
> Not at all, if we are to judge by its cursory treatment in schools, textbooks, examinations and syllabi. Articles in this journal take a similar view ...

Donnelly goes on to criticize particular writers (e.g. Prest 1976) and points out that their 'attempts to state the "scientific method" have the air of Baconian folklore'. Clearly there has been a serious failure in the teaching profession to understand the implications for teaching in the recent curriculum projects. Equally clearly those who are concerned about this failure do not agree among themselves about the philosophy of science or its implications for classroom practice. In such a situation one cannot be sure that teachers do convey to their pupils an acceptable view of science and of the methods of thinking that lie behind scientific investigations.

Many writers have pointed out the need to include specific teaching on the philosophy of science (e.g. Forge 1979) but few suggest how this can be done in an effective manner. This is one reason why research in this particular area of science education is most needed. Research should be seen to be relevant to what actually occurs in the classroom for, as Whitfield (1979) says,

> It remains something of a paradox that almost the whole of what we teach in science courses from the primary to the tertiary level is research based whereas few of the processes by which we teach science have an equivalent scholarly foundation.

Thus, even if one could be sure that science teachers had a good understanding of the philosophy of science, it would not follow that they would necessarily also possess the skill to impart this to pupils. An investigation is necessary to determine to what extent the desired outcome, pupil understanding of philosophy and methodology of science, is actually influenced by the intentions of the teacher designing the course and choosing the teaching strategies because, after all,

> ... our curriculum, work schemes and laboratory courses are essentially hypotheses designed to achieve valued outcomes, and ... as such they must be open to modification in the light of both research evidence and professional experience.
> (op.cit.)

2.3 The Research Background

No piece of research exists entirely in isolation but depends on a framework that has been built up by the investigations of others. In this particular field many pieces of information contribute to the necessary background. Four areas have some bearing on the planning of this study, and are discussed in some detail in this section. These concern:

i. the kinds of teachers who become involved in curriculum reform and their motives for doing so.

ii. the philosophy of science in science courses and its relationship with teachers' philosophy of science, if any.

iii. the effects of teaching styles and strategies on pupil attainment and on pupil understanding of science.

iv. the effects of teaching styles and strategies on pupil attitudes to science.

2.3.1 Teachers and Curriculum Reform

Although it is not necessarily the case that all teachers who have become involved in curriculum projects are more aware of the philosophical assumptions and implications embodied in what they teach, it is of interest to see what differences there are between those who have become involved in developing projects or teaching project material and those who have not.

Jenkins (1971) and Nicodemus (1975, 1977) have studied teachers who have adopted Nuffield teaching schemes, compared them with non-adopters, and looked at their reasons for doing so. In general they found no significant differences in the academic background and professional training of the two groups. Nor was there any difference between them in the amount of experience in research or in industry.

Nuffield schools did seem on average to have larger sixth forms and this could indicate that teachers in well-established schools have the confidence to try something new. Teachers who adopted new schemes were more likely to be in areas used in trials, to read scientific journals, to have closer ties with centres of higher education and, therefore, to be better informed about current views.

Those teaching the new curriculum schemes thought the development of favourable attitudes to science by pupils was important and gave as reasons for adopting the schemes the similarity of the content or methods in the project with their previous teaching, the inclusion of aims concerned with the social effects of science and technology, and the inclusion of aims to do with the understanding of and use of scientific method. Those adopting projects may already be using a similar approach and have similar aims before making their decision to use the project material. For example, Lewis (1977) tells how he first encountered physics at secondary school as a fragmented study of heat, light, electricity and mechanics. Each topic was introduced by a list of definitions to be learned for examination purposes. He was determined not to use such an approach with his own pupils and was therefore attracted by the Nuffield scheme because of its unity, seeing physical phenomena as linked by theories such as energy and waves. For him, teaching for understanding and not by formal definition was the correct approach to physics, and the Nuffield scheme provided that approach.

There is then evidence that teachers involved in curriculum reform are more concerned with science as an activity than merely as an established body of factual knowledge and that they may be more aware both of the methodology and the social implications of scientific progress.

2.3.2 Course Philosophy and Teacher Philosophy

In designing a curriculum project the authors may give much thought to both content and teaching methods in the hope of producing a coherent package that will embody a consistent view of science and its methodology. In a possible framework for the construction of school science courses, Prestt (1976) includes not only scientific facts but also: understanding and use of scientific method; social and economic implications of the applications of science; and science as an activity of the community at large. This list is not unusual nowadays and undoubtedly Prestt is right to say that

> ... the greatest problem is that of encouraging biologists, chemists and physicists to see science education as an entity which ... has as its main concern the development of scientific understanding rather than the aquisition of facts. (op.cit.)

Although most curriculum projects have advocated increasing the amount of practical work for pupils, their aims in doing so may not always be achieved. Laboratory investigations give pupils the opportunity to carry out enquiries of their own, but they can be reduced to routine exercises by the way the teacher introduces the work or talks during the laboratory activities (Robinson 1969). Unless the teacher is aware of his own attitudes and beliefs and modifies them where necessary, there may be no real change in his lessons just because he uses some experiments recommended by a curriculum scheme.

A teacher may feel that he has achieved something when he adopts a new curriculum project but this may have little effect on his pupils unless he changes the way he talks and introduces discussions or practical work in his lessons. Most pupils first meet someone trained in a scientific discipline when they enter a secondary school and this can have a lifelong effect on them wether or not the teacher concerned consciously projects an image. The pupils will see the way he approaches his lesson content as the way in which a scientist will approach his subject material. The important years are those of compulsory schooling for if young pupils are not sympathetic towards the aims of science they may cease studying it, reducing their chances of achieving real understanding of science or of becoming the practising scientists of the next generation.

Jungwirth (1971) summarises the way in which a teacher's image is projected and the way in which pupils can be affected by their perception of teacher image. On his model, the teacher image cannot be ignored as there is no short-cut between teacher behaviour and the pupils' acceptance of his objectives. In fact Jungwirth and Tamir (1973) found that teacher image was a good predictor of student achievement and they questionned how aware the teachers were of the discrepancy between the pupils' perception of the 'teacher image' and their own self-image. Book work does not necessarily lower the pupils' image of the teacher, but it was found that, while teachers tried to project an enquiry-orientated image, the pupils' perception of the image was more balanced and realistic (Tamir & Zoor 1977). Raths (1973) quotes two examples of classroom dialogue to illustrate what happens in actual lessons with teachers who believe themselves to be committed to an approach which encourages pupil involvement in hypothesis formation and criticism:

1. Teacher: "What happens to hypotheses over time?"
   Class Answers: "They become discredited."
   "No," roared the teacher, "They become laws!"
2. The class had been reading about the Adam and Eve theory of creation and it had been suggested that animals at many different levels of complexity might be evidence of regression rather than progress.
   Pupil: "If this were the case, how would the data presented in the Biology textbook be different?"
   Teacher: "Stop asking foolish questions."

Such examples as the above raise questions about the clarity of the philosophical aims of curriculum projects and about the education of the teachers who use the material in the projects. Certainly the

American projects such as CHEM Study, CBA and PSSC have been criticized for failing to give a correct representation of the method and philosophy of science (Diederich 1969) and British projects (e.g. SCISP) can also be misleading, particularly if the teachers are themselves unsure about the approach they should use. It has been recognized for some time (Rutherford 1964) that teachers ought to have a thorough grounding in the history and philosophy of science so that these become part of their concept of science itself. A teacher's philosophy of science should affect his behaviour as well as his choice of instructional materials and the laboratory tasks he sets his pupils. What goes on in his lessons should convey the nature of the scientific enterprise to his pupils. Whitfield (1974, p 16) stated this position clearly as follows:

> ... if we are claiming to teach science ... the nature of the discipline must be reflected in the teaching methods we employ. Certainly it ought to become clear to pupils that science is concerned with empirical enquiry of the physical world; that it is a body of facts set in a flexible framework of man-made concepts which are always open to modification in the light of new or improved experimental evidence. They should become aware of the continuous interplay between theory and experiment ...

In spite of the agreed importance of the philosophy of science in science courses and the recognition of the way in which teacher behaviour could affect pupil perceptions of the nature of science, there is some evidence that teachers do not rise to the challenge posed by the curriculum reform movement and that they fail to use the new course materials in the way intended.

The Scottish Alternative Syllabus in Chemistry states that the subject should be taught in 'an exploratory manner, where a pupil is not told all the facts, but as far as possible discovers them for himself'. Although this clearly implies the use of discovery methods, a survey (Gunning & Johnstone 1976) found that such teaching methods were not in widespread use in Scotland. Gunning and Johnstone suggest three possible explanations for this discrepancy: first, that most of the experiments suggested in the syllabus are confirmatory in type (cookbook type); second, shortage of time; and, finally, that open-endedness leads to problems of classroom organisation. Their rather dismal conclusion was that, for many teachers, the main objective of practical work was simply to keep pupils occupied.

The first of their possible explanations is of doubtful validity. Whether an experiment is of the 'cookbook' type or not in the eyes of the pupils depends on how it is actually introduced to them. If it is presented as a problem for which they have to devise possible answers rather than as a technique to be practised by following closely a set of teacher instructions, this can affect their perception of the nature of the work even though the actual work performed is the same. Some criticisms of the Nuffield courses (e.g. Tampion 1977) are based on the same misunderstanding. As Warmer (1977) points out, the success of discovery teaching depends on attitudes of cooperation and intellectual honesty from teacher and pupil rather than on particular course content.

Shortage of time is also a poor excuse although it is often claimed that course content needs to be cut (Prestt 1970). Thompson (1971) showed that pupils in this country have an average of between twice and five times the numbers of hours devoted to science teaching as their continental competitors. The mismatch between course philosophy and the philosophy implied by teacher behaviour seems to be bound up with the way the teachers use practical work in their lessons.

Wilson (1977) studied the views of teachers about practical work and investigated what was actually taking place in the classroom situation. The stated aims of the teachers differed from their classroom practice. They said they used practical work with younger pupils to arouse interest, to encourage accurate observation and careful recording, to develop manipulative skills and to illustrate applications of science to real-life situations. For those nearing examinations the aims changed to aiding understanding of concepts, finding facts and arriving at principles by investigation, training pupils in problem solving by experimental investigation and promoting scientific methods of thought.For both age ranges the aims rated lowest in importance were verification of facts and principles already taught determination of physical constants.

Wilson expressed severe doubts about whether the teachers he investigated were implementing the philosophy of the course they were teaching because of the contradiction between the stated aims and what he found to be common classroom practice. In the actual lessons he found the commonest type of practical work to be 'experiments to investigate phenomena and arrive at principles'. 'Experiments to verify facts and principles already taught' were also common in spite of the teachers' professed low ranking for this as an aim. On the other hand, 'experiments designed to solve a problem raised in class' were extremely rare reflecting the difficulty of organising open-ended situations in school laboratories. The commonest way of organising practical work was to have all pupils in small groups doing the same experiment with the same apparatus.

Teachers who used demonstrations mentioned lack of apparatus but also talked of saving time or of the need to obtain accurate results. Reliability of results was obviously important for teachers gave detailed verbal instructions or used workcards in all class practicals. There was also much copying from blackboards and writing from teachers' dictation. One question raised by Wilson's work is whether teacher directed practical work can be regarded as investigational. If not, the aims of the curriculum reformers are unlikely to be achieved. Although pupils may be involved in a high degree of practical work, there can still be little experimental work. If the creative aspects are removed or replaced by a series of directions from teachers, the experiments are reduced to the level of following recipes from a cookery book.

Differences between the aims of course writers and the practice of teachers would be unimportant if teachers did not influence their pupils' view of science and pupil attitudes towards science. However evidence shows that teaching style and teaching methods affect not only pupil attainment but also understanding and attitude. This evidence is reviewed below.

2.3.3 Teaching Styles, Attainment and Understanding

Although the well known work by Bennett (1976) is no longer accepted, there is little doubt that teaching style can have effects on pupils. A teacher's style of teaching is determined by how he sees his pupils (Paisley 1975) and at least four teacher traits do reach significance in terms of differences in student learning (Rosenshine 1971, Biddle & Dunkin 1974, Travers 1973). These may be summarized as follows:

1. Warmth - characterized by empathy and association with pupils; sensitivity in using pupils' ideas and awareness of the need to give them feedback in an encouraging and praiseworthy rather than negative manner.

2. Demand - characterized by high expectations of pupils in terms of their attention, task achievement and resource for learning; businesslike, well prepared and orderly rather than slipshod.

3. Flexibility - shown by an ability to create a variety of classroom options, materials and activities; imaginative and adaptable rather than routine.

4. Conceptual clarity - demonstrated by careful and deliberate structuring of material, the sensitive use of language and the choice of appropriate experiences in relation to the conceptual development of pupils.

Houston (1975) showed that an open-ended style of questionning produces better achievement than a straight-forward expository style of teaching but research on pupil and teacher talk in lessons (Evans 1976, Johnson 1977) show that most teachers dominate almost all classroom discourses, commonly suppressing ideas volunteered by pupils.

Teachers vary in the way they handle practical lessons (Slater & Thompson 1977) and the differences have been studied in a variety of ways including analysis of filmed lessons (Platts 1976). Jardine, McIntyre and Standley (1974) point out that the amount of practical work actually carried out by the pupils themselves is still small, but evidence about the effectiveness of increasing the amount or varying the type of practical work is inconclusive. Coulter (1966), Barnett (1974), Sukmyser (1974) and Johnson (1976) all claim that highly teacher directed laboratory situations are not better than student directed investigations. They claim a non-directive style produces better student achievement. This is disputed by other workers who found students performed better after being in structured situations (Bubikion 1971, Wright 1977) where concepts were explained before use and where laboratory work was used to verify concepts taught previously.

If there is disagreement about the effects of teaching style on pupil attainment, this is equalled by uncertainty about other effects. Skymansky and Matthews (1974) found that students learned to work independently if they could structure their own work and became less teacher-dependent. Conversely Tjosvold, Marino and Johnson (1977) reported that pupils commonly rejected enquiry orientated teaching and disapproved of the teachers involved in this situation. They found that pupil anxiety was reduced by teachers who were prepared to give 'right answers'. These results were obtained in American schools and it is not always wise to assume that results obtained in other countries are directly applicable to the British educational scene and Ainsworth and Batten (1974) have pointed out the importance of environmental factors in education. These factors, social atmosphere or degree of authoritarianism, vary greatly even from school to school and may invalidate studies (e.g. Heaney 1971) which set out to compare discovery type approaches with traditional didactic styles of teaching by looking at the results obtained by teachers working in different schools.

Nobody, least of all the pupils themselves (James & Choppin 1977), denies the importance of the teacher's lead in the classroom but it is extremely difficult to study the effect of a particular style of teaching. In one area, however, there is a measure of agreement. This concerns effects on pupil understanding of the nature and aims of science. Although pupils do have many misunderstandings about the nature of science (Mackay 1971), this may be due to their teachers concentrating on the factual side of science (Tricker 1971, Prestt 1970). Theobald (1970) blames this on the teachers' view of pupils examination needs and it is not difficult to find others (e.g. Amos 1970) who share this view. Where attempts have been made to include teaching about the philosophy of science, it has been found relatively easy to improve the students' understanding (Barnfield, Bethel & Lamb

1977). Many other authors report positive effects (Crumb 1965, Yager 1966, Lawrenz 1975), while some are more cautious. Jungwirth (1968, 1969, 1972) has done a considerable amount of work in Israel following the introduction of a version of BSCS and his results show that some teachers of the course were effective in communicating some aspects of understanding of science to their pupils. Even after four years he still found serious deficiencies in pupil understanding.

Seymour and Sutman (1973) claim modern chemistry courses improve critical thinking and open-mindedness but they failed to find any improvement in understanding of science produced by the same courses. Hadden, Hardy and Johnston (1974) also sound a note of warning about the interpretation of results. They agree that pupils following science courses may be better at solving problems in a scientific way but argue that this may be due, not to their being taught how scientists behave, but to their choosing science courses initially because they already incline towards thinking in a scientific way.

The one thing that emerges clearly from the literature on this topic is that no attempt has been made to find if pupil views about the philosophy of science can be changed in an experimental teaching situation by changing the teaching style while keeping constant other variables such as course content and environmental factors. This is one of the aims of the present study.

2.3.4 Teaching Styles and Pupil Attitudes

Although this investigation is more concerned with pupils' understanding of the philosophy of science, it is not entirely possible to divorce this from their attitudes towards science. An improvement in understanding may produce a change in attitude and most teachers do have great faith in their ability to influence the future lives and attitudes of their pupils (Fensham 1974).

Pupil attitudes are affected by the balance between book work and practical work, but attitudes are more inflenced by the teacher than by modernity of facilities or equipment (Evans & Baker 1977). Not all the sciences are viewed in the same way. The most comprehensive survey of pupils' attitudes to science is that by Ormerod and Duckworth (1975) and they summarize their findings as follows:

1. There is a great variation in personality of science teachers and this affects pupil attitudes.
2. Biology is seen as different from the physical sciences.
3. Physical sciences are regarded as difficult for three reasons: i) conceptually - somethings presented too soon.
   ii) mathematical content.
   iii) technical vocabulary.
4. Interest in science ripens earlier than with other activities.
5. Practical work is seen as an attraction - but discovery methods are overrated for producing good attitudes.
6. Girls like physical sciences less than boys do.
7. The influence of the teacher is great.
8. Science has an unfavourable image - atom bombs, pollution etc. are blamed on scientists.
9. Home background, including parents' interest in science, influences pupils' attitudes towards science.

This last point is confirmed by Coxhead (1974) who found little difference in pupil attitudes due to differences in practical conditions; he found the main predictor of pupil attitude was parental interest in science. Keys and Ormerod (1976) confirm all one's prejudices about the ways in which the differences in attitude between girls and boys affect their choice of science courses.

One important question arising out of such work is whether modern courses are better at promoting positive attitudes than are the more traditional ones. Meyer (1970) looked at the reactions of pupils to the Nuffield courses and concluded that these could claim some limited success in improving attitudes towards and interest in science especially with girls. He found a significant increase in interest in science as a method of enquiry but little difference of interest in the facts of science. The Nuffield chemistry scheme was the most effective in promoting scientific thinking and a positive orientation towards science. The biology scheme was less effective and the physics scheme the worst. This is particularly interesting as the chemistry scheme is the one requiring most clearly a hypothetico-deductivist style of teaching. The biology scheme professes to follow the same approach but still puts much emphasis on factual knowledge, while the physics scheme lacks a clear philosophical standpoint but inclines towards the inductivist approach, particularly in the earlier stages of the course.

Meyer carried out his study on pupils in trial schools where the teachers were expected to teach the schemes as intended by the writers, but a follow-up study five years later (Kempe & Dube 1974) did not confirm his results and found Nuffield courses no better than others in producing scientific thinking or good attitudes towards science. In fact better attitudes were found in the less-able children who were following non-Nuffield courses. These results suggest that, as Nuffield courses were adopted by more schools, a smaller proportion of the teachers concerned remained faithful to the aims and methods intended by the project teams.

Studies in Australia following adoption of PSSC (Gardner 1976) produce similar results. Enjoyment of physics declined as the course progressed except in situations where intellectual pupils were taught by a teacher who pressed for intellectual achievement.

The evidence does seems to suggest that modern courses are not entirely successful in one of their avowed aims, that of improving pupil enjoyment of science. In the investigations that have been carried out, the teacher/pupil effect was found to be greater than any differences between the effects of modern and traditional courses.

SUMMARY OF CHAPTER 2:

Three views of the philosophy of science are described. These are:

1. the verificationist position, in which experiments are used to provide proof of scientific statements.
2. the inductivist position, in which experiments are used to increase the range of observations available before generalization takes place.
3. the hypothetico-deductivist position, in which experiments are used to test predictions derived logically from hypotheses.

Since science was introduced into the school curriculum in the last century, there has been a continuing controversy about whether its value lies in it being a body of knowledge or a method of enquiry.

It is known that teaching styles affect pupil attainment, understanding and attitudes but, in spite of the difficulties teachers have in adopting the teaching approach recommended by curriculum project writers, nobody has attempted to carry out a study linking the teachers' own views on the philosophy of science with both their teaching methods and their pupils' understanding of the philosophy of science.

CHAPTER 3:

RESEARCH DESIGN

3.1 Main Aims

The aims of this study may be simply stated. They were:

1. To investigate the kinds of understanding that science teachers have of the philosophy of science.
2. To investigate whether teachers' views on the philosophy of science affect what they plan to do in their lessons, particularly with regard to the inclusion of practical work.
3. To investigate whether the use of different teaching styles affects pupil understanding of the philosophy of science.

In practice these aims had to be refined in order to provide a set of hypotheses which could be tested in a reasonable amount of time by the methods available to the experimenter. As the more detailed research plan was drawn up, this provided an opportunity for interaction to occur between the original aims and the practicalities involved in a scheme of research based upon them.

At various points in the planning of the research scheme it became necessary to work towards more limited objectives, mainly concerned with the development of suitable test instruments which were required if the main aims were to be realised. Although taking much time and leading to much detailed description below, reaching such objectives should be regarded as merely making a contribution towards realising one or more of the main aims stated above.

3.2 The Research Plan

In the initial phase of the study it was planned to develop a questionnaire, part of which would include a test of the respondents' understanding of the philosophy of science. This section of the questionnaire in its developed form was to be used to classify teachers according to their view of the philosophy of science and to identify those individuals who held extreme views on the philosophy of science. As it was also necessary to develop a test for measuring pupil understanding of science, the early development work on the questions to be used in the philosophical section of the teacher questionnaire was also intended to form a basis for the pupil test.

Other sections of the teacher questionnaire had to be designed and these were to probe the educational background and teaching experience of the teachers, their involvement with curriculum projects and choice of textbooks, and their attitudes towards and reasons for using practical work. In the original plan for the study, the first year was set aside for the development of the teacher questionnaire and the pupil tests. It was expected that developing the philosophical questions would present the most difficulty and this was indeed the case. In the event revisions were still being made in the pupil test instrument up to the end of the second year of the investigation.

Once the data from the pilot version of the teacher questionnaire had been analysed and any necessary amendments made, the plan allowed for the second year of the study to be devoted to the administration of the final version of the teacher questionnaire. It was hoped that this would provide two kinds of result. First, analysis of the responses should show whether teachers could be classified as verificationist, inductivist and hypothetico-deductivist types, corresponding to the three viewpoints discussed in Section 2.1 above. Secondly, the plan was to use the results to identify a small number of individuals whose responses to the questionnaire indicated that they might be extreme in their philosophy of science. Those defined as having extreme views were to be those who deviated markedly from the average in a similar direction on both the section of the questionnaire concerned with their philosophy of science and on the one assessing their views on practical work.

As a check on the efficiency of the questionnaire in selecting teachers with certain views, it was planned to hold a series of individual interviews with the selected 'extreme' teachers some months after completion of the questionnaire to ensure that their responses to the printed questions agreed with the views expressed by them in a more searching situation. Although this check was important, the main reason for the teacher interviews was to probe for possible links between their stated views on the philosophy of science and their reported teaching styles. Establishing such a link would be essential to the realisation of the second aim of this study.

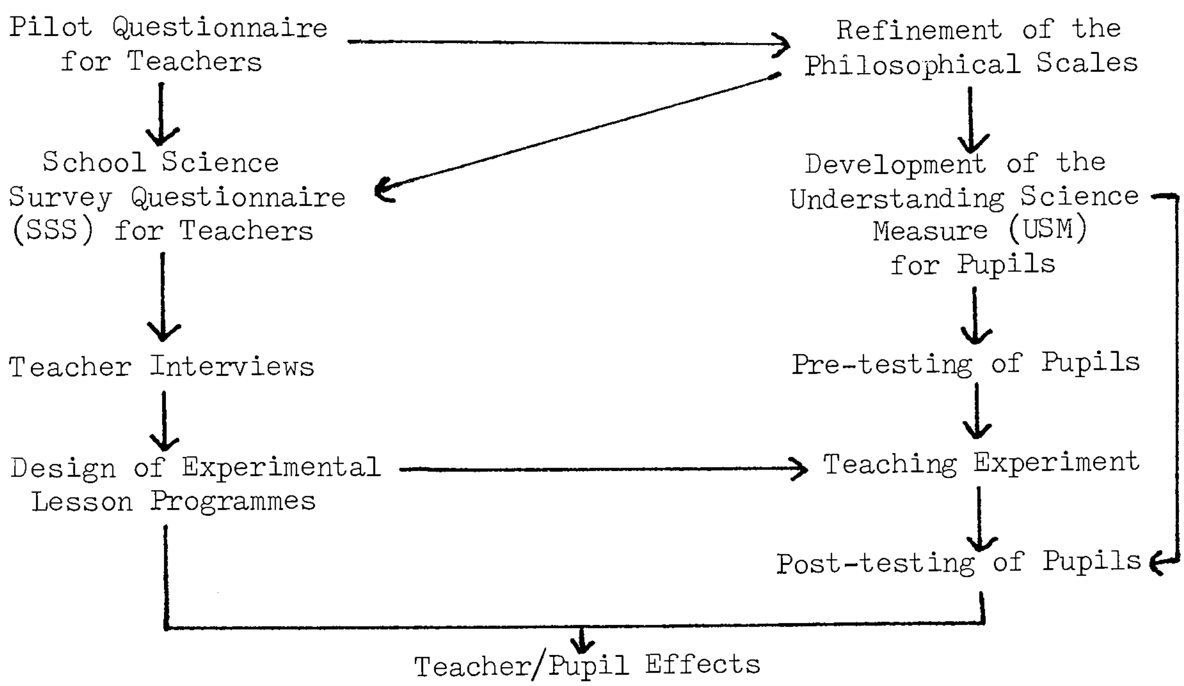
An early idea had to be abandoned at the planning stage. Observing the selected teachers over along period in their normal teaching would have been desirable as a further check on their responses but the practical difficulties involved were insurmountable. The third stage of the project, the teaching experiment, therefore had to be based on the information obtained from the selected teachers during the interviews. Information about their teaching style and in particular about the ways in which these teachers introduced and used practical work in their lessons was used in the planning of the schemes of work to be used with the groups of pupils involved in the teaching experiment.

During the experimental phase, the plan was to teach similar classes in different ways, corresponding to the stated priorities of the extreme types of teachers already identified, and then to test the pupils in a search for differences in their views about the philosophy of science which could be attributed to the teaching they had received. Many experimental teaching situations are conducted in artificial circumstances and over a short period of time. For the experimental phase of this investigation it was considered essential to use a teaching situation as near as possible to that which normally obtains in schools. For this reason the experiment used ordinary class groups which would be subjected to the planned programme of lessons as a part of their normal school curriculum over a period of most of one academic year. Because of this it was important that the experimental phase should be planned to begin at the start of a new school year. Rather than accept the delay of a full year, the decision was taken to begin this phase on time even though the teacher interviews were incomplete. As it transpired, such compromises did not seriously affect the course of the research. In this case the bulk of the information obtained from the teachers was available early enough to influence the planning of the courses followed by the pupils in the subsequent phase.

Finally, the research plan allowed time for some follow-up work to be done with pupils after the conclusion of the teaching experiment and the analysis of the results obtained. The purpose of this final phase was to look for other possible effects of the teaching treatment which might provide suggestions for more detailed investigation at a later date.

A summary of the research plan can be found in Table 3.1, which is reprinted at the beginning of Chapters 4, 5 and 6.

Table 3.1 Research Plan Summary



Details of the pilot study of teachers are given in the first section of Chapter 4. The remainder of that chapter explains how the philosophical scales were drawn up both for the final version of the teacher questionnaire and for the pupil test. The results obtained from the main survey of teachers and from the teacher interviews are described in Chapter 5, while Chapter 6 is devoted to a description of the teaching experiment and the results from the pupil tests.

Although there is some discussion of the teacher/pupil effects in Chapter 7 and a summary of conclusions in Chapter 8, it will be apparent that this investigation was more involved than many and this has meant that there is a need to report and discuss the results of each phase before proceeding to a report of the next. It is for this reason that results from the pilot study, the test development, the survey of teachers and the teaching experiment are discussed in the appropriate chapters.

In all phases of the investigation it was necessary to analyse considerable amounts of data. Of necessity this data analysis involved the use of a number of statistical techniques. In order that others should be able to follow or repeat the statistical procedures used in the data analysis and scale development, it was decided to make use of a readily available system of computer programs at all stages of the investigation. The system adopted was the Statistical Package for the Social Sciences (SPSS) developed by Nie et al (1975). This package is available at over 600 computer installations. In many places in the following chapters statistical significance is indicated by making use of the following convention: one, two or three asterisks (*) correspond to significance at the 0.05, 0.01 and 0.001 levels of probability respectively. Non-significant results are indicated by the abbreviation 'ns'.

3.3 Hypotheses

This investigation may be regarded as an attempt to test a small number of related an interconnected hypotheses concerning the philosophy of science and science education. These hypotheses arose from the aims described above in Section 3.1.

The first main aim was concerned with teachers' understanding of the philosophy of science and it gave rise to three hypotheses. These were:

Hypothesis 1: Science teachers in schools have some understanding of the philosophy of science.

This hypothesis led to the prediction that science teachers, even if they had had no formal training in philosophy and had given no conscious thought to the matter, would not respond in a random manner to questions about the nature and functions of science. It was therefore predicted that teachers would adopt a philosophical standpoint even if it did not correspond to the current orthodoxy. This is bound up with the second hypothesis.

Hypothesis 2: Teachers differ in the philosophy of science to which they subscribe.

Whether it is because of the lack of formal training or to other differences in back ground, it was suggested that there would not be a consistent view of the philosophy of science throughout the teaching profession. Some teachers were predicted not to have coherent views, while others would have coherent but opposed viewpoints. This gave rise to the third hypothesis.

Hypothesis 3: It is possible to identify teachers who subscribe to the extreme philosophical positions.

In Section 2.1 three extreme views of the philosophy of science were described. These were the verificationist position, the inductivist position and the hypothetico-deductivist position. This hypothesis embodied two distinct predictions:

a) Some, although probably a relatively small number of, science teachers will actually hold views about the philosophy of science corresponding to these extreme positions.

b) It is possible to select these extreme individuals from a larger group consisting mainly of individuals with more balanced and less extreme views about the philosophy of science.

The second main aim of the study was concerned with looking for links between the philosophical beliefs of teachers and their teaching styles in the classroom. The hypothesis connected with this aim was:

Hypothesis 4: The teaching style of an individual who holds an extreme view of the philosophy of science is affected by this.

An individual who holds extreme views about the philosophy of science was expected also to have firm views about his priorities in the classroom. It was predicted that the way in which such teachers used practical work in their lessons would be drived from, or logically connected with, their philosophical beliefs, even if these were not the result of conscious and careful consideration of the issues involved.

As soon as the possibility of teaching style being affected by philosophical beliefs was accepted, this led naturally to the third aim concerning the effects of differing teaching styles on the pupils. Hypothesis 4 postulated a logical connection between the philosophical viewpoint of a teacher and his teaching style. As pupils must get their view of science at least in part from their science teachers, it was a small step to the final hypothesis.

Hypothesis 5: Pupil understanding of the philosophy of science is determined by their teacher's implied philosophy of science.

The prediction derived from this hypothesis was that pupils in a science class would form their view of the philosophy of science by realising what was implied by the actions and speech of their teacher. As hypothesis 4 predicted that the teacher's own philosophy would be implied by his approach to his subject matter, the two hypotheses together gave rise to the prediction that the pupils' philosophical views would correspond, to some extent at least, with those of their teacher, particularly if he were an extreme type.

The above are the five main hypotheses which formed the basis of the thinking behind the present investigation, but hypotheses can exist only within a framework of generally agreed assumptions. One assumption which has underpinned many other research projects was called into question during the early stages of this investigation. Usually it has been regarded as suffiecient, when designing tests of understanding of the philosophy of science, to include test items which determine whether or not the respondents know the answers the test compilers regard as being correct. In this study a different assumption was made. It was assumed that respondents could, with equal sincerity, take at least two other viewpoints both of which are at variance with the personal beliefs of the test compiler.

If one accepts this approach, one is led to the conclusion that much of the work which has been done previously in the field of testing understanding of the philosophy of science has been misconceived because the possibility of the existence of alternative viewpoints has gone unrecognized. This question is discussed more fully in the section on test development (Section 4.2). At this stage in the investigation it became necessary to test a subsidiary hypothesis of limited scope concerned with the nature of tests of the philosophy of science. This hypothesis was:

Hypothesis 6: It is possible to construct a test to measure understanding of the inductivist philosophy of science.

Previously test compilers have tended to assume that the hypothetico-deductivist philosophy is the correct one. Such tests appear to be very successful and in order to establish the need to devise tests which contained alternative answers corresponding to other philosophical positions it was necessary to question the possibility of designing a test biased towards another viewpoint.

The subsidiary hypothesis and the results which are relevant to the issues it raises are discussed in Chapter 4. This is because it had a great effect upon the kind of test items used to form the scales used both in the final form of the teacher questionnaire and in the pupil tests. The five main hypotheses are interconnected and the bearing upon them of the results of the investigation are discussed in Chapter 7.

SUMMARY OF CHAPTER 3:

The research plan divided the investigation into three main phases:

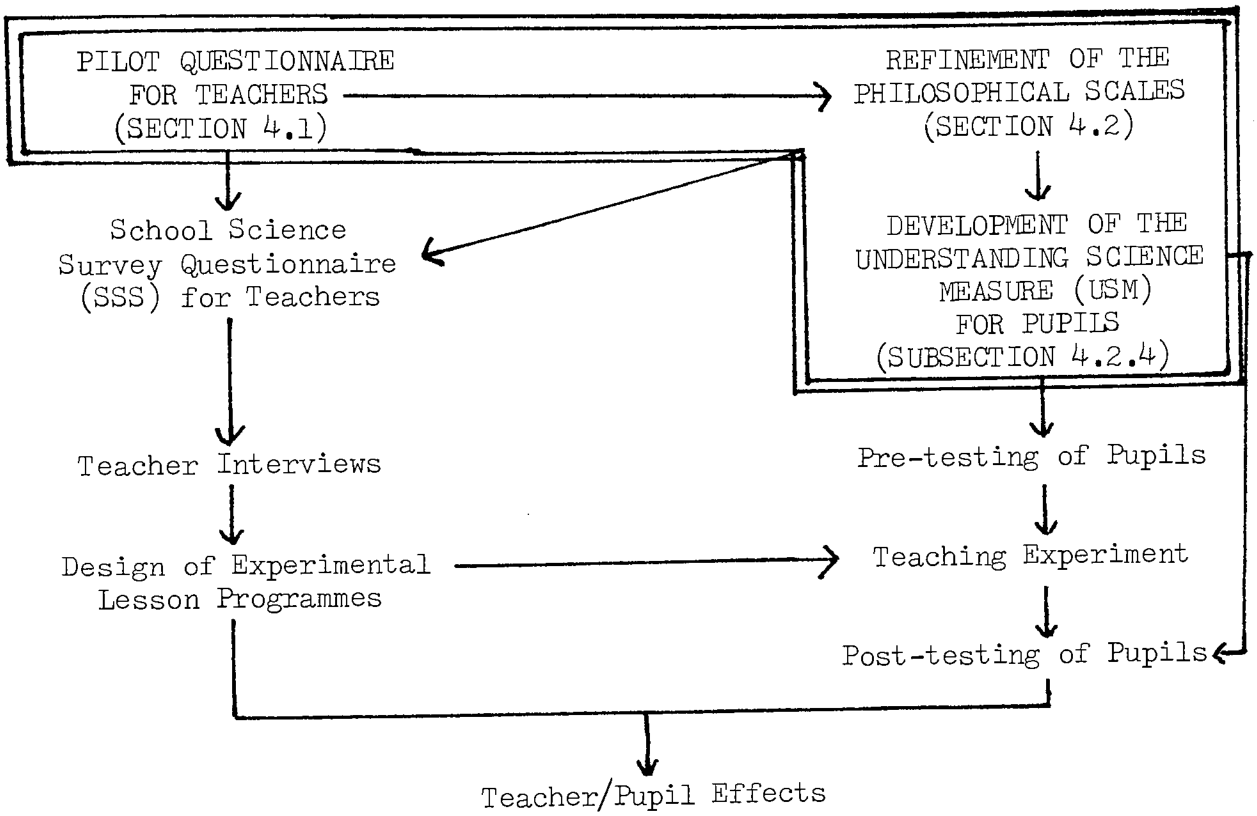
1. Development of tests of understanding of the philosophy of science to be used with teachers and pupils.
2. Using such tests to identify teachers holding extreme views about the philosophy of science, and then interviewing selected teachers

about the teaching methods they use.

3. Carrying out an experiment to find whether using such methods affects the pupils' understanding of the philosophy of science.

CHAPTER 4:

DEVELOPMENT OF TEST INSTRUMENTS



4.1 The Pilot Study

As a first stage in the development of the teacher questionnaire, a pilot study was undertaken with a small group of teachers from an area which would not be used in the main phases of the study. The pilot version of the questionnaire was used to find how teachers would respond to the types of question used and to provide some indication of the range of answers that might be obtained in the main study. It was planned to use results from the pilot study as a guide to construction of the final teacher questionnaire and as a basis for the design of the pupil test needed for the experimental phase. The complete Pilot Survey Questionnaire is reproduced in Appendix 1.

4.1.1 Pilot Questionnaire Design

Throughout the following description reference is made to the four sections of the pilot questionnaire by number.

Section 1 of the questionnaire was designed to provide information on the background of the respondents: their sex, position, teaching experience, main subject and level of qualification. Although information from this section could have been useful in providing possible explanations for differences in responses on other sections, this was not the main reason for including it. The section was intended to put respondents at ease by presenting them first with questions that they could answer without difficulty. It also enabled identification of respondents which would be necessary in the main survey to make possible follow-up interviews. All the teachers were assured in an accompanying letter that nobody in their education authority would be allowed to see individual replies, so there was little reason to suppose that having to give their names and the other details requested would deter them from completing and returning the questionnaire.

Section 2 was also intended to be fairly straightforward to build up the confidence of the respondents. It asked for information about familiarity with, and use of, some of the Nuffield and Schools Council projects. Also included in this section was a request for a list of books found useful for teaching purposes, together with a space for comment on the value of the books selected.

It is possible that teachers are influenced most in their choice of books by extraneous factors such as convention, cost, size or availability, but it was hoped that some indication of careful consideration of content might be apparent in answers to this section. Studies of textbooks often do little more than consider such things as amount of text, quality of diagrams, reading level or difficulty of vocabulary (Evans 1976). Unless they have used a book before or have obtained a specimen copy, many teachers have little information to assist with book selection and can only rely on reviews in educational journals or on sheer guesswork (Weston 1958). In any case reviews tend to concentrate on accuracy of factual content or correspondence with examination syllabus requirements rather than commenting on wider issues such as the impression a book could create in the reader's mind of the philosophy and methodology of science.

Many school science books do begin with some statement of the author's view on scientific method even if this does not altogether reflect the impression that one gets by reading the remainder of the text. Three examples of this kind of introduction follow:

> Do you ask questions? If you don't you will be most unusual ... This book might help to answer a few questions, but only a few ... This is a book about science ... What is a scientist? He is one who searches for knowledge and understanding ... by asking questions of nature. This book

> ... will describe many experiments and suggest others you might try ... (Brocklehurst & Winterbottom 1962)

> The science of chemistry sets before itself, as its primary objects, first, the determination of the nature and properties of the non-living matter which surrounds that portion of the crust of the earth to which we have access, and, secondly, the preparation of new substances, scientifically interesting or generally useful from the materials which Nature has provided. (Holderness & Lambert 1964)

> The application of scientific principles to the affairs of daily life has produced the world in which we live. The object of this series of ... books is to help you understand your scientific background ... your studies should give you some understanding of scientific method. Scientists have made their discoveries by applying their minds ... to the problems they meet in trying to understand their environment. ... patient investigation, recording results accurately, formulating theories to account for what has been observed and testing such theories by experiment, are all part of the way scientists work ... you must learn to follow this method if you are to develop the right attitude to your work and indeed to the problems of life itself. (Bate 1961)

All of these extracts lead one to form an impression of the authors' intentions in writing their books, but what an author says in his introduction is not an infallible guide to the way in which he approaches his subject in the rest of the book. All three of the extracts quoted above are from fairly traditionally styled school textbooks. In one sense, the second extract is the most honest in that it raises no expectations which may be disappointed.

More modern textbooks do try to achieve a balance between the traditional fact-laden format and a more progressive enquiry-orientated approach. For example, one more recent book begins:

> To the student:
> A scientist approaches his subject in the following way. First, he studies the existing knowledge that other scientists have already discovered. Second, he learns this body of knowledge including all its technical terms. Third, he makes sure he understands what he learns. Fourth, he may repeat some experiments that others have already done to verify the results. Fifth, and most important, he devises new experiments to investigate new subjects and perhaps create new knowledge. (Beckett 1976)

This author claims that his book allows the pupils to follow similar steps. In addition to the text itself, recall tests and comprehension tests, he includes verification exercises and inquiry exercises designed to simulate stages four and five of his stated scientific method. Clearly this is an attempt to make the student feel that he is participating in the activities of the scientific community while still acknowledging that learning of factual information will occupy a large part of a school science course.

It is clear that authors of school science textbooks do attempt to present a view of science to the pupils who read them. One reason for the design of Section 2 of the pilot questionnaire was to discover if the view presented did appear to have any influence of the teachers' choice of books for class use.

Section 3 of the questionnaire was designed to probe the respondents' attitudes to different classroom activities and to form some sort of picture of the teaching methods they use. In this section the teachers were ask to respond by indicating their views on a five point scale, from strongly agree to strongly disagree, to a series of statements. This technique, originated by Lickert (1932), is widely used for attitude measurement in questionnaire surveys (Oppenheim 1966).

Some of the items used in Section 3 were original and some were taken from, or modified versions of items in, the Inquiry into Teaching Strategies (ISTS) measuring instrument (Lazorowitz & Lee 1976). Four examples of items from this measure for comparison with those in the pilot questionnaire are quoted below:

6. Students are often capable of designing valid experiments.
11. Conflicting data can lead to useful post-laboratory discussion.
12. In an investigation, students should know from the beginning the steps they will perform.
33. A textbook should contain both the problems to be studied and the answers. (op.cit.)

The data obtained from Section 3 was intended to provide information about teaching methods used by the respondents and about their attitudes to certain classroom activities, particularly those involving practical work. It was hoped that this information would enable comparisons to be made between the teachers' classroom style and their philosophy of science.

Section 4 was considered the most important section of the questionnaire and was also the most difficult to design. It was this section that should provide the data needed to identify teachers with extreme views about the philosophy of science.

Various other studies have attempted to assess understanding of the nature of science and scientific method. Welch and Pella (1967) describe the Science Process Inventory (SPI) which requires subjects to mark statements to show whether they agree or disagree with them. Two examples from the inventory are:

79. A hypothesis is a simple guess or 'hunch' that tries to explain several observations.
124. Once a statement becomes a law of science it will not be changed.

In the Nature of Science Scale (NOSS) some statements require an agree/disagree response and some on a 1-5 scale to indicate strength of agreement. Examples from the scale (Kimball 1967) are quoted below:

5. While a scientific hypothesis may have to be altered on the basis of newly discovered data, a physical law is permanent.
11. The best definition of science would be 'an organised body of knowledge'.
19. The essential test of a scientific theory is its ability to correctly predict future events.
29. An important characteristic of the scientific enterprise is its emphasis on the practical.

Probably the best known test of this kind is the Test on Understanding Science (TOUS), compiled by Cooley and Klopfer (1961). Because of its widespread use and apparent acceptability, this test was studied in some detail as a possible model on which to base the

Section 4 questions. TOUS is made up of multiple choice questions of the following type:

12. The principal aim of science is to
    A. verify what has already been discovered about the physical world.
    B. explain natural phenomena in terms of principles and theories.
    C. discover, collect and classify facts about animate and inanimate nature.
    D. provide the people of the world with the means for living better lives.

15. Of the following, which is the best statement about scientific knowledge?
    A. Scientific knowledge is a systematic collection of facts.
    B. Data and ideas from the past contribute to today's scientific knowledge.
    C. Each generation starts anew to build up its own scientific knowledge.
    D. Statements are not accepted as scientific knowledge unless they are absolutely true.

This test has been widely used, not least in the International Association for the Evaluation of Educational Achievement (IEA) survey of science education in nineteen countries. In this survey, Comber and Keeves (1973) reported significant differences in scores on TOUS obtained by fourteen year olds and pre-university pupils in various countries studied (see Table 4.1). Pupils from Australia, West Germany and New Zealand gained high scores on TOUS in both age groups,

Table 4.1 Standard Scores on TOUS from IEA Survey

COUNTRY	14+ AGE GROUP	PRE-UNIVERSITY
Australia	0.55	0.70
Belgium - Flemish	-0.36	-0.57
- French	-1.48	-0.48
England	0.07	0.26
West Germany	0.39	0.97
Finland	-0.36	0.00
Hungary	-0.29	-0.55
Italy	-0.17	-0.51
Netherlands	-0.34	0.14
New Zealand	0.78	0.93
Scotland	0.15	0.11
Sweden	-0.64	-0.29
U.S.A.	0.68	-0.10

while those from Belgium, Hungary and Italy did rather worse than those from other countries. It would be interesting to speculate about the reasons for such differences. It could be that the reported differences in standard scores are a reflection of cultural differences which affect a nation's views of the nature of science or it may be that they reflect the effects of different teaching methods adopted in science classes attended by pupils in the countries studied.

As well as being used in a number of countries, TOUS has been administered to a wide age range from young schoolchildren to aged university professors. It has been found that some pupils can achieve higher scores than their teachers on the test. For instance, Miller (1963) found that 38% of high ability 11th and 12th grade pupils (equivalent to sixth formers) were able to do better than half of the biology teachers he tested on TOUS, and 68% of the pupils did better than the lowest quartile of the teachers. Schmidt (1968) repeated this work, but with physical science teachers included in his sample as well, and still found 9% of students scoring above half of the teachers and 47% of the pupils above the bottom 25% of the teachers.

However, in spite of the overlap in scores between the different age groups tested, there does seem to be a trend in all the results published for scores on TOUS to increase with age and with experience of science (see Table 4.2). Much of this work has been done in America but results obtained from groups tested in Australia (e.g. Mackay 1971), Israel (Jungwirth 1964) and England (Barlow 1970, Platts et al 1971) correspond to the same general pattern. Because of the mass of data available and the clear pattern of the results obtained with the test, it is generally regarded as the most reliable of the tests of understanding of scientific processes which have been published.

Closely related to TOUS and developed from it is the <u>Science Understanding Measure</u> (SUM). As this version of the test (Coxhead &

Table 4.2 Percentage Scores on TOUS of Various Groups

GROUP	SCORE	NUMBER IN GROUP	REFERENCE
Grade 7 Pupils	39	-	Yager et al (1969)
Grade 7 Pupils	32	c.400	Mackay (1971)
Grade 8 Pupils	50	55	Yager et al (1969)
Grade 8 Pupils	36	c.400	Mackay (1971)
4th Form Pupils	42	370	Platts et al (1971)
Grade 9 Pupils	43	c.400	Mackay (1971)
Grade 9 Pupils	49	198	Test Manual (1961)
Grade 10 Pupils	47	c.400	Mackay (1971)
Grade 10 Pupils	48	1055	Test Manual (1961)
Grade 10 Pupils	58	752	Jungwirth (1972)
Grade 11 Pupils	53	985	Test Manual (1961)
Sixth Form Pupils	54	140	Platts et al (1971)
6th Form Arts Pupils	53	37	Barlow (1970)
6th Form Science Pupils	58	13	Barlow (1970)
11/12th Grade Pupils	52	60	Smith (1963)
11/12th Grade Pupils	67	c.40	Cossman (1969)
Grade 12 Pupils	54	742	Test Manual (1961)
High School Pupils	53	2808	Klopfer & Cooley (1963)
High School Pupils	56	2419	Welch (1969)
High School Pupils:			
Trad. Physics Course	54	13 schools	Trent (1965)
PSSC Physics Course	61	13 schools	Trent (1965)
College Students	61	166	Siemankowski (1969)
College Students	61	87	Jones (1969)
Biology Undergraduates	58	800	Schefler (1965)
Chemistry Undergraduates	63	43	Jungwirth (1972)
Science Students	68	43	Schmidt (1968)
Science Students	69	55	Yager et al (1969)
Education Students	73	69	Olstad (1969)
Agriculture Graduates	68	48	Jungwirth (1972)
Post-graduate Biologists	70	25	Jungwirth (1972)
Post-graduate Science Education Students	77	50	Platts et al (1971)
Science Methods Students	80	29	Schmidt (1968)
Biology Teachers	73	-	Miller (1963)
Physics Teachers	70	51	Rothman (1969)
Science Teachers	74	68	Platts et al (1971)
Science Teachers	76	-	Schmidt (1968)
BSCS Teachers	82	57	Jungwirth (1972)
Scientists in Industry and Universities	85	116	Schmidt (1968)

Whitfield 1975) is shorter, quicker to administer, more reliable and has a vocabulary more suitable for pupils in this country, it has considerable advantages over the original version of TOUS. For these reasons, the philosophical questions used in Section 4 of the pilot questionnaire were based on items from SUM and TOUS. These items were modified where this seemed desirable either to make the vocabulary more suitable or to provide a range of alternative answers in accordance with the principles discussed in detail in section 4.2.

4.1.2 Pilot Questionnaire Results

An approach was made to an education authority outside the area to be used for the main survey for help in selecting a sample of schools to which pilot questionnaires could be sent. This was done to prevent copies of the pilot questionnaire being seen by teachers who might later be involved in the main survey. A list of twelve schools was obtained. These schools were a mixture of sizes, type, sex composition and situation, and the list included one voluntary aided denominational school (Table 4.3). A letter (see Appendix 1) was sent

Table 4.3 Schools in the Pilot Study

SCHOOL	NUMBER OF PUPILS	SEX	TYPE	SITUATION
1	890	Mixed	Secondary Modern	Rural
2	620	Mixed	Secondary Modern	Town
3	420	Boys	Secondary Modern	City
4	500	Girls	Secondary Modern	City
5	1060	Mixed	Comprehensive	Town
6	1050	Mixed	Comprehensive	City
7	1160	Mixed	Comprehensive	Rural
8‡	940	Mixed	Comprehensive	Rural
9	1260	Mixed	Comprehensive	Rural
10*	825	Mixed	Comprehensive	City
11	860	Boys	Grammar	Town
12	840	Girls	Grammar	Town

Notes: ‡ No replies were received from this school.
* Voluntary Aided Denominational School.

to the head of science department in each of the schools inviting him to complete the pilot questionnaire and a number of questionnaires, depending on the size of school, was enclosed in the hope that the recipients would encourage some of their colleagues to complete and return copies as well.

Completed questionnaires were obtained from all but one school, and in most cases more than one reply was received. The smallest school in the sample returned one completed questionnaire; others sent up to four. In all, replies from 33 teachers were analysed. Again the four sections of the questionnaire are referred to by number.

Section 1.

Analysis of data from the first section of the questionnaire showed that the respondents formed a good cross-section of those teaching science, including heads of science department (10); staff responsible for biology, chemistry or physics within science departments (12); and assistant teachers (11). The number of years experience of science teaching varied from two to twenty years, and most of the respondents had taught in two or more schools. The average number of years of teaching was 9.3, of which 5.3 years was in the respondent's current school. Information about the qualifications, training and main subject of those who replied is summarised in Table 4.4. The majority of the teachers were graduates with a post-graduate

Table 4.4 Qualifications, Training and Subject of Teachers completing Pilot Questionnaire

QUALIFICATION:	FREQUENCY	PERCENTAGE
Higher Degree	1	3
Good Degree (Class 1 or 2)	18	55
Degree or equivalent	8	24
Non-graduate	6	18
TRAINING:	**FREQUENCY**	**PERCENTAGE**
Education Degree	3	9
Advanced Diploma	2	6
Certificate in Education	21	64
Not Trained	7	21
MAIN SUBJECT:	**FREQUENCY**	**PERCENTAGE**
Biology	15	46
Chemistry	8	24
Physics	9	27
General Science	1	3

certificate in education. Although teachers of all three main science subjects were represented, nearly a half of the respondents were biologists and only one claimed to be a general scientist.

From studying the completed forms, it was clear that Section 1 of the questionnaire posed little difficulty for teachers. It was decided that this section could be used in the main survey without further trials. Only two small changes were made as a result of experience gained in the pilot survey. One was the inclusion of a subject category for environmental or rural science, and the other was a shortening of the qualification subsection.

Section 2.

Section 2 was concerned with the teachers' use of material from curriculum development projects and with their choice of textbooks. While a sizable minority used some of the Nuffield and Schools Council materials, the only project to be adopted or taught in a modified form by a large number was the Combined Science scheme for the 11-13 age range (Table 4.5). In the case of the single subject projects, the large number not using the material is explained in part by specialist teachers taking classes in a restricted range of science subjects.

Table 4.5 Use of Curriculum Projects by Teachers completing Pilot Questionnaire

PROJECT:	Adopt or teach modified version	Use some material from course	Not familiar with course	Do not use this course
Nuffield:				
Biology O level	0	24	0	76
Chemistry O level	3	21	3	73
Physics O level	3	15	3	79
Combined Science	54	18	0	27
Secondary Science	9	21	15	55
Schools Council:				
5-13	3	0	18	79
Integrated Science	12	3	3	82

Note: All figures are percentages.

With some minor changes in layout and a reduction in the number of response categories from six to four, this subsection was used for the main survey, but the other part of Section 2, concerned with the teachers' choice of textbooks, did not produce such clear results in the pilot survey and therefore required considerable modification.

As this part of the questionnaire was relatively unstructured, it proved difficult to compare views of any particular text, but certain types of comment appeared several times. Many books were used simply because they were in the schools and no money was available to replace them. Some were used because of their cheapness or because 'little else was available'. Factors mentioned in assessing the value of books were: clarity of text, suitability for the less able reader, accuracy/amount of factual material, quality of photographs and diagrams, inclusion of suggestions for practical work, logical approach, and availability of teachers' guides. Different schools used books in a variety of ways: they were sometimes issued to all members of a class to use for reference; some were used only 'to set work when colleagues were absent'; several schools used a library of books for resourse based topic work instead of having class texts, while others had replaced textbooks by school-produced worksheets.

None of the respondents mentioned considering whether books represented science as an activity of a particular kind with its own methodology and so it was decided to revise this subsection of the questionnaire completely for the main survey. The revised version still allowed teachers to list books which they had found useful but then asked them to rate various criteria for textbook choice in terms of importance to them. The items chosen for inclusion in this part of the questionnaire were derived from two sources. Many were based on comments from the teachers who replied to the pilot survey and others were taken from the list of criteria for rating textbooks as an aid to selection recommended by Sund and Trowbridge (1967, pp168-169). It was hoped that this change in format would allow for better camparison between teachers, even though their rating of the various criteria would no longer be related to particular books.

Section 3.

In this section the objective was to measure teacher attitudes to practical work and to assess their views on the utility of various kinds of practical activity. In an attempt to reach some understanding of the responses to this section, the data obtained from the questionnaire were subjected to factor analysis. As with all other statisical analyses in this study, use was made of the Statistical Package for the Social Sciences (SPSS) developed by Nie et al (1975). In this case it was the sub-program FACTOR that was used.

The initial factor analysis provided an unrotated factor loadings matrix from a principal components extraction. Twelve factors had an eigen value greater than 1 but, as there were no loadings in excess of 0.50 (or -0.50) for factors 8-12 and the 'scree' test indicated a break at about the six factor point, the analysis was repeated using varimax and oblique rotation techniques seeking solutions with 3, 4, 5, 6 and 7 factors. In the six and seven factor solutions, the last two factors had large loadings (0.40 or more) on three or fewer of the variables. The first five factors showed similar groupings of loadings whatever the method used (no rotation, varimax rotation or oblique rotation) or the number of factors chosen (5, 6 or 7 factors). The solutions with fewer factors seemed less clear but some of the groupings were still apparent.

For these reasons the clearest of the five factor solutions, that obtained with varimax rotation, was used as the basis for the construction of five scales from the Section 3 questions. Table 4.6

indicates all the loadings on the varimax five factor solution that were equal to or in excess of 0.50. Some lower values are included in

Table 4.6 Factor Analysis of Section 3 Questions (Pilot Version)
(Varimax 5 factor solution, decimal points omitted)

QUESTION	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
1		58			
2					40
3		67			
4	(55)			(44)	
5	(55)				
6	50				
7					46
8		65			
9					
10	50				
11	62				
12				37	
13			72		
14				59	
15					
16		55			
17				52	
18					44
19	69				
20		73			
21		52			
22	71				
23					42
24					77
25					
26					
27			-48		
28			65		
29					
30	69				
31				62	
32				68	
33					
34			71		
35					
36	(55)				
37			46		
38	(53)				
39	59				
40	55				

the table if they are of interest or if they affected decisions about the constructions of the five scales based on the factor analysis. The loadings shown in brackets are for questions which were not used in the five scales. Question 4 was rejected as it had high loadings on two factors. Although questions 5, 36 and 38 had high loadings on factor 1, they were not so obviously connected with the other questions in this group on theoretical grounds. Agreement with the statements in these items could not definitely be said to represent one view of science rather than another. Where items were included in scales in spite of having loadings below 0.50, the loading for the scale in which they were used was higher than that on any other factor and there also seemed to be good theoretical justification* for their inclusion. The five scales which were drawn up to correspond to the five factors are shown in Table 4.7.

Table 4.7 Scales Derived from Factor Analysis of Section 3

SCALE	FACTOR	QUESTIONS	RELIABILITY
H - hypothetico-deductivist	1	6,10,11,19,(22),30,(39),40	0.84
V - verificationist	3	13,-27,28,34,37	0.70
I - inductivist	4	12,14,17,31,32	0.68
S - science-awareness	2	1,3,8,16,20,(21)	0.76
T - technical skill	5	2,7,18,23,24	0.62
Note: Question 27 scored in reverse direction because of negative loading on factor analysis.			

The H, V and I scales were considered to be a measure of the teacher's implicit philosophy of science as exemplified by his attitudes to and beliefs about practical work. These three scales have some theoretical correspondence to the three philosophies of science described in the first section of Chapter 2. The other two scales, considered to be of less importance, reflected the respondent's concern with practical work as a tool in science education or as a specific training in techniques.

* See note 1 on page 99.

Scale H, the scale derived from the first factor, measures a teacher's inclination towards using a hypothetico-deductivist style of teaching in practical lessons. He introduces his classes to what Medawar (1969) calls critical or Galilean experiments in which actions are carried out to test preconceived hypotheses or opinions by examining their logical consequences. A high scorer on scale H believes that pupils are capable of designing their own experiments (6) to test predictions (11) or ideas (30) and he uses practicals as an integral part of classroom investigations (19). Practicals are also used by such teachers to answer pupils' questions (40) and to emphasize the importance of having evidence for one's opinions (10). (Numbers in brackets refer to question numbers in the scale.)

Scale V was based on factor 3 and reflects a teacher's inclination towards the verificationist teaching style. In this style of teaching practical work would be an adjunct to a theory dominated course. The main kind of experimental work introduced into such a course would be what Medawar (1969) calls demonstrative of Aristotelian experiments, intended to illustrate a previously stated idea and to convince pupils of its validity. A teacher scoring high marks on scale V uses practicals to give pupils experience of concepts he has taught them (13), to provide evidence for the truth of what he has said (28) and thus pupils know the results they should obtain beforehand (-27). The emphasis is on verification of work covered in theory lessons (34), although practical work may be used to arouse interest (37).

Scale I, which comes from factor 4, represents a measure of the teacher's inclination towards the inductivist approach. Such a teacher believes it is difficult to discover something new (14) and that careful measuring and recording is necessary to discover the regularities in nature (17). He thinks it is worth repeating experiments to establish general patterns (32) because observation of many different examples is important (12) even if demonstrations have to be used to provide reliable sets of results (31). This view of practical work accords well with the classic Baconian position. As Medawar (op.cit. pp 34-35) points out:

> We could spend a whole lifetime observing nature without once seeing two sticks rubbed together, seeing sunlight refracted through a crystal, or witnessing the distillation of fermented liqour. Francis Bacon therefore charged us to contrive or invent experiences ... It was these contrived experiences, invented happenings, that Bacon called experiments ... Experimentation in Bacon's sense is not a critical procedure. Its purpose is to nourish the senses, to enrich the repertoire of factual information out of which inductions are to be compounded. It is that enlargement of experience which in the inductive view, cannot but lead to an enlargement of the understanding.

It did seem that the factor analysis of the Section 3 responses revealed three factors showing some connection with the three philosophical viewpoints previously described, but there were also two other factors which affect teachers' views about practical work in their science lessons.

Scale S reflects the teacher's general awareness of the usefulness of practical work in the context of science lessons. A high scorer on this scale believes that practicals are important in keeping pupils occupied (20) and in providing enjoyment in science lessons (1). He sees practicals as good for illustrating scientific principles (8) and generally for promoting scientific methods of thought (16); indeed, without practicals, he believes pupils would get a false idea of science (3).

Scale T measures the respondent's concern with the pupils' technical skills. A high score indicates the beliefs that practicals develop manipulative skills (2), encourage accurate observation (18) and teach skillful handling of apparatus. It also indicates that a teacher believes that pupils need clear instructions (7), but enjoy getting the right results (23).

That teachers regarded the factors embodied in scales S and T as important was to be expected and these finding reinforce those of Wilson (1977) who found that arousing and maintaining pupil interest was said by teachers to be the most important consideration in choice of practical work. The teachers in his sample rated encouraging accurate observation and recording and developing manipulative skills next in importance.

Once the five scales had been constructed, a check was carried out to find if all the items in each scale were contributing to the measuement of a single factor. Each scale was tested using the RELIABILITY sub-program of SPSS which provides an internal consistency estimate of reliability and calculates alpha coefficients. The reliability coefficients of the five scales are quoted in Table 4.7. Considering the small number of items in each scale, these reliability coefficients can be regarded as more than satisfactory. For comparison, TOUS has an internal consistency reliability estimate of 0.76, and this is for a 60 item test. If TOUS were only a 20 item test, its reliability (using the Spearman-Brown formula) would fall to 0.51 (Coxhead & Whitfield 1975), so obtaining reliabilities in the range 0.62-0.84 for scales of five to eight items is remarkably good.

Although the consistency of all five factors was of interest, it was the composition of the three scales (H, V and I) related to the three philsophies of science which was of greatest importance in the context of this investigation. Items 22 and 39 (shown in brackets in Table 4.7) were deleted from scale H as they seemed to fit less well than the others on theoretical grounds. Even so, scores on these three scales were not as highly negatively correlated as one might expect, because of the views they represent being to some extent mutually antagonistic. It was felt that this relationship might be obscured by greater individual differences between teachers on whether or not they were favourably disposed towards any reason for doing practical work. To overcome this problem a 'correction factor' was applied to scores on these three scales. A total score was calculated by adding the marks obtained on all sixteen items in scales H, V and I. A high total score indicated a tendency to agree strongly with everything put forward, and a low score a reluctance to agree with anything. Applying the 'correction factors' shown in Table 4.8 enables one to allow for this difference between the respondents and to clarify differences in the way they responded to the H, V and I questions.

Table 4.8 Formulae for 'Correction' of Scales H, V and I

TOTAL = Sum of scores on scale H, scale V and scale I

$$H' = \text{Scale H score} - \frac{6}{16} \times \text{TOTAL}$$

$$V' = \text{Scale V score} - \frac{5}{16} \times \text{TOTAL}$$

$$I' = \text{Scale I score} - \frac{5}{16} \times \text{TOTAL}$$

If respondents had no internal preferences for any of the three philosophical positions, they would be indifferent to the views expressed in the statements included in these three scales. If this were the case, it would be possible to predict their scores on each scale. Each score would be a simple fraction of their total score on the three scales and would reflect only their tendency to agree with all the statements presented to them. The 'correction' formulae thus remove that component of the scores which can be regarded as being due to this tendency. Once this was done, the 'corrected' scores (H', V' and I') indicated that there were real differences of opinion concerning the relationship of philosophy and practical work, which were independent of differences between individuals in their tendency to agree with statements on the questionnaire generally. Using the 'corrected' scores obtained by applying the above formulae and the PEARSON CORR sub-program of SPSS, correlations between the three scales were calculated. The scores on the three scales were clearly negatively correlated, and in all cases the negative correlation was significant (Table 4.9).

Table 4.9 Correlations between Scales H', V' and I' (Pilot Version)

	V'	I'
H'	-0.41**	-0.59***
V'	-	-0.49**

Note: In this and all similar tables one, two and three asterisks respectively indicate that a correlation is significant at the 0.05, 0.01 and 0.001 levels of probability.

As the scales in Section 3 of the questionnaire derived from the factor analysis of the teachers' responses had high reliabilities, were significantly negatively correlated, and seemed to be related to the three theoretically derived philosophical positions, it was decided to make use of the similar format for Section 3 in the final version of the teacher questionnaire. It was always intended that the final questionnaire should be shorter than the pilot version and Section 3 was cut from 40 to 25 items. This meant that, in the final version, each of the five scales (H, V, I, S and T) had five items. The reduction was brought about by using the factor loading and reliability data from the analysis of the pilot responses. The renumbering of the questions for the main survey questionnaire and the reliabilities of the shortened scales are shown in Table 4.10, which also indicates which of the old items from the pilot were actually used in the revised version. It will be noted that item 27 (renumbered 18), which is part of scale V, is scored negatively in accordance with its factor loading.

Table 4.10 Renumbering of Section 3 Questions

SCALE	H		V		I		S		T	
RELIABILITY	79		70		68		72		62	
QUESTION NUMBERS	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
	10 11 19 30 40	6 7 14 20 25	13 -27 28 34 37	9 -18 19 23 24	12 14 17 31 32	8 10 12 21 22	1 3 8 16 20	1 3 5 11 15	2 7 18 23 24	2 4 13 16 17

Although the fifteen items relating to the hypothetico-deductivist, the verificationist and the inductivist approaches to practical work were of the greatest interest and importance, the other ten items were considered useful for two reasons. First, they would partially obscure the purpose behind this section of the questionnaire and prevent respondents from guessing what answers the experimenter was expecting. Secondly, they would provide opportunities for teachers to show that they have genuine non-philosophical reasons for including practical work in lessons. To deny them the possibility of such responses would have led to unnecessary respondent frustration as there was little doubt that, for some teachers, their attitudes to practical work were coloured by considerations of expediency, utility or merely fashion.

The scales from Section 3 were to be used to identify individuals who used practical work in such a way as to imply adherence to particular philosophical positions, but they could not be used to establish if the teachers subscribed to such views explicitly. This was the function of Section 4 of the questionnaire.

Section 4.

The Section 4 questions were designed to identify respondents' views about the philosophy of science. Many of the items used were modifications of those in TOUS (Cooley & Klopfer 1961) and SUM (Coxhead & Whitfield 1975). In these tests the 'correct' answers correspond to the hypothetico-deductivist view of science. The modifications which had been introduced in an attempt to increase the possibility of inductivist or verificationist respondents finding answers which would reflect their views about the philosophy of science. From the data of the pilot survey it was intended to derive the information necessary to refine this section to allow for indentification of extreme types of teacher of the three kinds.

A somewhat unusual method of analysis was adopted in dealing with the data from Section 4.* All sixty possible responses to the fifteen questions were treated as separate items for the purposes of the factor analysis. This procedure is unusual as the four possible responses to each question are alternatives and are thus inherently negatively correlated. However the results obtained were expected to provide a guide to the structure of any factors underlying the pattern of responses. As most of the large negative correlations would be because respondents could select only one from each group of four responses, it was decided, when interpreting the analysis, to ignore all negative loadings and to select from each group of four the item which had the highest positive loading on each factor.

The first analysis, extracting principal factors with no iterations and no rotation, produced fifteen factors with an eigen value greater than 1 and no clear break in the 'scree' test. However, the first four factors seemed to be the most important as all the loadings, especially the positive ones, were low in the remaining factors. The analysis was therefore repeated looking for possible solutions with 2, 3, 4 or 5 factors and using varimax rotation. On all these analyses the loadings in the first factor identified similar items. In all except the two factor solution, the second factor

* See note 2 on page 99.

appeared to be consistent, but third and subsequent factors were less clear. A three factor solution with oblique rotation was no better and indicated that the factors were orthogonal, so the three factor varimax solution was taken as the best overall. Details of this solution are given in Table 4.11.

Table 4.11 Factor Analysis of Section 4 Questions (Pilot Version)
(Varimax 3 factor solution, decimal points omitted)

QUESTION	FACTOR 1		FACTOR 2		FACTOR 3	
	RESPONSE	LOADING	RESPONSE	LOADING	RESPONSE	LOADING
1	A	(32)	B	(28)	C	(19)
2	A	62				
3	C	69				
4	A	58				
5	A	50	B	(22)	C	51
6	B	(34)	A	(36)	D	(27)
7			C	(12)	D	58
8	B	83	D	58		
9			C	(44)	A	(-24)
10			A	53		
11	A	59	C	(10)	D	(-20)
12	B	83	D	(34)		
13	B	83	C	(48)		
14			B	52	C	(04)
15					D	(38)
SCALE	PV		PH		PI	
RELIABILITY:	0.79		0.73		0.38	

Although it might be expected that the 'correct' answers according to the TOUS pattern, corresponding to the hypothetico-deductivist view of science, would emerge as the most clearly identifiable factor, this was not the case. Factor 1, which had some very high loadings (up to 0.83) corresponds to the verificationist position, in which science is seen as a collection of factual data which can be verified by experiment. Factor 2 represented a view closer to the hypothetico-deductivist standpoint and the third factor, although weak, reflected the inductivist philosophy.

The figures given in brackets in Table 4.11 are loadings that might be considered too low (below 0.50) to justify their inclusion, but in this case they were quoted because of the items having high negative loadings on the other scales. Two items, 9A and 11D, were included in the scale developed from Factor 3 in spite of having negative loadings on that factor because of their theoretical connection with what that scale was designed to measure.

The three scales extracted from Section 4 were scale PV, based on Factor 1, scale PH, from Factor 2, and scale PI, partly based on Factor 3 and partly based on more theoretical considerations to provide the third philosophical alternative. As might be expected this third scale, being derived only in part from the empirical data, had a lower alpha coefficient when the internal consistency reliability estimate was carried out on the three scales. The philosophical scales were tested using the RELIABILITY sub-program of SPSS and the results obtained are shown in Table 4.11.

Scale PV was a measure of the teacher's agreement with the verificationist philosophy. A high score on this scale indicates that the respondent believes that scientific knowledge is a collection of facts (1A) and that the principal aim of science is to discover, collect and classify facts about nature (3C); scientists try to improve experiments to get the right results (12B) by making them more accurate (11A) and experiments are used to prove the regularity of natural phenomena (8B); scientists make discoveries by careful experimental work (4A) and, when a scientist establishes a new theory, he has uncovered one of the laws of nature (6B); scientific societies exist to inform people about scientific discoveries (2A). This outlook on science clearly puts its emphasis on the factual nature of science and the proof provided by accurate experimental measurement.

Scale PH, based on the second factor, measures agreement with the hypothetico-deductivist philosophy. Anyone who achieves a good score on scale PH agrees with the standard Popperian hypothetico-deductive philosophy of science (9C, 11C). He believes hypotheses are guides to future experiment (14B), considers hypotheses other than his own (13C) and uses experiments to test his predictions (8D) revising them if necessary (12D) in the light of the results obtained; scientific theories are products of man's understanding (6A) and may be revised or improved (10A) in the future; as well as considering raw data, scientists interpret it in the light of their personal ideas (7C) and those of other scientists (1B).

Scale PI was the one which emerged least clearly from the factor analysis of the Section 4 responses, but it does correspond to the Baconian inductivist philosophy of science. The high scorer on this scale emphasizes the dependency of science on large numbers of observations (1C), and on experimental evidence (6D, 7D) as well as upon the need for systematic recording of data (11D). He regards it as important to suspend judgement until the evidence is in (15D) and is suspicious of hypotheses (14C) because of the lack of prior observation (9A).

It was intended that the Section 4 scales would be used in the main survey to identify teachers who consciously subscribed to one of the three extreme philosophical positions. Comparison with scores on the Section 3 scales would then permit the identification of those who both held one of the philosophical doctrines and also let this influence the way in which they introduced practical work into their teaching.

The correlations between the three philosophical scales were all negative (see Table 4.12). Scales PH and PV certainly represented different points of view, but the inductivist scale is not so clearly an alternative. Negative correlations between PI and the other two scales, particularly scale PV, were weak and were not significant.

Table 4.12 Correlations between Scales PH, PV and PI (Pilot Version)

	PV	PI
PH	-0.48**	-0.32 ns
PV	-	-0.01 ns
Note: ns = not significant.		

Because of the importance of the Section 4 scales in the identification of individuals later in the research plan, the apparent weakness of scale PI was regarded as a serious defect and it was decided to devote considerably more time to the development of the philosophical scales, rather than just to rely upon the data from the pilot survey as had been done with the other sections of the questionnaire.

The rewriting and further testing of the philosophical scales are described in the second section of this chapter. This section also explains how the test instrument to be used with pupils to test their understanding of science was developed.

Note 1 (from page 88):

Here and elsewhere (pp. 91, 134 & 136) phrases such as 'theoretical justification', 'theoretical considerations' or 'theoretical grounds' are used to explain the inclusion or exclusion of items in spite of their loadings in the factor analyses when such a decision was made in order to preserve the face validity of scales which were intended to be related to the three philosophical positions described in Chapter 2.

Note 2 (from page 95):

This use of factor analysis is questionable as it can be held that the data obtained from Section 4 is categorical and would have been more correctly analysed by a non-parametric technique such as cluster analysis. In practice the problem was solved in another way: by redesign of this section of the questionnaire for its final version so that the data obtained could be analysed by factor analysis in the normal way.

4.2 The Philosophical Scales

4.2.1 Problems of Developing Philosophical Scales

It was only gradually that the complexity of the problems involved in developing philosophical tests became apparent. The research plan allowed for the development of an improved version of Section 4 of the teacher questionnaire and a simplified version of this to be used as a pupil test in the experimental phase of the investigation.

The first problem to be faced was the apparent weakness of the inductivist scale, PI, derived from the pilot data. Consideration was given to the possibility of rewriting Section 4 of the teacher questionnaire completely to change its format. Two alternative formats were prepared for testing (see Appendix 2).

One format abandoned the multiple choice arrangment of items and statements were paired, forcing respondents to choose one statement from each pair as the one closer to their own view. Each statement appeared twice in the test, sometimes with the wording slightly changed, and was paired each time with a statement expressing one of the alternative viewpoints. Some original material was introduced but the statements were mainly those used in Section 4 of the pilot questionnaire. The material was used to form pairs of H/V, H/I and

Table 4.13 Philosophical Questions - paired statements format

SUBJECT AREA	ITEM NUMBER WITH		
	H/I PAIR	H/V PAIR	V/I PAIR
Scientific knowledge	1	13	22
Hypotheses	11	23	3
Theories	21	2	12
Laws	25	4	14
Aims of science	15	24	5
Scientific societies and journals	6	16	26
Scientific discovery	30	18	7
Experiments	17	8	29
Typical scientific activities	9	20	28
Evidence in science	27	19	10

V/I statements. There were three pairs of statements in each of ten areas concerned with scientific method or philosophy where there might be expected to be disagreement. Table 4.13 indicates which pairs of statements were concerned with each of the ten areas of disagreement and which combinations of statements were included in each item.

The second format for the section retained the multiple choice format used in the pilot but reduced the number of possible answers in each item from four to three. The answers retained were those which had positive loadings in the three factor solution using varimax rotation obtained from the analysis of the pilot data. The total number of questions was reduced from fifteen to ten and each had one hypothetico-deductivist (H), one inductivist (I) and one verificationist (V) answer. The relationships between these ten questions and the old questions in the pilot version of Section 4 are shown in Table 4.14.

Table 4.14 Philosophical Questions - revised multiple choice format

REVISED QUESTION	PILOT QUESTION	SCALE PV	SCALE PH	SCALE PI
1	1 A,B,C	A	B	C
2	4 A,B,D	A	B	C
3	5 A,B,C	A	B	C
4	6 A,B,D	B	A	C
5	8 B,C,D	A	C	B
6	9 A,C,B+D rewritten	B	C	A
7	12 A,B,D	B	C	A
8	13 B,C,D	A	B	C
9	15 A modified, C, new answer	B	A	C
10	7 New answer, C, D modified	A	B	C

It was proposed to test the alternative formats in two ways. First, the tests were to be submitted to a panel of experts, a group made up of four university lecturers with backgrounds in science and philosophy, for comments on both the philosophical content and the arrangement of the test items. Following this, the questions were to be tried out on university students on science courses. Information from these trials would then be used as a guide in drawing up the final version of Section 4.

However the experts were united in their condemnation of the paired statements format. They were sophisticated subjects and, with one possible exception, committed to the hypothetico-deductivist view of scientific method. For this kind of respondent, a format which forces one to choose between two 'wrong' answers on a third of the test items is intensely irritating even though little difficulty is experienced in selecting the 'correct' answer (i.e. the H response) on the remaining questions. As the reaction against the paired statements format was so strong, it was abandoned in favour of further testing of the multiple choice format. This version received the general approval of the experts although minor changes in wording were suggested for a few items.

The multiple choice version was therefore administered to the student groups. Test administration was carried out by university lecturers, usually by the lecturer normally with the students tested. The questions were completed by 70 final year undergraduates in the science faculty of one university and by 26 science graduates on a post-graduate certificate in education course at a second university. The PGCE students had all followed undergraduate courses in one or more of the laboratory sciences; mathematicians were excluded from the group. Although the original intention had been to try out the questions on science students, the inclusion of a group of students who were planning to become teachers allowed for a slight change in plan. The results of the PGCE students were also analysed separately in case the responses of those preparing for entry to the teaching profession are not typical of those from science students in general. The responses from all those tested, and from the PGCE students separately, are shown in Table 4.15 in terms of the V, H and I classification of answers to each question.

Table 4.15 Student Responses to Philosophical Questions

QUESTION NUMBER	% OF ALL RESPONDENTS V	H	I	% OF INTENDING TEACHERS V	H	I
1	10	24	65	4	42	54
2	14	54	31	12	50	38
3	22	38	40	4	69	27
4	7	76	16	15	77	8
5	0	88	12	0	88	12
6	22	57	20	8	69	23
7	1	96	3	4	96	0
8	24	69	7	8	84	8
9	7	4	88	0	0	100
10	18	23	59	27	27	46

Although there were some differences, these were not so great as to suggest that the education students should have been regarded as a distinct group among those who have studied science at university. In looking at the results as a whole, it became clear that those selecting the V and I responses were a large minority or even a majority on some questions. This did not seem to be because some students held a strong inductivist or verificationist philosophical standpoint. Rather it was due to many picking a variety of responses which together formed no coherent philosophical position. This was reflected in the low reliability coefficients of the three scales. Even the PH scale, which might be expected to be the most reliable, had a reliability of less than 0.30.

At first sight these results were unexpected. In the original Section 4, higher alpha coefficients had been obtained for the three philosophical scales particularly for scales PV and PH. The poor reliabilities of the revised version admit of two possible explanations: either there was such a lack of clarity in the test items that respondents were unable to identify the responses which corresponded to their philosophical beliefs, or else the respondents simply lacked a completely clear and coherent philosophy of science.

These results constituted a serious problem for tests such as TOUS produce results which are easily reproduced and therefore highly reliable. Experience of such tests would lead one to accept the first explanation for the low reliability of the revised philosophical questions and to reject them as unsuitable for their purpose.

However, analysis of some results obtained with TOUS suggested an alternative explanation. To understand the part of the argument presented here, it is necessary to bear in mind two of the questions on TOUS Form W (Cooley & Klopfer 1961):

> 12. The principal aim of science is to
>   A. verify what has already been discovered about the physical world.
>   B. explain natural phenomena in terms of principles and theories.
>   C. discover, collect and classify facts about animate and inanimate nature.
>   D. provide the people of the world with the means for leading better lives.
>
> 15. Of the following, which is the best statement about scientific knowledge?
>   A. Scientific knowledge is a systematic collection of facts.
>   B. Data and ideas from the past contribute to today's scientific knowledge.
>   C. Each generation starts anew to build up its own scientific knowledge.
>   D. Statements are not accepted as scientific knowledge unless they are absolutely true.

For both of these questions the required response is B, but Jungwirth (1968) reports that over half of the students he tested chose response C for item 12. On item 15, he found 41% chose response A and 45% chose D. These responses were not correlated with intelligence. Even with final year science undergraduates and teachers 30% gave C as their response to item 12 and nearly half picked A in question 15 (Jungwirth 1972). Jungwirth questions whether his results show a lack of understanding of science or a misunderstanding of the terminology used in the questions. However, an alternative explanation of his results is possible.

TOUS and tests based upon it, such as SUM (Coxhead & Whitfield 1975), assume that the Popperian hypothetico-deductivist view of science is correct, and the responses of those tested are scored accordingly. Other responses are simply regarded as wrong. This attitude may lead to a failure to recognize that a distractor may be perceived as being wrong for two different reasons. It may be rejected by a respondent because it does not make sense at all, or it may be rejected because it does not accord with his own view of the philosophy of science. It is suggested here that such tests can have a high reliability because respondents are able to recognize wrong answers of the first kind without difficulty. Where the test compilers have included distractors which happen to fit an alternative view of science, as in questions 12 and 15 on TOUS, these are chosen by a large percentage of respondents (Jungwirth 1968, 1972; Platts et al 1971). This is not to say that those tested necessarily subscribe to the verificationist or inductivist philosophy, merely that they have greater difficulty in selecting a coherent set of responses in circumstances when all the possible answers are real alternatives. As many may not have given a great deal of conscious thought to what they believe the nature of science to be, it must be expected that such questions would be very difficult to answer.

It has generally been assumed that tests such as TOUS measure understanding of a somewhat idealized view of science not based on any particular style of teaching or course content. The test manual for SUM is quite explicit, stating that one thing it measures is whether respondents see that

> problem solving in science is a complex process and involves the interaction of ideas (concepts), hypotheses and experiments; one part of this process [being] the attempt to verify (interpreted as 'fail to falsify') or reject

hypotheses by planned experiments. (Coxhead & Whitfield 1975, p 5)

In other words, one aim of the test is to measure the extent to which respondents agree with the hypothetico-deductivist approach to science. In spite of the high reliability of the test, quoted as 0.80 in the manual, the questions in it do not allow the respondents to choose answers corresponding to this view of science as alternatives to any other coherent view or views. Because the tests are not of the same kind, it is therefore not reasonable to compare the reliabilities of tests such as TOUS or SUM with that of the revised Section 4 from the teacher questionnaire, which was an attempt to provide respondents with a choice of three different but coherent views of science.

If this explanation of the high reliability of the standard tests and the low reliability of the Section 4 philosophical scales is correct, it follows that it should be possible to devise a reliable inductivist or verificationist test corresponding to the hypothetico-deductivist TOUS or SUM. This is the subsidiary hypothesis mentioned above (see p 71) and it was necessary to test this before the development of the philosophical scales could be continued.

4.2.2 Developing an 'Inductivist' Test

The subsidiary hypothesis (Hypothesis 6) was as follows:

It is possible to construct a test to measure understanding of the inductivist philosophy of science.

To test this hypothesis SUM was rewritten and called the Understanding Science Test (UST). It is reproduced in full in Appendix 3. The rewriting left the order and general wording of the SUM questions as before but substituted inductivist answers for the hypothetico-deductivist ones in questions 1, 2, 4, 5, 6, 10, 11, 12, 16 and 17. The other questions are non-philosophical and these were largely unmodified, the only change being to remove the biased reference to 'testing' a new theory in the wording of question 18.

Initially this revised test was administered, following the instructions printed in the SUM test manual, to 71 pupils aged 13-14. Table 4.16 shows the percentage of respondents giving each answer to allow comparison between SUM and UST (the inductivist test). An internal

Table 4.16 Percentage Responses on UST (13-14) and on SUM (13-14)

QUESTION	A		B		C		D	
	UST	SUM	UST	SUM	UST	SUM	UST	SUM
1*	6	10	7	13	1	9	86	69
2*	80	79	4	8	14	8	1	5
3	4	5	6	5	83	87	6	4
4*	9	10	16	15	49	58	27	17
5*	13	14	70	65	3	5	14	17
6*	73	66	16	9	6	13	6	12
7	3	4	10	11	61	68	27	17
8	23	14	3	5	10	17	65	64
9	10	7	75	77	6	3	10	12
10*	49	65	25	13	16	8	10	15
11*	1	9	4	9	85	73	10	9
12	20	28	9	12	11	8	61	51
13	17	19	61	60	16	14	7	7
14*	1	14	11	12	17	19	70	58
15	27	28	41	49	17	16	16	7
16*	42	48	28	27	11	5	18	20
17*	41	48	17	12	28	25	14	15
18	16	10	63	65	14	20	7	5
19	51	37	18	18	21	34	10	11
20	7	5	17	20	11	18	65	57

Notes: 1. Inductivist questions modified for UST are starred (*).
2. 'Correct' answers are underlined.
3. SUM data from P. Coxhead (personal communication).

consistency reliability estimate was made for the whole test, for the modified questions alone and for the unchanged questions. This was done using the RELIABILITY sub-program of SPSS. The reliability coefficients were 0.68 for the whole test, 0.54 for the inductivist questions and 0.47 for the other, unmodified, questions. Although the reliability of the inductivist test, UST, was not as high as that quoted in the manual for SUM, this was due to the lower standard deviation with the UST sample (see Table 4.17) and the results seemed to bear out the suggestion that pupils are able to reject wrong answers irrespective of the nature of the 'correct' answers. The general pattern of responses to the two tests is remarkably similar and it is worth noting here that the reliability of the ten inductivist questions alone is higher than the reliability of the ten unmodified questions. The worst items in the test are questions 13 and 20, both unchanged from SUM, and their inclusion reduces the overall reliability of the instrument.

Table 4.17 Statistical Data on UST (13-14) and SUM (13-14)

	SUM	UST
Overall mean	12.4	12.4
Mean on philosophical questions	6.3	6.4
Mean on other questions	6.1	6.0
Standard Deviation	4.71	3.47
Standard Error	1.9	1.96
Reliability	0.84	0.68
Number of students tested	427	71

Note: part of SUM data from Coxhead & Whitfield (1975), and part from P. Coxhead (personal communication).

Mean scores obtained by pupils on SUM and UST are similar, so changing the nature of the 'correct' responses seemed to have little effect on the pupils' ability to select the expected responses from among those given. These results obtained by administering the test to a group of restricted age range were interesting enough to warrant a trial of UST with a larger sample of pupils covering the full 11-14 age range for which SUM was intended.

UST was therefore administered to about 300 pupils in the first, second and third forms of an 11-16 comprehensive school in a different local authority from the school used in the original trial. The school had an annual intake of 200 pupils and the test was given to about half of the pupils in the first three year groups by their normal science teachers. As the pupils were normally in mixed ability groups, the sample tested represented the full range of ability within the school population. The percentage responses to questions and the statistical data derived from the test of the larger sample are shown in Tables 4.18 and 4.19 respectively.

Table 4.18 Percentage Responses on UST (11-14) and on SUM (11-14)

QUESTION	A		B		C		D	
	UST	SUM	UST	SUM	UST	SUM	UST	SUM
1*	18	12	13	16	7	13	63	59
2*	76	72	11	11	7	13	6	4
3	8	9	7	8	83	78	2	5
4*	12	9	19	15	40	54	29	22
5*	19	11	61	62	3	5	18	22
6*	55	63	21	10	9	17	15	10
7	5	5	7	10	67	64	21	10
8	2	13	5	6	24	20	70	61
9	6	10	69	67	7	5	18	17
10*	33	61	24	14	21	9	21	16
11*	7	10	7	11	73	62	12	16
12	36	26	14	15	8	10	42	47
13	12	14	60	61	18	16	10	9
14*	11	15	10	14	12	19	66	52
15	24	34	43	37	18	20	15	8
16*	18	42	49	27	10	7	24	24
17*	41	38	22	15	24	27	12	21
18	13	13	58	53	16	25	12	9
19	49	38	16	21	20	24	14	15
20	7	6	19	20	12	19	61	54

Notes: 1. Inductivist questions modified for UST are starred (*).
2. Correct answers are underlined.
3. SUM data from P. Coxhead (personal communication).

As with the smaller 13-14 sample, question 19 had more wrong responses than correct ones, but this was the case in the original SUM and it is one of the unmodified questions. Question 16* also had more respondents choosing a wrong response (B) than choosing the expected answer (A). However response B was picked by a significant minority in the original SUM (27%) and no doubt the response to the expected answer in UST could be improved if the item were reworded. Some of the SUM questions had been tested in five different versions during the trials before publication and there is no reason to suppose that UST questions 10* and 16* could not be 'improved' to increase the percentage of respondents giving the expected response. Considering the

Table 4.19 Statistical Data on UST (11-14) and SUM (11-14)

		SUM	UST
Mean		11.1	11.0
Standard Deviation		4.36	3.59
Standard Error		2.0	1.96
Reliability		0.80	0.70
Number tested:	Year 1 (11-12)	387	112
	Year 2 (12-13)	398	106
	Year 3 (13-14)	427	108
	Total	1212	326
Note: SUM data from Coxhead & Whitfield (1975).			

amount of work necessary to develop SUM to the point where it had a reliability of 0.80, the reliability of UST (0.70 with the 11-14 sample) is more than satisfactory. The difference is due to UST being tested with a smaller sample having a lower standard deviation rather than any defect in the test itself. As was found with the 13-14 year old pupils, the reliability of the inductivist questions, modified from SUM, was higher than that for the other ten unchanged questions (0.61 compared with 0.50).

The results obtained with UST give no reason for rejecting the subsidiary hypothesis. Rather they show that it is possible to construct a reliable test on which respondents can pick out a coherent set of inductivist responses.

4.2.3 Implications for the Teacher Questionnaire

The results obtained from the trials of UST help to clarify the differences between tests such as TOUS or SUM and Section 4 of the teacher questionnaire. In the former, the aim is to measure general awareness and understanding of science as opposed to their absence. In the Section 4 questions, where alternative answers are not just distractors but give differing views of the philosophy of science, the aim is to find out something about the nature of the respondent's understanding of the philosophy of science. Although many respondents have little difficulty in selecting answers which seem to have something to do with the methodology of science in a unidimensional test, whether the test is a hypothetico-deductivist or an inductivist one, this does not imply that they have a clear understanding of the philosophy of science. If they do not have a clear view of the methodology of science and have not previously given the matter careful thought, it is not surprising that they have great difficulty in selecting a set of answers which correspond to a coherent philosophy when confronted with a test in which all the answers to the multiple choice items seem plausible. This could explain the results obtained when the revised philosophical questions were tested on the university students.

In the light of the results obtained with the inductivist test, it was decided to change the format of Section 4 of the questionnaire to be administered to teachers. The format finally adopted was that which had been proved successful in the pilot survey for Section 3. Instead of the multiple choice format, the section was rewritten to include thirty separate statements. Respondents could then indicate strength of agreement or disagreement on a five point scale. This allowed respondents to chose a less restricted pattern of replies. If they wished, they were able to agree with two statements which others would regard as contradictory. Their replies could still be analysed in terms of the hypothetico-deductivist, inductivist and verificationist philosophies by applying the same kind of correction factor previously applied to the Section 3 questions (see Table 4.8).

Although derived from the questions tested on teachers, university students and schoolchildren, the wording of the statements for the revised Section 4 was taken mainly from the paired statements version of the philosophical questions. The statements therefore covered the ten areas of scientific interest listed in Table 4.13.

The final version of Section 4 thus gave a better coverage of the areas of disagreement between the three philosophies while allowing respondents a certain freedom of response which did not force them into making choices they regarded as false. The final version of the whole School Science Survey questionnaire used with teachers in the main survey, including the revised Section 4, is reproduced in Appendix 4.

4.2.4 Development of the Pupil Test Instrument

The experience gained from administration of UST to pupils from two schools was valuable when writing the test instrument to be used in the experimental phase of the investigation. This instrument was to be used in pre-test and post-test situations to measure pupils' beliefs about the philosophy of science and to see if these had changed during the teaching experiment.

To achieve some continuity with previous work, a further modified version of SUM was used as the test instrument. The ten philosophical questions which had been modified in writing UST were again rewritten, this time more extensively so that the four possible answers to each question contained at least one hypothetico-deductivist, one inductivist and one verificationist alternative. The fourth response was either a 'wrong' answer retained from SUM or a weaker alternative of one of the three other answers. As far as possible, the hypothetico-deductivist answer was the original from SUM, the inductivist one was derived from UST and the verificationist alternative was based on items tested with teachers and students but reworded where this was necessary for the target age group. This third version of the test was renamed the Understanding Science Measure, abbreviated to USM. It is printed in full in Appendix 7.

The responses to the new philosophical questions were scored in such a way as to provide a measure of the pupils' leaning towards any of the three philosophical positions. The classification of each response is shown in Table 4.20. Using this classification, each

Table 4.20 USM - Scoring of Philosophical Scales

QUESTION	RESPONSE A	B	C	D
1	I	V	H	I
2	V	H	I	V
4	I	H	V	
5	I	V		H
6	H	V	I	
10	V	H	V	I
11		V	I	H
14	V	I	H	
16	H	V	I	
17	V		I	H

respondent could be given H, I and V ratings for comparison with the mean on each scale. The remaining ten questions were marked as being correct or incorrect as in SUM. This meant that some degree of comparison was possible between data derived from USM and that published for similar groups tested using SUM. The scoring of these questions in USM (and in SUM and UST) is given in Table 4.21.

Table 4.21 USM - Scoring of Non-philosophical Questions

QUESTION	CORRECT RESPONSE
3	C
7	C
8	D
9	B
12	D
13	B
15	B
18	B
19	C
20	D

As a trial of the Understanding Science Measure, it was administered to over 400 pupils in a mixed 12-18 comprehensive school by Powell (in preparation). The percentage responses obtained in this trial are shown in Table 4.22. Except for question 19, the pattern of responses for the non-philosophical questions was similar to that for SUM and for UST. The increased number of correct responses to question 19 would be expected because of the inclusion of older pupils in this sample.

The only non-classified response to a philosophical question that attracted a high positive response was answer B to item 17, indicating a belief that experiments are used to 'inquire into the mysteries of nature'. Apart from this, the H, I and V answers accounted for almost all the responses. Sometimes all three seemed equally attractive (item 5); some appeared strongly one sided, such as the I response to item 10.

Table 4.22 Percentage Responses on USM

QUESTION	RESPONSES			
	A	B	C	D
1	9 I	13 V	42 H	36 I
2	29 V	25 H	27 I	20 V
3	9	7	81	4
4	7 I	62 H	22 V	9
5	32 I	35 V	2	32 H
6	48 H	12 V	39 I	2
7	3	7	75	16
8	10	4	14	73
9	6	75	3	16
10	12 V	11 H	3 V	73 I
11	5	12 V	40 I	43 H
12	28	13	12	47
13	8	71	14	7
14	8 V	67 I	20 H	4
15	20	53	19	8
16	33 H	23 V	43 I	2
17	13 V	30	13 I	45 H
18	14	64	17	5
19	39	15	40	6
20	9	6	14	71

Notes: 1. Correct answers to non-philosophical questions are underlined.
2. Coding of responses to philosophical questions are shown after percentages.
3. Data from M.J. Powell (personal communication).

Powell (in preparation) reported differences in the way in which pupils of different age respond to items in USM. On the non-philosophical items (scale OT), which were unchanged from SUM and UST, there was a significant increase in score with age. On the three philosophical scales (PH, PI and PV) derived from responses to the remaining items, it appeared that the hypothetico-deductivist answers were chosen more often by the older pupils and the verificationist answers by the younger ones. The inductivist answers had a steady response independent of age (Table 4.24). A breakdown by sex of

Table 4.23 USM - Breakdown of Scores by Sex

SEX	MEAN SCORE			
	OT	PV	PI	PH
BOY	6.30	2.07	3.79	3.58
GIRL	6.66	1.91	3.92	3.61
	p=0.08 ns	p=0.24 ns	p=0.38 ns	p=0.84 ns

Table 4.24 USM - Breakdown of Scores by Age

AGE	NUMBERS	MEAN SCORE			
		OT	PV	PI	PH
12-13	105	5.91	2.28	3.90	3.00
13-14	88	6.00	2.14	4.03	3.10
14-15	107	6.22	1.95	3.50	4.01
15-16	85	7.19	1.96	3.87	3.85
16+	42	8.05	1.21	4.17	4.55
SIGNIFICANCE:		p=0.001	p=0.001	p=0.08 ns	p=0.001

respondent indicated no significant differences between boys and girls (Table 4.23), but there were differences depending on ability and subject choice (Tables 4.25, 4.26 and 4.27). Higher ability or participation in more advanced science courses seemed to raise scores on the non-philosophical scale (OT) and on the hypothetico-deductivist scale (PH). As scores on scale PH increased, there was a corresponding decrease on the verificationist scale (PV). The effects of ability on

Table 4.25 USM - Breakdown of Scores by Ability Group (Third Form)

GROUP	NUMBER	MEAN SCORE OT	PV	PI	PH
TOP	25	7.36	1.84	3.64	3.84
MIDDLE	51	5.75	2.20	4.25	3.00
BOTTOM	12	4.25	2.50	3.92	2.00
SIGNIFICANCE:		p=0.001	p=0.38 ns	p=0.26 ns	p=0.003

Table 4.26 USM - Breakdown of Scores by Subject Choice (Fourth and Fifth Forms)

GROUP	NUMBER	MEAN SCORE OT	PV	PI	PH
3 SCIENCES	51	7.45	1.90	3.51	4.35
PHYSICS + ONE	81	6.84	1.99	3.70	3.93
BIOLOGY + CHEM	46	6.35	1.72	4.04	3.72
GENERAL SCIENCE	10	2.60	3.20	2.20	3.10
SIGNIFICANCE:		p=0.001	p=0.02	p=0.004	p=0.09

Table 4.27 USM - Breakdown of Scores by Subject Choice (Sixth Form)

GROUP	NUMBER	MEAN SCORE OT	PV	PI	PH
ARTS	20	7.10	1.45	4.55	3.90
SCIENCE/MIXED	22	8.91	1.00	3.82	5.14
SIGNIFICANCE:		p=0.001	p=0.17 ns	p=0.13 ns	p=0.04

the inductivist scale (PI) was less clear, but the weakest pupils in the fourth and fifth forms, those on the General Science course, had much lower scores on this scale than all the other pupils of their age.

Powell's work served to test USM in a non-experimental situation and the trends he observed provide a background against which the results obtained in the teaching experiment (Chapter 6) may be judged. Using the techniques described below in section 5.1 he classified the eight science teachers in his school and reports (personal communication) that three were H types, one strongly so; three were weak I types; one was a V type and one an O type. In such circumstances there is hardly a consistent philosophical influence on pupils and this is probably the normal situation in schools. If this is indeed the case, the gradual trend towards a hypothetico-deductive philosophy of science with increasing age or experience of science can also be regarded as the norm, against which any experimental effects should be evaluated.

SUMMARY OF CHAPTER 4:

This chapter describes the development of the School Science Survey questionnaire (SSS), which was to be administered to teachers, and the Understanding Science Measure (USM), for use as a test instrument with the pupils in the teaching experiment.

The School Science Survey questionnaire had four sections:

Section 1: designed to elicit background information about respondents.

Section 2: designed to probe respondents' familiarity with major curriculum projects and their criteria for textbook selection.

Section 3: designed to measure teachers' attitudes towards practical work. Teachers were assessed according to their scores on five scales:

- H - measured inclination towards a hypothetico-deductivist style of teaching.
- I - measured inclination towards an inductivist style of teaching.
- V - measured inclination towards a verificationist style of teaching.
- S - measured awareness of the usefulness of practical work in science lessons.
- T - measured concern with the teaching of technical skills.

Section 4: designed to identify respondents' views about the philosophy of science. Teachers were assessed according to their scores on three philosophical scales:

PH - measured degree of agreement with the hypothetico-deductivist philosophy of science.

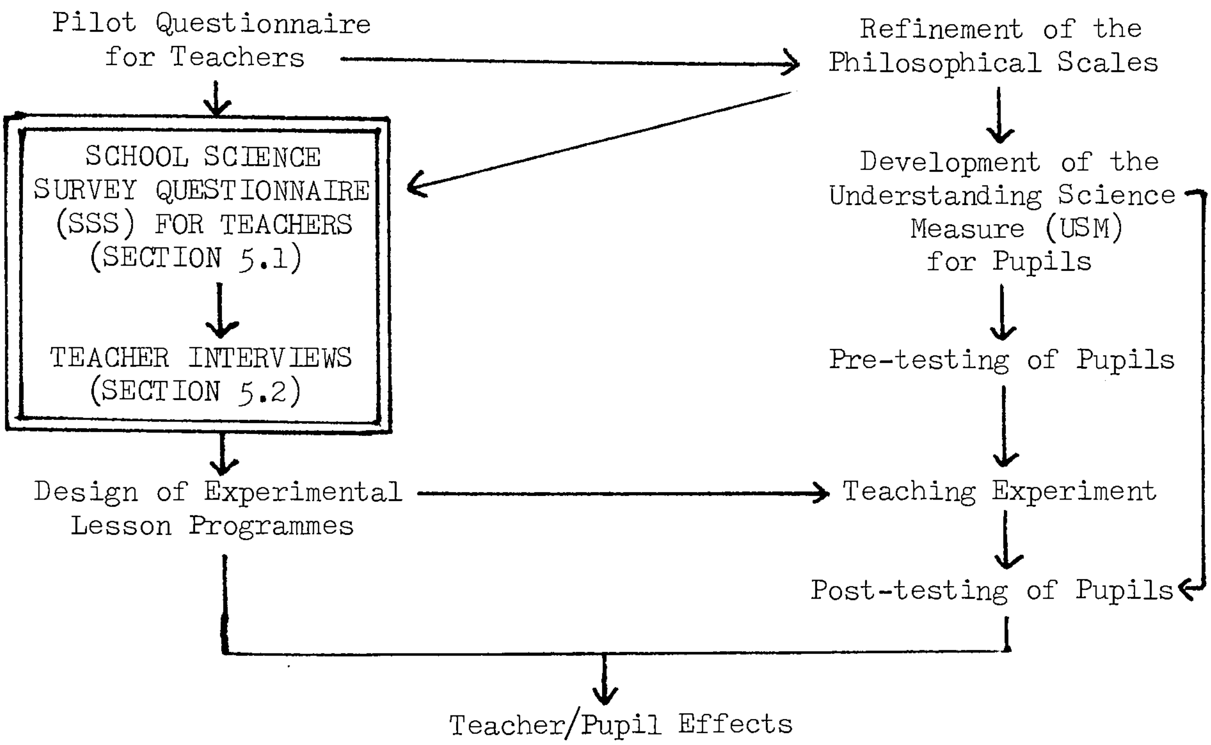
PI - measured degree of agreement with the inductivist philosophy of science.

PV - measured degree of agreement with the verificationist philosophy of science.

The Understanding Science Measure was a twenty item multiple choice test derived from TOUS and SUM. Ten questions, making up scale OT, are non-philosophical questions unchanged from SUM. The others test pupils' understanding of, and agreement with, the three philosophies of science. Pupils are scored on three scales corresponding to the three philosophical scales from Section 4 of the teacher questionnaire (PH, PI and PV).

CHAPTER 5:

TEACHERS' PHILOSOPHY OF SCIENCE



5.1 The School Science Survey

5.1.1 Organisation of the Survey

The second main phase of the research plan was the investigation of science teachers' views concerning the philosophy of science. The plan called for use of the revised teacher questionnaire to identify individuals holding extreme viewpoints, if indeed any such individuals existed.

Three local education authorities were approached with a request for access to their science teachers. One did not reply; one offered to arrange access to the teachers in a small group of schools; the third agreed to provide unlimited access to its teachers. This last offer was the one accepted.

In the chosen local authority, all headteachers have to submit a yearly staffing return. In the case of the secondary and high schools, the headteachers indicate the main teaching subject of each member of staff. As the education authority provided for access to these staffing lists, it was possible to draw up a complete list of all secondary science teachers in the authority's schools. Most of the middle school heads did not list subject responsibilities in their returns, so the information about these schools was less complete.

As well as making available this information, the education office made arrangements for copies of the School Science Survey questionnaire (SSS) to be circulated to schools through the local authority internal postal system, thus saving considerable time and expense. Permission was also given for the covering letter to state that the survey had the approval of the local inspector responsible for science.

The authority was an interesting one to use for the survey because of its variety of school types. It was formed by amalgamation in the 1974 reorganisation of local government boundaries. One part of the authority has 5-8 first schools and 8-12 middle schools feeding some 12-16 and some 12-18 high schools. A few 5-12 combined schools also exist. In a second region, there are 5-9 first schools, 9-13 middle schools and 13-18 high schools, two of which are single sex establishments, the others being mixed. The third area in the authority has 5-11 primary schools, 11-16 secondaries and a sixth form college. The primary schools and the few 5-12 combined schools were excluded from this study because, for most pupils, formal science teaching begins at about the age of eleven.

Questionnaires were sent to all middle schools, whether 8-12 or 9-13, and to all secondary and high schools. In the case of the middle schools, three copies were sent to each headteacher with a request that copies be given to the teacher or teachers responsible for science in the school. There can be no certainty that all these questionnaires reached the teachers concerned. It is possible that in some middle schools no teacher had been given specific responsibility for science. In such cases, the headteacher may have decided that the questionnaire was inappropriate.

The situation in the secondary and high schools was somewhat different. As the names of individual science teachers were known from the school staffing returns, each science teacher was sent a personally addressed copy of the questionnaire. In addition a copy was sent to each headteacher for information, together with a request that he encourage his science staff to complete and return their copies (see Appendix 4). Two of the heads were scientists and they were invited to complete and return their own copies as well.

It was unfortunate that the circulation of the questionnaire coincided with the period during which there was a series of explosions at the Birmingham postal sorting offices and it is possible that some returns were lost in these incidents. However, nearly a hundred replies were received, about three quarters of these being from secondary and high school teachers (Table 5.1). It was not possible to calculate the percentage return from the middle schools as the total was not known. Replies were obtained from less than half of the middle schools, whereas almost all of the others sent at least one reply. However, if many of the middle schools, particularly those with the 8-12 age range, have no specialist science teaching, it is possible that the small number of replies received did represent a substantial proportion of the middle schools science teachers.

Table 5.1 Replies to School Science Survey

	MIDDLE	SCHOOL TYPE SECONDARY OR HIGH	NOT KNOWN
Number of schools contacted Number of schools replying % of schools replying	28 13 46%	26 25 96%	
Number of science teachers Number of teachers replying Percentage return rate	Not known 20 -	162 74 46%	1

In view of the percentage return rate for the secondary sector, where the number of science teachers was known, it seemed that the returns represented a reasonable sample of the science teachers in the area and that, therefore, some reliance could be placed on the results of the survey.

5.1.2 Results of the survey

As with the results from the pilot survey, these will be reported section by section.

Section 1 of the questionnaire sought information about the background of the respondents. They formed a fair cross section of the science teaching population, varying from those in their first year of teaching to those with over thirty years experience. The average number of years experience of science teaching was twelve. About three quarters of the respondents were men. This may well represent the sex ratio among science teachers although it is far from typical of the teaching profession as a whole. A summary of the information obtained from Section 1 is given in Table 5.2.

Table 5.2 SSS - Background of Respondents

SEX:	
Male	74%
Female	26%
POSITION:	
Headteacher	2%
Deputy Head	8%
Pastoral/Administrative Post	5%
Head of Science Department	30%
Science Subject Respobsibility	20%
Assistant Science Teacher	35%
MAIN SUBJECT:	
Biology	30%
Rural Science	2%
Chemistry	25%
Physics	23%
General Science	4%
Not Science	16%
QUALIFICATIONS AND TRAINING:	
Certificate in Education only	36%
B.Ed. Degree	12%
Science Degree - untrained	19%
Science Degree and PGCE	33%

For the purposes of the analysis, a teacher's main subject was taken to be the subject in which he was qualified. In the majority of cases this corresponded with the main teaching subject. The non-science teachers were mainly in middle schools where someone trained in geography may be placed in charge of 'Science and Environmental Studies' or an art teacher may be responsible for 'Practical Studies and Science'. In fact only two of the secondary teachers were not science trained; both were home economics trained but teaching human biology. In view of the small numbers involved, the rural science teachers were reclassified as biologists and the general science teachers combined with the chemists for the purposes of later analysis.

Physical sciences and mathematics are the only subject areas in which untrained graduates are still allowed to enter teaching. Obviously many science departments rely on such entrants to the profession and it is often these teachers who have had experience in industry. 9% of the teachers who completed the questionnaire had higher degrees which in some cases would have given them experience of carrying out a research project under supervision. Most of those teaching science in the middle schools were certificate trained teachers, while the majority in the secondary and high schools were graduates.

Most science teachers have been trained as biologists, chemists or physicists. To get a balanced view of science, it may be desirable for the pupil to meet all varieties of scientist early in his school career and before his views about science are fully formed. For this reason the distribution of subject specialists (Table 5.3) is of interest. It is clear from this analysis that pupils in the middle

Table 5.3 Distribution of Subject Specialists in Middle and High Schools

SUBJECT	% IN TOTAL SAMPLE		% WITHIN SCHOOL TYPE	
	MIDDLE	SEC/HIGH	MIDDLE	SEC/HIGH
Biology	4%	28%	18%	35%
Chemistry or General Science	4%	25%	18%	32%
Physics	0%	23%	0%	30%
Not Science	14%	2%	64%	3%

schools have no chance at all of meeting a physics graduate or a teacher who has studied physics as his main subject at college. In the secondary sector there is approximately equal chance of the pupil being introduced to science by a biologist, a chemist or a physicist and almost no chance at all of being taught by a non-scientist. Almost two thirds of the teachers introducing pupils to science in the middle schools are not themselves science trained. If, as one suspects, the situation is even worse than this, there must be concern about the effect of delayed entry to the secondary sector which is the inevitable result of having a middle school system. At worst, if all the middle schools not replying were without a teacher trained in science, the proportion teaching science without appropriate training may approach 85% in the middle schools as a whole.

One does not know to what extent these differences between middle and secondary schools affect pupils' reaction to science, but a report was prepared on the findings of the School Science Survey (see Appendix 5) for the local education authority and copies were sent to any of the participating teachers who expressed an interest. This ensured that more people than previously were made aware of the problem. It is of interest to note that the authority is now preparing plans to phase out middle schools and return to a system with transfer at the age of eleven.

Section 2.

To some extent the pupil's view of science may be expected to be coloured by what he is taught in science lessons. Section 2 of the questionnaire was concerned with the use of published materials, both textbooks and the products of various Nuffield and Schools Council curriculum projects.

Only a minority of teachers reported using project material designed for the 11-14 age range, although for the Nuffield Combined Science scheme the minority was a substantial one (Table 5.4). As only about a quarter of all respondents were in middle schools, the 18% of

Table 5.4 SSS - Use of Curriculum Project Materials

PROJECT	ADOPT THE COURSE	USE SOME MATERIAL	CHOOSE NOT TO USE	NOT APPLICABLE OR NO REPLY
Nuffield Biology	-	21%	6%	73%
Nuffield Chemistry	3%	21%	4%	72%
Nuffield Physics	-	19%	6%	75%
Nuffield Combined Science	-	40%	15%	45%
Nuffield Secondary Science	-	31%	11%	58%
Schools Council 5-13	-	18%	16%	66%
SCISP	-	11%	15%	74%

respondents using the 5-13 material may in fact represent a very high proportion of middle school teachers as the course is unlikely to be widely used in the secondary sector.

Interpreting the figures in Table 5.4 is not easy. 'Using some of the material' may mean using a teachers' guide because it lists apparatus for an experiment and saves the trouble of writing it out for a laboratory assistant. It does not mean that project material is taught in the classroom in all cases as the project developers intended it should be. Certainly it is clear that very few teachers adopted the schemes in the sense of teaching them through and entering pupils for the project examination. On the other hand, the numbers using the project material in some way show that the effects of the projects are not confined to those sitting a project examination.

Most teachers in the sample seemed to draw on published materials and use them in their own way. The second part of Section 2 was designed to investigate the priorities of teachers in selecting books for class use. Half of the teachers regarded no book as particularly suitable for class use in the 11-14 age range and most of the other recommended only one or two books (Table 5.5). A few reported preparing their own worksheets, and some said that they simply could not afford to buy books.

Table 5.5 SSS - Suitability of Textbooks

NUMBER OF BOOKS RECOMMENED	PERCENTAGE OF TEACHERS
0	50%
1	26%
2	17%
3	3%
4	2%
5	1%
6	-
7	1%

As might be expected, the number of books mentioned was very wide, most books being recommended by only one respondent. Only four titles were recommended as suitable by more than three teachers and these are listed in Table 5.6. As Duncan's books are based on the Nuffield

Table 5.6 SSS - Recommended Textbooks for 11-14 Age Range

TITLE OF BOOK	AUTHOR	NUMBER OF TEACHERS LISTING BOOK
Science for the 70's.	Mee et al.	15
General Science	Windridge	8
Nuffield Biology Texts	(Various)	6
Exploring Physics	Duncan	5

Physics approach, the last two titles indicate that the Nuffield projects do have some support. On the other hand Windridge's General Science is an old and extremely traditional textbook. Another of his books, Essential Science, was mentioned a few times and many of the books listed by two or three teachers were traditional in their approach and often aimed at older pupils. These results were interesting as teachers were asked to list only those books they could recommend as suitable for pupils in the 11-14 age range.

What teachers hope to find in the books they select was indicated by their responses to the criteria for book selection suggested in the questionnaire. They were asked to rate the importance of each criterion on a five point scale from 'not important at all' to 'very important indeed'. A total score was calculated for each criterion by finding the sum of all the individual teacher responses (scored 0-4 on the five point scale). This enabled a rank order for the criteria to be drawn up (Table 5.7) which represented the weight given to each criterion by the teachers in the sample.

Table 5.7 SSS - Criteria for Textbook Selection

RANK	NUMBER	CRITERION	TOTAL SCORE
1	8	Accuracy of factual information	372
2	1	Level of reading difficulty	346
3	14	Price and value for money	341
4	2	Quality of illustrations	330
5	9	Logical organisation of concepts introduced	320
6	7	Emphasis given to applications of science	309
7	15	Strength of binding and cover	298
8	6	Emphasis on 'scientific method' in text	265
9	5	Inclusion of data from which pupils can draw conclusions	261
10	11	Emphasis on problem solving as a scientific activity	250
11	4	Suggestions in book for pupil investigations	220
12	17	Coverage of topics in examination syllabus	218
13	12	Inclusion of historical aspects of science	160
14	10	Inclusion of alternative theories	155
15	13	Size and shape of book	152
16	16	Inclusion of past examination questions	128
17	3	Qualifications of authors	88

Note: The number in the second column indicates the order of criteria as listed in the questionnaire.

The criterion highest in the rank order, 'accuracy of factual information', was rated 'very important indeed' by 82% of the respondents. At the other extreme, 'qualifications of authors' was rated 'not important at all' by 47% and 'very important indeed' by only 1% of respondents. Although the rank order showed the overall priorities of the teachers tested, it also obscured important differences in the way that individuals had responded to the criteria presented. To clarify the underlying factors influencing the pattern of answers on this part of the questionnaire, the data was subjected to factor analysis using the FACTOR sub-program of SPSS. After examination of an initial solution using no rotation, it was decided to attempt a six factor solution using varimax rotation. Loadings in excess of 0.40 obtained in this solution are shown in Table 5.8.

Table 5.8 SSS - Factor Analysis of Book Selection Criteria
(Varimax 6 factor solution, decimal points omitted)

CRITERION NUMBER	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
1						66
2				55		
3						-73
4	71					
5	74					
6	70					
7			41			
8					49	
9						46
10	(32)				65	
11	53					
12					82	
13				76		
14			87			
15			86			
16		87				
17		86				

Note: Numbering of criteria corresponds to the order in which they were listed on the questionnaire, not to their rank order.

Some of the influences corresponding to the six factors are easy to explain. Factor 2 relates to a desire for textbooks to follow examination syllabuses. Factor 4 reflects concern for the standard of presentation of books. Factor 3 is mainly to do with obtaining value for money from books. One might have expected the 'inclusion of alternative theories' and the 'inclusion of history of science' criteria to be related as they are in Factor 5, but 'accuracy of factual information' is also a part of the same factor. Perhaps this indicates that those who favour an explicit historical approach are those who set out to show that modern science has established the true facts and shown how easily mistaken people were in the past.

More interesting are Factors 1 and 6. Teachers are right to be concerned about the 'level of reading difficulty' and the 'logical organisation' of books (Factor 6), but they obviously feel that highly qualified authors are unable to satisfy them in this matter. Perhaps this indicates a belief that the less well qualified author will be more in sympathy with the problems of the average reader in the 11-14 age group. If one is attempting to convey new factual information, it is not sensible to make the same book an insuperable problem because of its reading level.

Factor 1 reflects the requirement that books should not be just catalogues of facts but should contribute to the pupils' appreciation of science as an investigative activity. Criterion 10, 'inclusion of alternative theories', might fit in here although its loading on this factor was not as high as the other criteria included. These five criteria were used as the basis of a short scale (BH) on which teachers could be rated. Those with high scores on this scale want books to have suggestions for pupil investigations (4), to include data from which pupils can draw conclusions (5), to emphasize scientific method (6), to include alternative theories (10) and to emphasize problem solving as a scientific activity (11).

The reliability estimate for this scale (0.69) is remarkably high for a five item scale and it shows that teachers clearly see the connection between these items. Initially it was thought that this scale might reflect concern on the part of some teachers for the philosophy of science implied by the approach of the textbook writer. However a breakdown of the scores on this scale by subject and by school type (Table 5.9) suggested that there might be an alternative explanation for the strength of this factor in influencing the respondents.

It was the non-science trained teachers who had the highest scores

Table 5.9 SSS - Scale BH - Breakdown by Subject and by School Type

	NUMBER	MEAN	STANDARD DEVIATION	SIGNIFICANCE
SUBJECT:				
Biology	30	16.6	3.0	p=0.007
Chemistry	28	16.5	2.9	
Physics	22	18.2	7.4	
Not Science	15	23.0	11.7	
SCHOOL TYPE:				
Middle	20	21.5	10.5	p=0.006
Sec/High	74	17.0	4.7	
OVERALL:	95	17.9	6.6	-

on scale BH. There was no significant difference when scores were broken down by sex and it therefore seemed that the difference in responses between the two school-type categories was a result of the concentration of non-science trained teachers in the middle schools. It is possible that middle school teachers are more conscious of a need to present science as a process, while secondary and high school teachers are more concerned with coverage of factual content for examination purposes. This could be an explanation of the higher scores obtained by the middle school teachers, but other interpretations are possible. It may be that, with less experience of working in laboratories during their own training, the middle school teachers rely more on books for suggestions about experimental work for their pupils. If this is the case, their high scores are related more to their lack of training in science rather than to a better understanding of the philosophical implications of their choice of pupil texts. The latter explanation derives some support from the questionnaire data as scale BH was not highly correlated with other scales which were designed to measure teachers' commitment to the three philosophies of science.

As these scores on scale BH indicate, it may not be valid to compare results of non-scientists teaching in middle schools with those of trained specialists teaching science in the secondary sector. For this reason the decision was taken not to use teachers from middle schools in the interviews which follwed the analysis of the results from the questionnaire survey. Also, because of the uncertainty in interpreting the results obtained, scale BH was not used in the identification of individuals with extreme philosophical beliefs. This was done on the basis of scores on the scales derived from Section 3 and Section 4 of the questionnaire.

Section 3.

Although this section had been shortened following the pilot survey, the intention behind its use remained the same. Section 3 measured the extent to which a teacher introduces and uses practical work in ways which may imply to his pupils that science is to be seen as a hypothetico-deductivist, an inductivist or a verificationist activity. It did not set out to measure whether or not the teacher actually holds the beliefs which may seem to be implied by his reported activities and behaviour in the classroom.

Five scales had been drawn up following the analysis of the data from the pilot questionnaire, but it seemed desirable to analyse the data from the main questionnaire in the same way to check on the validity of the scales for the larger sample. This was done as before by a combination of factor analysis and reliability estimation. The scales were to be used to identify extreme teachers within the sample and it was important to make sure that the scales being used did reflect the normal spectrum of views within the sample group itself, rather than that which had been found in the pilot group.

The data obtained from replies to Section 3 were first subjected to factor analysis. The solution was derived by extracting principal components and preparing a varimax rotated factor loadings matrix with five factors. When the pilot data had been analysed in this way (see

Table 4.6), the five factors obtained had been used as a basis for the construction of five scales. The factors which emerged when the data from the main questionnaire were treated in the same way were not identical with those derived from the pilot data. Most of the items which had formed scales S and T in the pilot version had loadings on Factors 2 and 3 but the questions were not linked in the same way as previously. This change was not regarded as serious for two reasons. These two scales had been positively correlated in the pilot survey, and it was the independence of the other three scales which was more important. These three scales (H, I and V) were to be used, together with the philosophical scales from Section 4, in the identification of individual teachers with extreme views.

Table 5.10 SSS - Factor Analysis of Section 3 Questions
(Varimax 5 factor solution, decimal points omitted)

QUESTION	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
1			74		
2			59		
3			50		
4					
5				60	
6	55				
7	70				
8	(48)				36
9				44	
10	(44)				33
11		76			
12					47
13		78			
14	40				
15			39		
16			46		
17		69			
18					
19				58	
20	61				
21					(18)
22					53
23				62	
24			48		
25	59				

The results of the factor analysis of the Section 3 data from the main survey is shown in Table 5.10. Factor 1 contained all the original scale H items with positive loadings in excess of 0.40. It also contained items 8 and 10, which were regarded as components of scale I. However, both of these items had lower positive loadings on Factor 5 which thus contained four of the five I statements. The fifth, item 21, had no high loadings on any factor, but its highest positive loading was on Factor 5. Factor 4 approximated to the V scale. Statements 9, 19 and 23 were part of that scale and all had positive loadings on Factor 4. Statement 18 had no high loadings on any factor and statement 24 appeared with the S/T factors. However, item 5 (Practical work is good for illustrating scientific principles) received a high loading on Factor 4 and it could be argued that this grouping of statements is better on theoretical grounds than was the arrangement derived from the pilot data.

Using the results of the factor analysis, the I and V scales were rewritten. Item 21 was deleted from the I scale because of its low loading in the factor matrix. The V scale was also brought into line with the factor matrix by deleting items 18 and 24, and replacing them with item 5. This produced three scales, each with an estimate of internal consistency reliability of 0.60 or higher. Details of the rewritten scales are given in Table 5.11.

Table 5.11 SSS - Scales H, V and I (Rewritten)

SCALE:	H	V	I
ITEMS:	6 7 14 20 25	5 9 19 23	8 10 12 22
RELIABILITY:	0.71	0.61	0.60

Although the three scales were short, they reflected real differences in the way teachers responded to the test items as revealed in the factor loadings matrix. Also they were made up of items which clearly corresponded to the viewpoints on the use of practical work which one would associate with the three philosophical positions described above in Section 2.1.

As with the pilot data, it was considered advisable to correct for respondents' tendency to agree with all statements presented by the application of a correction formula as summarised in Table 4.8. This provided for each respondent on each of the three scales a score which reflected the extent to which his responses on that scale were different from his responses to all the items on all three scales. This resulted in the scales giving good discrimination between teachers with different views. The three corrected scales (H', V' and I') are significantly negatively correlated (Table 5.12).

Table 5.12 SSS - Correlations between Scales H', V' and I'

	V'	I'
H'	-0.57***	-0.38***
V'	-	-0.54***

Section 4.

A considerable amount of work had been devoted to the development of the philosophical scales (see Section 4.2), but the Section 4 questions had not been pre-tested in their final form. As a result of the trials of various versions of Section 4 of the questionnaire, the final version had been prepared with a similar format to Section 3 and with three philosophical scales as shown in Table 5.13. These scales were regarded as a tentative classification. They were based in part on analyses of results from the previous versions of the section and partly on theoretical considerations. The tentative classification was to be checked by using factor analysis, the aim being to derive scales with reliabilities of at least 0.50 that were all negatively correlated with each other.

Table 5.13 SSS - Section 4 Philosophical Scales

SCALE PH (agree with statements:)	SCALE PV (agree with statements:)	SCALE PI (agree with statements:)
3	1	2
6	4	5
9	7	8
12	10	11
15	13	14
18	16	17
20	21	19
24	23	22
27	25	26
28	29	30

The same procedures were adopted in the analysis of the data from Section 4 as had been used with Section 3. A factor analysis was carried out to find a three factor solution in accordance with the pattern of responses to the pilot questionnaire. The items receiving high loadings on the factor analysis were then compared with the items on the philosophical scales to find if the scales required further modification before being used to identify extreme individuals within the sample population.

As can be seen from the factor matrix in Table 5.14, the pattern which emerged from this analysis did not correspond with the expected arrangement as shown in Table 5.13. What the factor analysis seemed to indicate was more in the nature of a verificationist/non-verificationist dichotomy. Factor 2 contained all but two of the scale PV items and also had one PI and two PH items with negative loadings. The items from scale PI were found in Factors 1 and 3, but Factor 1 also contained some PH items, mostly with lower loadings shown in

Table 5.14 SSS - Factor Analysis of Section 4 Questions
(Varimax 3 factor solution, decimal points omitted)

QUESTION	FACTOR 1	FACTOR 2	FACTOR 3
1			40
2			52
3		(-38)	
4		41	
5			48
6	(32)		
7			(38)
8			69
9	(34)		
10			
11	47		
12	(37)		
13		(21)	
14	48		
15			
16		77	
17	45		
18			
19			
20		-72	
21		55	
22	56		
23		65	
24	(30)		
25		(21)	
26	56		
27	69		
28	52		
29		(32)	
30		(-38)	

brackets in Table 5.14. Only questions 27 and 28 from the latter scale had loadings over 0.40. This analysis indicated a clear difference between the verificationist position which is exemplified by a high score on scale PV and the more process-orientated approach to science of the other philosophies.

If the main difference in attitude towards the philosophy of science was a straightforward either/or distinction depending on whether the teachers saw science primarily as an established body of fact or as an activity, then there would have been certain implications for the design of the subsequent teaching experiment.

There would have been little point in carrying out an experiment to find the effects of an inductivist teaching style if no teacher actually believed in the inductivist approach. However this issue was not prejudged and the attempt to use the results from Section 4 in the indentification of extreme inductivists and confirmed hypothetico-deductivists was continued.

Examination of the loadings in the factor matrix led to changes in the philosophical scales. Items 15 and 18 were deleted from scale PH as they had no high loadings on any factor. Items 10 and 19 were dropped from scales PV and PI respectively for similar reasons. Item 1 was also removed from scale PV as the factor analysis linked it with items from scale PI. Shortening the three scales from ten to eight items each gave all the scales internal consistency reliability estimates in excess of 0.50 and preserved the theoretical differences between their philosophical content, while removing those items which appeared ambiguous. The shortened versions of the scales, together with their reliability estimates, are given in Table 5.15.

Table 5.15 SSS - Scales PH, PV and PI (Rewritten)

SCALE:	PH	PV	PI
ITEMS:	3 6 9 12 20 24 27 28	4 7 13 16 21 23 25 29	2 5 8 11 14 17 26 30
RELIABILITY:	0.64	0.55	0.64

In the pilot version of the questionnaire, Section 4 had consisted of multiple choice items. In the main survey the section was a series of statements with which respondents could agree or disagree. Scores on this section were thus subject to the same tendency that had previously been noted with this type of test item in Section 3; this was the tendency for some respondents to be more inclined than others to agree with all the statements presented. Such differences could obscure smaller differences due to opposing philosophical viewpoints. To overcome this problem a similar process was adopted to that used with the Section 3 scales (outlined in Table 4.8). This produced corrected scores for the three philosophical scales and the correlations between the scales were then all negative (Table 5.16).

Table 5.16 SSS - Correlations between Scales PH', PV' and PI'

	PV'	PI'
PH'	-0.69***	-0.23*
PV'	-	-0.54***

The weakness of the scales in distinguishing the inductivist position is made even clearer if one examines the correlations between the Section 3 scales and the philosophical scales from Section 4 (Table 5.17). Whereas the correlations are as expected between the PH', H',

Table 5.17 SSS - Correlations between Section 3 and Section 4 Scales

	H'	V'	I'
PH'	0.44***	-0.27**	-0.15 ns
PV'	-0.43***	0.30**	0.09 ns
PI'	0.06 ns	-0.09 ns	0.04 ns

PV' and V' scales, none of the correlations involving the PI' and I' scales reaches even the 0.05 level of significance. One possible explanation for this was that the number of teachers with high scores on both PI' and I' scales was very low. The majority of the teachers in the sample seemed to fit somewhere on the H-V spectrum.

The differences between teachers' scores on the Section 3 and Section 4 scales did not seem to depend greatly on sex, school type or subject background, although there were some non-significant differences which could be of interest. Physicists obtained higher scores on the V' scale than other subject specialists, and middle school teachers scored slightly higher on PV' and lower on PH' and PI' than did the secondary and high school teachers. This second difference was probably due to the large percentage of non-scientists teaching science in middle schools as the same difference was apparent when those with science training were compared with those who were trained in other subjects.

Overall, the difference of greatest interest was a sex difference on the philosophical scales. Male teachers obtained better scores on scale PH' and the difference was significant ($p=0.007$). In contrast, females were slightly more inclined to get higher marks on the PV' and PI' scales. This seemed to be a true sex difference, not due to school type or subject background. Although there may be more women teaching in middle schools or with biology training, the difference was much less marked in the school type comparisons and absent from the comparisons of teachers with different subject specialisms.

In spite of the difference in mean scores, it should not be assumed that female teachers are extreme inductivists or verificationists while men are confirmed hypothetico-deductivists. Most of the teachers in the sample were not extreme in their views at all. Slight differences in scores on the questionnaire cannot be used as a basis for arguing about possible effects of being taught science by a woman rather than a man. Within both sex groups it was possible to find extreme individuals of each type. How this was done is described in the following subsection.

5.1.3 Identification of Extreme Individuals

The selection of teachers for the follow-up interviews was done on the basis of scores on both the Section 3 and Section 4 scales. For each scale a mean was calculated. Each respondent's score was then expressed in terms of how far above or below that mean it was. Thus an individual obtaining a score equal to the mean for the whole group of teachers on a scale was given a zero score (0). Any respondent with a mark above the mean was given a positive score (+1, +2, +3 etc.) and the low scorers were given a negative rating (-1, -2, -3 etc.) on the scale. To simplify the data as the mean was not always a whole number, all scores were approximated to the nearest whole number. Overall total scores were calculated for each respondent by adding scores on the related Section 3 and Section 4 scales (Table 5.18). An extreme <u>hypothetico-deductivist</u> or H type teacher was defined as one with a high positive HTOT score. He would have above average H' and PH' scores and be average or below on both VTOT and ITOT. Similarly the extreme <u>verificationist</u> or V type was defined as one with a high VTOT score, and the extreme <u>inductivist</u> or I type was defined as one with a high ITOT score.

Table 5.18 <u>SSS - Calculation of Total Scores for Extreme Types</u>

TOTAL SCORE SCALES	FORMED BY ADDING SCORES ON:
HTOT	Scale H' and Scale PH'
VTOT	Scale V' and Scale PV'
ITOT	Scale I' and Scale PI'

Examination of the scores obtained by individual teachers on the total scales (Table 5.19) showed that a few were indeed extreme types in terms of the definitions given above. Many more showed either no particular bias or inclined away from one position while having leanings towards both of the alternatives.

Table 5.19 SSS - Individual Teachers' Scores

CASE	TEACHER	H	I	V	PH	PI	PV	HTOT	ITOT	VTOT	TYPE	ICODE
35	H	3	-1	-2	4	-1	-4	7	-2	-5	H	H1
18	P	1	-1	-1	5	-3	-3	7	-3	-4	H	H2
2	W	-1	2	-1	1	4	-4	0	6	-5	I	I1
40	O	0	-1	0	-3	6	-2	-3	5	-2	I	I2
80	D	-3	0	3	-4	0	3	-7	0	7	V	V1
38	J	-1	-3	4	-5	-2	8	-6	-5	12	V	V2
34	B	1	-1	0	-1	1	0	0	0	0	0	01
50	Pr	-1	0	2	1	0	-2	0	0	0	0	02
36	R	-5	3	2	-6	-4	11	-12	-2	13	V	-
19	Br	1	1	-2	3	3	-5	3	3	-7	HI	-
60	Ro	4	0	-4	4	5	-8	8	5	-12	HI	-

Teachers H and P (cases 35 and 18) were both easily classified as H type teachers. They not only had high HTOT scores but scored below the mean on all the V type and I type scales. I type teachers appeared to be both less common and less extreme. The only two from the sample tested that could be classified as I types were teachers W and O (cases 2 and 40) and even these appeared extreme only in their ITOT scores. Teacher W scored slightly above average on scale PH and teacher O had a below average score on scale I. There were more individuals who were strongly V types than either of the other extremes. Teacher J (case 38) was more extreme than most, but the scores obtained by D (case 80) were by no means unusual in their degree of bias towards the verificationist position. The V type teacher seemed to be a fairly common phenomenon, at least in the sample studied, although even the individual with the highest VTOT score in the sample (case 36) was not immune to other influences as his I score was also above average.

What did emerge clearly was a V/not-V distinction. More common than either the extreme H type or the extreme I type teacher was the type who seemed to prefer a process orientated approach to science rather than a verificationist one, but maintained a balance between the extremes of the hypothetico-deductivist and the inductivist positions. Teachers of this type (such as case 19) could be classified as HI individuals, although in some cases (such as case 60) it might be more appropriate to describe the individual as a not-V type.

Although one suspects that the HI viewpoint is a fairly natural one for scientists to take, it is possible that it appeared so often among the teachers studied because of a relative lack of discrimination in the I and PI scales. There was no doubt, however, about the distinction between the verificationist position and the alternatives. Many teachers were strongly V type and all those with high scores on HTOT, ITOT or both scored well below average on the V scales. No HV types were found and only two individuals with strong V leaning had above average ITOT scores.

There was also a number of teachers who had scores which did not differ markedly from the mean on any of the measures. As one would like to think that teachers have some philosophical foundation for what they attempt to do with their classes, this required some explanation. At least two explanations could possibly explain their lack of deviation from the middle ground. One is that such teachers are so lacking in understanding of the philosophy of science that no pattern is discernible in their answers; the other is that they regard the philosophy of science as irrelevant to their work and have other quite valid, but non-philosophical, justifications for the practices they adopt in the classroom. To attempt to resolve this question, two of these teachers were added to the list for follow-up interviews. These individuals (cases 34 and 50), who achieved average scores on HTOT, ITOT and VTOT scales were designated O types.

On the basis of their scores on HTOT, ITOT and VTOT, eight teachers were selected for follow-up interviews. These were the first eight individuals listed in Table 5.19. This group included two H types, two I types, two V types and the two O types. The teacher interviews are described in section 5.2.

5.2 The Teacher Interviews

5.2.1 Arrangements for the Interviews

The teacher questionnaire had been used to select extreme types of teacher. These were teachers who had strong views about the philosophy of science and who allowed those views to influence their classroom practice. For the extreme individuals, even if not for science teachers in general, their philosophical beliefs about the nature of science seemed to provide an explanation for their teaching style. This approach to teaching style, from its philosophical justification, is somewhat different from that reported by other investigators. A more normal approach has been to observe teachers in action and then to attempt an a posteriori classification of types (Eggleston et al. 1975, Galton & Eggleston 1979). In this study, an attempt was made to do the reverse, to identify types of teacher with differing philosophical beliefs and then to predict what teaching styles they would adopt. The purpose of the teacher interviews was to find out if the teachers selected by the questionnaire technique did report using the teaching methods which would correspond to their philosophical classifications.

The interviews were conducted about six months after the teachers had completed the questionnaires. The delay between the sending out of questionnaires and the interviewing of the extreme teachers was intended to give the individuals selected for interview time to forget the details of the questionnaire items. In these circumstances, the interviews could be regarded as a check on the validity of the classification based on the survey results. If, for example, teachers selected as extreme V types on the basis of questionnaire responses gave H type answers to interview questions, this would have cast severe doubts on the original classification. On the other hand, a repetition or reinforcement of the original viewpoint would provide evidence of the accuracy of the classification procedure.

For the interviews, only teachers from the secondary sector were selected as many of those teaching in middle schools were not originally trained as science teachers. The eight individuals chosen for interview were those given an ICODE in Table 5.19 and they are identified by these codings throughout this section. Two teachers were selected to represent each extreme type, one male and the other female. An effort was made to ensure that those interviews also covered a range of subject specialisms and length of experience.

The selected teachers were first contacted by telephone and told that they had been picked by the computer as part of a 10% sample of the original respondents. They were not told that they were regarded as individuals with extreme opinions but were asked to take part in a tape recorded interview as a check of the questionnaire's validity. All eight of the selected teachers agreed to be interviewed and arrangements were made to conduct the interviews at times and places convenient to the teachers themselves. Two (H2 and I1) were interviewed at their homes in the evening. The others were visited at their schools at the end of normal teaching hours and the interviews were conducted in the teachers' laboratories or preparation rooms.

In most cases the interview situation was satisfactory with a minimum of disturbance. The one exception was the interview with H1 which was conducted in a room from which a school band practice and water pipe noises from adjacent toilets were clearly audible. Although this did not affect the interview itself, it did make subsequent interpretation of the tape extremely difficult.

As it was the intention to conduct the interviews in as relaxed an atmosphere as was possible, a detailed interview plan was not prepared. Instead a short interview schedule was drawn up. This consisted of twelve topics to be discussed during the course of each interview. The interviewer carried the schedule with him as a reminder of the questions to ask but the order in which the topics were covered differed in each interview. The interviews we intended to appear more as informal discussions rather than direct question and answers sessions.

Before recording began, the teachers were told that the interview would cover their views on the use of practical work in science lessons and on the place of science in the school curriculum. The teachers were encouraged to ask for explanations if they did not understand questions, and the interviewer probed with supplementary questions if answers were unclear or incomplete. As can be seen from the interview schedule (Appendix 6), the first few questions were intended to be non-controversial. These were included to get the interviewees talking in a relaxed way. The middle group of questions probed the kind of issues that had been raised in Section 3 of the questionnaire concerning the teachers' reasons for using practical work in certain ways. The final four questions were designed to draw out any opinions the teachers had about the philosophy of science. As the H, I and V type teachers had been selected because of clear bias in their HTOT, ITOT and VTOT scores, it was predicted that there would be noticable differences in the answers they provided to the questions in the latter two-thirds of the interview schedule.

In general the interviews lasted about 45 minutes to one hour each. Little difficulty was experienced in getting the teachers to talk on the interview topics. All the teachers were assured that answers would be treated in the strictest confidence and many talked at length about difficulties in their own schools. As far as possible none of the extracts from the tape recordings quoted below refers to individuals or schools in such a way as to make identification possible.

Some brief biographical details of the interviewees, obtained from their questionnaires and from comments made in the interviews, are given below:

H1: Female, Head of Biology, also teaching some chemistry in 13-18 girls school. Graduate with 16 years teaching experience.

H2: Male, chemistry teacher, also responsible for careers guidance, in 12-18 mixed school. Graduate with six years experience of research and development in plastics industry followed by five years in teaching; teaches some physics.

I1: Female, teaching human biology part-time in 13-18 girls school; has two young children. Biology graduate with eight years teaching experience, including five years as Head of Biology, in 11-18 mixed school.

I2: Male, physics teacher, also teaching some general science, in 12-16 mixed school. Metallurgy graduate, trained to teach mathematics and physics, but has also taught boys craft subjects; six years teaching experience.

V1: Female, teaches both chemistry and physics in 11-18 mixed school. Chemistry graduate with four years teaching experience.

V2: Male, Head of Science in 13-18 mixed school. Biology graduate with about 20 years teaching experience, some as Head of Biology in a grammar school.

O1: Female, Head of Science in 12-16 mixed school; non-graduate trained in chemistry but has taught all sciences; 16 years experience of science teaching.

O2: Male, Head of Mathematics and Science Faculty in 12-16 mixed school. Emergency trained; teaches physics and general science; 30 years teaching experience all in one school.

5.2.2 Comparison of H, I and V Type Teachers

All the teachers interviewed said that they included practical work as often as possible and that they would usually prefer to have a practical as part of a normal lesson rather than having separate practical sessions. The main exception to the latter seemed to be with sixth form classes where the length of time required for some experiments necessitates a whole lesson being set aside.

Disagreement between the three types of teacher began to be apparent when the question concerning preference for teacher demonstrations or class practicals was raised. The V types seemed concerned about the time wasted in pupil experiments and the possibility of pupils obtaining incorrect results:

> V2: Practical is time consuming. I can set up an experiment at the front of the room ... and get the results; they can observe the results ... By doing it that way, I save a lot of time. So what I might give as a class practical, if I'm under pressure for time, I'll change it and do it as a demonstration instead ... I can cover that and the theory in one lesson ... There are cases where they would enjoy it more doing it themselves, but it's so time consuming. It's very nice if the kids can see the results of an experiment in a double lesson. To get results quickly, we sometimes set up the apparatus before the kids come into the lesson ... they can see the results there and then.

> V1: If they can do it themselves, I'd much rather, but with a lot of things ... you don't feel they'll benefit very much because they're going to make a complete mess of it. Then I don't see any great point in doing a practical. Sometimes I think, with the results you get from the practical, it's not worth doing it - just a complete waste of time.

Both the H type and the I type teachers seemed to value practicals in spite of the time involved and the fact that the teacher is more skilled:

> I2: It's certainly much better than the theory approach where you sit in the classroom and listen to the teacher and he does some experiments and, if you're lucky, the class does a few experiments too.

> I1: Probably better results are achieved by my doing it because I am more skilled, but that would be only one result and as a scientific exercise not really very valuable.
> (Interviewer: Do you think it's important to have more than one set of results?)
> From the scientific point of view, yes; to work out averages and so forth, one needs more than one set of results - certainly.

> H2: Even though it would take much longer than the teacher demonstrating it, I'm all for the pupils doing it if they possibly can. I think they get more fun from it.

> H1: They're more likely to remember it if they've done it themselves.

The H and I types seemed to have little doubt about the advantages of the pupils doing practicals for themselves, either because they thought this makes the investigation more like the real thing or because they believe it is a better teaching technique. The V types either did not see these advantages or found them outweighed by the need to cover the factual content of an examination syllabus:

> V1: You can't get it all in, if you're going to get it all done ... There's no way you're going to do practical and get it all done, so ... we go over it quickly in note form.
>
> V2: We are under pressure to cover the syllabus.

One reason the V types had for being doubtful about the value of practical work was that they believed that pupils cannot be trusted to work on their own. Not only do they need to be shown what to do, which is time consuming, but then they get the wrong results:

> V2: What I would do is to have a chat about the experiment first of all; try to cover what I think are the important theory points involved, go over the apparatus that is needed, show it to the kids ... show them how the apparatus is set up in demonstration ... Like I say, 'That indicator is going to be poured in that tube' ... then I make sure that they understand the instructions they've been given before giving them any apparatus at all.
>
> V1: If you're heating something and weighing it to see whether you get a weight loss or not, you'll always get somebody who'll get a weight gain when there's supposed to be a weight loss - they've misread the balance; or you get them losing weight when they shouldn't because they've dropped half of it on the floor going across the room.

One forms the impression that, for a V type teacher, practical is worth doing only if the pupils can do nothing that is original or out of the ordinary:

> V2: I don't think any problems will arise, because I've been doing these practicals for a long time. When problems will arise is with the new practicals. With most of the practicals I do, I think I cover most of the possibilities ... With a lot of experiments, I make sure they get the right answer. I would lead them to the right answer if I thought that their experiment had been done incorrectly. I tell them what I think is the right answer: well, what <u>is</u> the right answer. (Stress in the original tape)

The importance of obtaining the correct answers and avoiding anything that could lead to uncertainty was to be found in the V type's attitude to demonstrations as well:

> V1: If it's a demonstration, I want to be sure it's going to work and make its point. Having experiments that work, and making sure that they do work is important.

If the H and I types seemed to be generally in favour of class practicals and the V types were cautious about them, preferring to use demonstrations, all still agreed that practical work of some kind was essential and that pupils derived some benefit from it. Their reasons for the inclusion of practical work varied considerably. In some cases it was just to satisfy pupil expectation:

> V2: It's born in them; well, it's developed in them very young that science is a practical subject. If you don't do any practical work with them in science they get very disillusioned with the subject ... their interest goes ... I could cover the syllabus perfectly satisfactorily, could get them through the exams as well ... I don't know if they would be as happy and they would definitely not have the manipulative skill.

> V1: I've done the theory first and then said, 'Unless you behave, we will not do the practical' and it's a very useful lever. That way you can get something in their books and they settle down to do some work ... then they do the practical and it's an added incentive that they want to get out on time, so they're going to get it done.

V1 had only four years teaching experience and had problems of control with some classes, but V2 was a very experienced head of department. In spite of this difference, one detects the need to keep firmly in control of the lesson, to prevent pupils getting carried away in the practical situation, in the answers of both V type teachers:

> V1: I clear up ten minutes before the end of the lesson so we can talk about the homework - they can even start doing it - the only way some of them can write up an experiment is copying from the board ... They get very excited doing practical work so I might write a few sentences on the board and get them to copy it down ... it just calms them down and puts a psychological halt on anything they might want to carry on doing.

> V2: If you're not careful it can have an opposite effect: they can get involved in the experiment ... they go off on tangents and concern themselves with what you're not after in the experiment ... You've got to keep a tight rein on it ... if necessary draw their attention to what they should be noticing ... Therefore what I'm inclined to do in a practical ... is to make sure they don't wander too far off what I want from them.

Even the examination boards are seen by the V type teacher as a source of difficulty:

> V2: In exams they set catch questions ... so many of the questions are to my mind practically based questions.

But it is because of the expectations of the pupils that the V type teacher does not abandon all class practical work:

> V1: The children feel cheated if they don't get a practical every so often ... Unless they get a practical once in a while they feel this is not what they signed up for ... When they're flagging half way through the afternoon, I say, 'Never mind, next week we are going to do a practical'. And you can get through the syllabus still, but break it up. It's an incentive to get through the bit they find difficult ... I don't think it's time wasted; it's a break for them and it's a break for me.

In so far as the V type teachers interviewed tried to include practical work, it was to satisfy pupil expectations or to increase pupil enjoyment. They may have seen it as a good visual teaching technique to back up theoretical points they had covered previously, but there was little evidence they they saw experimental work as having an important part to play for its own sake. The contrast with the I type teachers was marked:

> I2: Science is all based on practical work: on experiment and observation; and so I think it would be false to teach it in a purely theoretical way. That's how the body of scientific knowledge was built up: through experimental observation. And to train scientists you must train them to experiment and to observe, and to think up their own experiments.

> I1: One can draw a distinction between two aims of practical work: one aim is to train the average citizen to be observant, to collect data intelligently and to evaluate it; ... the other form of practical work (is that) in which it is the actual facts involved, the information, which is necessary. For the average pupil, learning facts is less important than developing powers of observation. Children can learn something from their experimental work: achieving results of some sort which add to the knowledge they already have, or they might discover something new they didn't know before ... Carefully organised practical work can train them in observation: the importance of paying attention to detail, being precise in their observations and recordings. To a lesser extent, I suppose it encourages cooperation and teamwork.

The I type teachers were not too idealistic. They realised that in a normal school with ordinary pupils one has to compromise, but their basic attitude was clear:

> I1: I know ideally pupils are supposed to discover everything for themselves ... but they need a fair amount of guidance and I try to guide them in such a way that answers seem to come from the class ... I try not to make it too obvious what they are looking for - that spoils the excitement ... Usually there is not enough time to repeat experiments, so we cannot repeat things often to check results ... so I have to present results as I have obtained them from other sources.

> I2: Basically we're trying to train them to observe and to see things for themselves and to try to explain them - but I don't think many of them are capable of carrying out an open ended scientific investigation. It's a bit much to ask for the average kid in this school ... it would be such a long-winded process, just finding out fairly simple things. I think a bit of direction is necessary.

Teacher I2 used large numbers of worksheets to guide pupils in their practical work. He said about these:

> I2: The cards are worded to make them think about what they are doing ... they've got to see what happens: well, to observe basically. They've got to try to explain what happens.

The I type teachers did not give the impression of hiding from the difficulties experienced by pupils in the practical situation or of trying to remove all sources of error as did the V type teachers. Rather they thought difficulties with experiments could be of use in the teaching situation:

> I2: We talk about it often. I think it's important ... to point out to them ... the subject of experimental error ... to impress upon them that to get a theory you have to do an experiment many times.

Although the H type teachers agreed with the I types that practical work was important for pupils because it is an integral part of scientific activity, this did not mean that their approach in the teaching situation was identical:

> H2: I'm a firm believer in asking questions. What I try to do in the previous lesson is to leave them with something

hanging in the air to pick up at the beginning of the next lesson ... So it could develop from that with a little bit of introduction to show how it relates with what we've done previously ...

H1: The ideal is that you do the practical first and then you use the information gained from that to do the theory afterwards; and, as far as possible, I try to do that. I want them to understand as far as possible the world they live in ... They do experiments to find if there is some truth in it and obviously to make them think. We use scientific experiments to find if what they think is right or wrong and if there is some truth in it. This is essential - very important. They can't prove that something is right because we can't do that ... We do tend to be too academic. We do find ourselves stating things categorically all the time when we shouldn't at all. Because time is short ... we state things are just so when they are not.

The differences in viewpoint did seem to influence the ways in which the teachers organised their practical classes. The practical lesson with an H type teacher could be very different from that described above for the V type teacher.

H1: As far as possible I always try to begin a practical lesson with a discussion, then I get some sort of ideas from them and then we decide how we would show this with an experiment - in order to get ideas for themselves and find if they're right or wrong. They get evidence from practical work to think about experiments they have done before and use this to help get a result.

Both the I type and the H type teachers regarded practical work as something which has intellectual benefits for pupils:

H1: The more science they do, the more common sense they develop ... it gets them to think about things; to try to think for themselves about something useful - about what is going on around them.

I1: They should become better scientists for having done it themselves ... developing the ability to evaluate evidence and criticize doubtful inferences from their collected data.

I2: ... to observe critically; you know, don't take results just as they are: to think,'Is that likely?'

In contrast the V type teachers did not appear to be quite so keen on thinking pupils:

V2: It's nice to have kids thinking about things; in no way would I discourage that ... while all the time you've got to bear in mind what these kids have got to know for the exam.

For these extreme V types, the true importance of practical work lay in the confirmation of factual data which pupils had already been taught; witness the following extract from one interview:

> Interviewer: You like to make sure they understand the theoretical background, and then really they're doing an experiment to prove that what you've said in the theory part of the lesson is true?
> V2: Yes.
> Interviewer (in disbelief): I'm not misrepresenting you?
> V2: In no way, in no way - I agree with that 100%.

One other benefit of practical work, according to the V types, is that it may provide opportunities to increase pupil confidence, especially for those who do not excel in other types of work:

> V1: They learn certain techniques; they are being scientists. There's nothing better than actually doing an experiment. If you show them, actually demonstrating an experiment, show them this is how you do it and they watch carefully, then they can do it themselves. They're pleased with what they've done and feel they've achieved something ... particularly with the ones that aren't so bright. They feel they haven't achieved very much: 'I'm thick; I can't do it' ... but if they follow a set of instructions and pour the right amount of acid on the copper oxide, they themselves are getting the satisfaction which motivates them to carry on.

The differences which became apparent between the attitudes of the H, I and V type teachers towards the inclusion of practical work in lessons and their beliefs about the benefits of practical work for pupils are entirely consistent with the theoretical differences that one would predict from their divergent philosophical standpoints. Whereas the V type teachers saw practical work as a teaching technique to reinforce their teaching of scientific facts and as a way to motivate or to control their classes, both the H type and the I type teachers saw practical work as having a value in itself as a part of the scientific process which they try to impart to their pupils. However there was a difference in emphasis between the H types and the I types. The I types placed the greatest importance on observation and recording. In contrast, the H types saw designing experiments to test the ideas, sometimes false, put forward by pupils as the best kind of practical work to use in the classroom.

The third section of the interview schedule was devoted to checking the views of the teachers on the philosophy of science and to finding out what contribution they thought science makes to the total curriculum of a school. Again the disparity was obvious: the H and I type teachers saw the contribution that science makes to the curriculum in terms of increasing pupil understanding of the natural universe and as a training in logical methods, whereas the V types put greater emphasis on external criteria such as the usefulness of a science qualification in an industrial area.

> I1: Human beings can operate better if they understand the workings of the materials around them: living and non-living ... I hope lead more fulfilled lives. Scientific progress is always making the popular news headlines and I would hope science in school enables the man in the street to understand the background to these kind of headlines ... and to be more critical of pseudo-science and advertising and so forth.

> H1: We live in a scientific world: everything around us is a part of science: what we are, how we live ... it's all a part of science - the whole universe and everything in it ... You can't help thinking about what is going on around us. The whole world is scientific material.

> H2: I think it encourages a particular way of thinking. That's one of the good points for it. It also encourages them to use their senses and to become more aware of things around them.

> I2: It's training them in a certain way of thinking. It gives them the ability to analyse something and to ask questions about it. You know, it's a scientific way of thinking that everybody needs to have in some degree or other. I think everyone should have experience of that way of thinking ... of being objective rather than subjective.

> V2: Well, I think: job opportunities - the value at the end of the day in having Physics and Chemistry on their certificates. One could pass an exam without going into a laboratory ten years ago. Nowadays it isn't like that at all as far as the exam situation is concerned ... they have to sort out the question that's being asked on the original bit of fact they've been given. For some of the B band kids, I think more maths and English would do them more good than science. I couldn't defend science in some cases. In other cases it comes back to careers again - employment.

V1: If you've got no scientists ... you're going to have even worse problems: ... pollution and things like that. There have got to be things that are going to be useful to you later in life, even if it's 'can I wire up a three pin plug when I buy myself a washing machine?' If you look at a factory, any sort of production process, you've got scientists ... We're in an industrial area here where engineering predominates.

It was particularly noticable that H2 did not mention the importance of science qualifications in obtaining employment in spite of his own experience in industry and his being responsible for careers guidance in his school. This view of the 'usefulness' of science education seemed to be particularly prominent in the V types, perhaps because they are unable to justify science in any cultural way. The other types put their emphasis on the methodology of science itself:

I2: ... for the lower ability kids, they get most satisfaction out of simply making observations. Being able to make observations is a useful result for them ... to devise your own experiments demands a higher level of intelligence. Observation is the simplest skill ... you've got to be good at observation before you can start testing out your own ideas.

Similar differences between the three extreme types of teachers became apparent when they were asked how they would distinguish between science and other school subjects:

H1: It's just another set of questions ... we don't know any actual facts ... A set of 'facts' at present may or may not be facts in the future. We make progress all the time. There is a set of techniques in order to find out things rather than facts which are set and the same each year. In our teaching we ought to make them realise it's an ever changing situation. In history you can just learn a set of facts and you can answer the questions in examinations; in science you can't. There are a few basic facts, but you have to use them in new situations to get anywhere. I would prefer to use practical rather than teach a body of knowledge ...

H2: It's basically the practical approach that sets science apart from the others ... it's the way of thinking that makes science different from other subjects. I think, without knowing it, the children realise that they are doing different thinking, different processes, in the science lessons from the other subjects.

I1: I would see the aims as being similar: a greater understanding of the universe if you like. Not just facts: a philosophy of life as seen by people of different disciplines. I would hope (a scientist) is less inclined to bias than some of the others, more inclined to be accurate. There is more in history that is a matter of opinion, a matter of your point of view. Science is based on more objective evidence, or should be based on objective evidence. I would hope that scientists are more ... dispassionate, though I think modern historians are becoming more scientific in their approach. Even history lends itself to precise observation and objective measurement. I think this illustrates my point that science is central in a school curriculum; it provides a basis from which other disciplines can work.

I2: They see science as different because it is a practical subject. Science is a way of thinking which lies behind all of science: the experimentation, the observation, which doesn't apply in (say) woodwork.

The V type teachers also saw science as a practical subject, but they viewed its practicality in a rather different way:

V2: At the end of the day, they, boys and girls, are going to be able to wire a plug ... They're going to meet science more in their everyday lives than they are history or geography, R.E., French. Last November's history O level had a question on history of medicine ... I could have answered this question ... so that's a grey area ... other subjects are now broadening their syllabuses and beginning to encroach on science.

V1: I would say science is more relevant than possibly history or geography. We cover a variety of useful topics: how to feed yourself properly, how to reproduce, household electricity, car mechanics, car electrics, household insulation - well, that's science.

Clearly the V type teachers did see that science is distinct from other subject areas in the school curriculum, but they saw the difference in terms of the subject content itself and therefore in terms also of its possible relevance after leaving school. In contrast the H and I types mentioned scientific ways of thinking as something which can be used to distinguish science from other subjects. These teachers were therefore asked what they believed these thought processes involved:

H2: It's going from observations to hypothesis, and then testing that in a specific case and then generalizing from it; and then being able to apply that to other situations when they arise.

H1: In discussion first you get ideas, then they form their practical ideas around that, then try to get involved in practical work, to understand the processes they're doing in practical work, then perhaps discuss the answers they get and how they fit in with the questions asked at the beginning.

I2: I go from the approach side of it. I don't think the factual side is all that important. The factual side is written down in books. As long as you know where to look for it, the facts and the information, you do not really need to know the facts, so I think it's training the mind to think in a certain way that's most important.

The other I type teacher was much more explicit, talking of 'collecting data and tabulating it' as a result of 'observational work in playground or school field' and even said about her own family:

I1: I'm very hot on observation: I'm bringing up my children to be observant. If a scientist isn't observant, he's lost - that's the basis of science.

Although both the H types and the I types saw practical work of some kind as an integral and indispensible part of the scientific process, they did not agree about where it should fit into the sequence of events. This difference of viewpoint has implications when such teachers plan their lessons and decide how to incorporate practical sessions. Even though differences between the school laboratory and the research laboratory are undeniable, these teachers did seem to attempt to introduce pupils to their own conception of scientific method. They reported that they organised their lessons accordingly:

H1: You can't start off saying: we are going to do an experiment; we are going to do the experiment this way; we are going to show this particular answer or whatever. You can say: we are going to look at this particular situation, ask how we could go about it and tackle it, and get them to plan what sort of experimental work we can do; and you can show them there is a variety of ways of tackling it, then cut it down to one we can do.

H2: There's a difference between using practical work for research when you don't know where you're going, and using practical as a teaching tool where you know what the answers are ... I suppose that the children see some connection, but I'm not sure myself that there's any real connection between the two. In the real world it's open ended; you don't really know where you're going next. It's always the unexpected that can happen and take you off down fresh avenues. With it in a teaching mode then it's completely closed; you know exactly what you want to achieve ... From their point of view, to them it is new; it should be new and it should be exciting and there should be discoveries and, if possible in the ideal situation, you should be able to develop and expand the pathways, the red herrings, they bring up. If you had a particular problem you wanted to investigate, you could introduce it completely openly, take the suggestions that would come along and let them develop and try them, knowing full well that some of them wouldn't work, but that doesn't matter because it's all part of research anyway, that you do things that don't work. In the work we're doing at the moment with the third year ... we provide an unknown, a green powder ... We say, 'Here's a green powder. How could we find out what it is? What sort of things can we do?' and hopefully someone will suggest you heat it, and you dish it out and say, 'Heat it and see what happens'. They find it goes black and someone says, 'Ah well, that's carbon' ... and then develop that, and then someone suggests adding acid to it, and then ... I feel practical is the heart of it ... That's the step that gives the observations which lead to hypotheses, which you can test out in the practical situation. I don't think you can do without practical, in spite of the fact that it has been done that way in the past.

As can be seen in the above extract, this teacher was prepared to give a considerable amount of thought to what he did in his lessons. He was able to justify why he did things in the ways he had chosen. He had a clear idea of what he meant by scientific method and of the way in which he believed science progresses:

H2: You can either have a hypothesis and test that by experiment, in other words you've got a good idea of what to start with, or you can go the other way round and have it completely open and go from the observations to the hypothesis. I would be very loath to put anything down as a law no matter what, because I think a law is only a law until someone comes along and disproves it. I don't think you can be sure that anything is sure ... We can't really we sure of anything. Someone can come along later and prove that what you were doing was not strictly true; you've got this with Newton and Einstein, haven't you? ... It may be in the future that someone will come along and show that Einstein is wrong. It's all uncertainty, isn't it? ... You can never be sure that what you've done isn't going to be proved wrong in the future.

As the extreme I type of teacher has a rather different view of scientific method, this could influence him to organise his practical lessons in a different way:

> I1: I think perhaps the mistake is made of making practical work too complicated. The same principles of observation and collection of data can be obtained by less elaborate, less expensive, practical work. I think the idea of scientific method is a little nebulous, but the idea of accurate objective observation, the collection of precise data, logically presented, is common to all scientific disciplines. It does need a certain talent, a certain kind of mind, to discover things, which very few people have. For most a discovery becomes very obvious after somebody else has discovered it ... (I) give pupils some of the thrill of scientific discovery ... by not telling them the answers at the beginning of the lesson.

It may be thought that pupils of both the I type and the H type teachers are fortunate in having science teachers who think about the way in which they use practical work and are certain of its value. Pupils of a V type teacher may get a very different introduction to science in the classroom. There even seems to be a danger that an extreme V type may become so bound by the constraints of the syllabus, the need to cover all the facts, that he does not have the time to include any real practical activities at all:

> V1: The ideal situation is where you're saying, 'We're going to find out. How do you think you would devise an experiment?' - you can't do it. It would be lovely to do it but you just haven't got the time. The Nuffield people rather assumed that everybody spent twice as long as they really do teaching science, because there is no way you can do all their experiments within the time. The Nuffield scheme has been useful, but I would not say I use many experiments from it now. The (textbook) we use - it's got experiments in. Well, sometimes it's useful to say, 'Look at this experiment' but then, it has questions for discussion and nothing about the results ... which is no good for a child who wants to look something up ... I give them two textbooks: ... Holderness and Lambert ... and this more experimental one ... (The former is) very useful for those areas of the syllabus where you want to press on and it's just facts. You can talk about it and say, 'It's there, you can make your own notes' ... We'd been doing kinetic theory and I said, 'I want you to look at this' and I got it under a microscope ... but because of the time I didn't get to do (it) ... Even with an experimental approach they have to take a lot on trust ... They have to take the teacher's word for it.

One V type teacher also had a simple view of scientific method:

> V2: The accurate recording of where information comes from. It does follow the same pattern in all the sciences ... you can ask them in some experiments what sort of apparatus they would set up, or how they would set it up ... then do the experiment and collect the results, all the time bearing in mind what you're collecting the results for ... then, as far as school is concerned, in the last part, having collected these results, you step in and say, 'Good results. Now, bang, bang, this is what you should be getting from them ...'

If V type teachers seem preoccupied with teaching the factual content of courses to the exclusion of methodology or pupil involvement, this is not an entirely true picture. They may want pupils to think about their results and about the science they are taught, but they give the impression that this thinking will come as a necessary concomitant of familiarity with the facts:

> V2: If I've taught them to think a little bit, I'd be happy. At the end of the day ... the exams come along. Whether he can think logically or not ... results are far more important. You can be sure, if he was going to end up with A's in his sciences, he would be thinking logically anyway. The two things go together: if they know the facts, they are thinking logically as well.

As these extracts from the teacher interviews show, the views expressed by the extreme H, I and V type teachers in the interview situation reinforced the impressions of their attitudes and beliefs which one obtains by studying their responses to the Section 3 and Section 4 questions of the School Science Survey questionnaire. In some cases it appeared that these teachers consciously tried to organise their lessons in accordance with their philosophical beliefs about the nature of science. In other cases, the connection was not a conscious one but it still appeared that the teaching approach described by the teachers corresponded to that which one would predict from knowing their philosophical positions.

As it seemed that a teacher's philosophical beliefs could then be deduced from his behaviour in the classroom, no change was made in the plans for the experimental phase of the investigation. The teaching methods used in this phase were based on those described by the three extreme types of teacher during their interviews and are discussed in more detail in the following chapter.

5.2.3 The O Type Teachers

In addition to the teachers who could be classified as hypothetico-deductivists, inducivists or verificationists, the questionnaire had revealed a few individuals who were extreme in another way: they exhibited no bias at all, scoring mean scores on all philosophical scales. Two of these, termed O types, were selected for interview and it was more difficult to predict what such teachers would say. Two possibilities seemed worth considering: either they would exhibit a random mixture of H, I and V answers, as they had done on the questionnaire, or they would turn out to have no clear idea at all about the methodology of science. If the latter prediction were true, one would expect them to value practical work, and possibly science itself, for largely extrinsic reasons.

Although there was some similarity between the views of the O type and the V type teachers in that they both used practicals to consolidate theory and both saw science as a key to employment, the total pattern of answers was different. The O types were much more concerned with the enjoyment of practicals, and the use of teaching methods that are effective and suit the teacher's personality. They also showed a clear absence of any views on the philosophy of science.

> O1: I would like to say that practical work stimulates enquiry, but I've got to be honest and say that the way my classes do practical doesn't stimulate enquiry in the true sense. They do set practicals. I'm working very much on using visual consolidation. My classes enjoy chemistry immensely. I think there's not much doubt about that. They sit there absolutely beaming; they love every minute of it. On the whole it's a very popular subject. It is stimulating, even if they're told what to do. Actually being in charge of a bunsen flame is a

stimulating experience for them ... It really is like magic ... it's just like magic to them. They do enjoy it and so do I. The practical is very much the centre-piece of the lesson.

02: It is a bit of a disappointment ... if I can't find a practical to do ... I don't do practical work just for the fun of it; it's got to be of some value. What I like them to feel when they come in through that door - they're not sure what they're going to get.

Both of the O type teachers had an immense enthusiasm for teaching science and believed in transmitting basic information effectively. Both stressed the real value of simple practical work if pupils were to succeed;

01: For me it work's; I'm a bit of a pragmatist I suppose and I've found it's the way I get kids through exams. I'm an avid believer in basics ... I will hammer basics, if necessary ad nauseam. We are trying to teach simple concepts that can be developed and expanded later. I think this is valid. I think this is more valid than not teaching basics. It would be nice to say that qualifications matter, but at this stage they don't seem to; it's the ability to put things across that matters.

02: I like to feel that I'm a teacher, not an instructor. It appals me when I see my son's book and there's every evidence there of dictated notes. I feel this may have value to him but he's missing the whole point of science.

01: I would much rather teach with cardboard boxes and bits of sellotape and bits of string and improvise ... That's probably because, when I started teaching, that's how I had to teach, so it's very much what I was brought up on. I was in a department in a very poor area ... no equipment and it was a case of what you did you had to make yourself ... and it worked and they loved it. It still seems to work ... our own philosophy has more to do with it than money. I really think kids like to see simple things working and showing basic principles, and I think they learn better like that ... I've never bought a piece of Nuffield equipment!

02: Even in those very early days when the HMI's used to put on courses for what might be called the general science teacher with the jam pots and all the rest of it, I was there to try to improve things. Most of my early science was literally with rubbish ... I can still make rubbish work. I had to learn how to ... I prefer to get by on very little and get the most out of it. I've become a little bit of an actor, a little bit of an entertainer and I think this is a part of it too ... That's when I'm in my element: with the room blacked out and the lights going off and having fun; and I will regard myself there as an entertainer in a sense ... there's something of the showman that comes out in me ... and I don't mind it at all because they know I'm enjoying myself.

This teacher pointed out that he included practical work often in his lessons both because it is an effective teaching technique and because the pupils enjoy it as a change from the less interesting non-science lessons they had elsewhere in the school:

> 02: I can remember at the age of ten watching Mr. Harris boil water in a paper saucepan - I didn't believe it! And I can still see it. Fancy boiling water in paper ... and I think, if these demonstrations are vivid enough, they implant something in the youngsters which they don't forget. I look at it from the point of view of the child to some extent. They've got a long day in school if it's just going to be sit there and listen to the teachers talking ... here is a chance for them to come in and do something different from what they've been doing in history or geography.

When asked for their justification for the inclusion of science in the school curriculum, the O types stressed the usefulness of a science background when looking for employment in a mainly industrial area:

> 01: I would straight away go in for the very basic career angle first ... Look, these kids live in an indudtrial society. They've got to get jobs ... in the present situation, I would have thought that's justification enough ... particularly in an area like this, the decent jobs are all science jobs. After maths and English, physics comes next, and in a lot of cases physics comes before maths and English ... If they've got physics, they're all right.

> 02: We're surrounded by factories and these children would find their livlihood in science around ... It should be English first, maths second and science third; and sometimes that order may be altered to give physics, maths and English in that order, depending on the circumstances and the child.

The television keeps telling us about scientific progress and the O type teachers said this element of progress is what makes science different from, and also more interesting than, other subjects the children have to study in schools:

> 02: A potent thing these days is the television ... so much of it relies on science. The information which comes over: how could they make sense of it? ... one cannot escape from science.

> 01: It's growing, it's developing all the time. That makes it exciting to teach and it should make it exciting to

learn ... Every time you turn on the television or pick up a science magazine, something new has been discovered and there is some connection with what you have been doing in class ... I find that very stimulating and that's what makes science different for me.

It would seem from what they said in the interviews that the O type teachers did not distinguish science from other human activities by its particular philosophy or methodology. Science was seen by them as a vital and interesting challenge, but also as a careful and disciplined process of experimentation and calculation. When pressed for details of their view of the methodology of science, both seemed to be uncertain:

> O1: (It is) something intangible, something vital. Perhaps it is that it's vital, that it is unpredictable, that it is changeable, that it isn't set, it isn't fixed. You would certainly think in terms of observation; that is one thing, and enquiry.

> O2: I know instinctively what it is. Each subject has a particular something to offer. Science is a sort of appreciation of our world, and what's around it as well, and the world of themselves as well, so we are getting very close to the reality of living ... I don't know; I'll give you a written answer later. There's a discipline that comes into it in science. If they don't do things in a certain way, then things go wrong, and that may be that you don't get your results but it may be that you get the result that someone gets hurt. The scientific method is used by me to challenge them ... I make them feel that they're doing it scientifically. It really means doing an experiment in such a way as to get as good an answer as possible and by using a number of techniques. There is the practical one, and then there is the recording, and the calculation, and the conclusion ... They go right through it and at the end they feel they've done a very good job.

Both of the O type teachers interviewed were extremely conscientious and dedicated teachers, who would have made all their pupils enjoy science. They were in many ways the most interesting to talk to of all those interviewed, and some of their enthusiasm must be apparent in the interview extracts quoted above. However, they cannot really be said to be imparting a philosophy of science to their pupils in the way that the other extreme types may do. No attempt was made, therefore, to duplicate their teaching styles in the experimental phase of the investigation. Indeed it would probably have been impossible to do so.

SUMMARY OF CHAPTER 5:

The School Science Survey questionnaire was administered to about 100 teachers of science in middle, secondary and high schools. On the basis of their scores on the philosophical scales in Section 3 and Section 4 of the questionnaire, extreme teachers of four types were identified:

H types: hypothetico-deductivists.

I types: inductivists.

V types: verificationists.

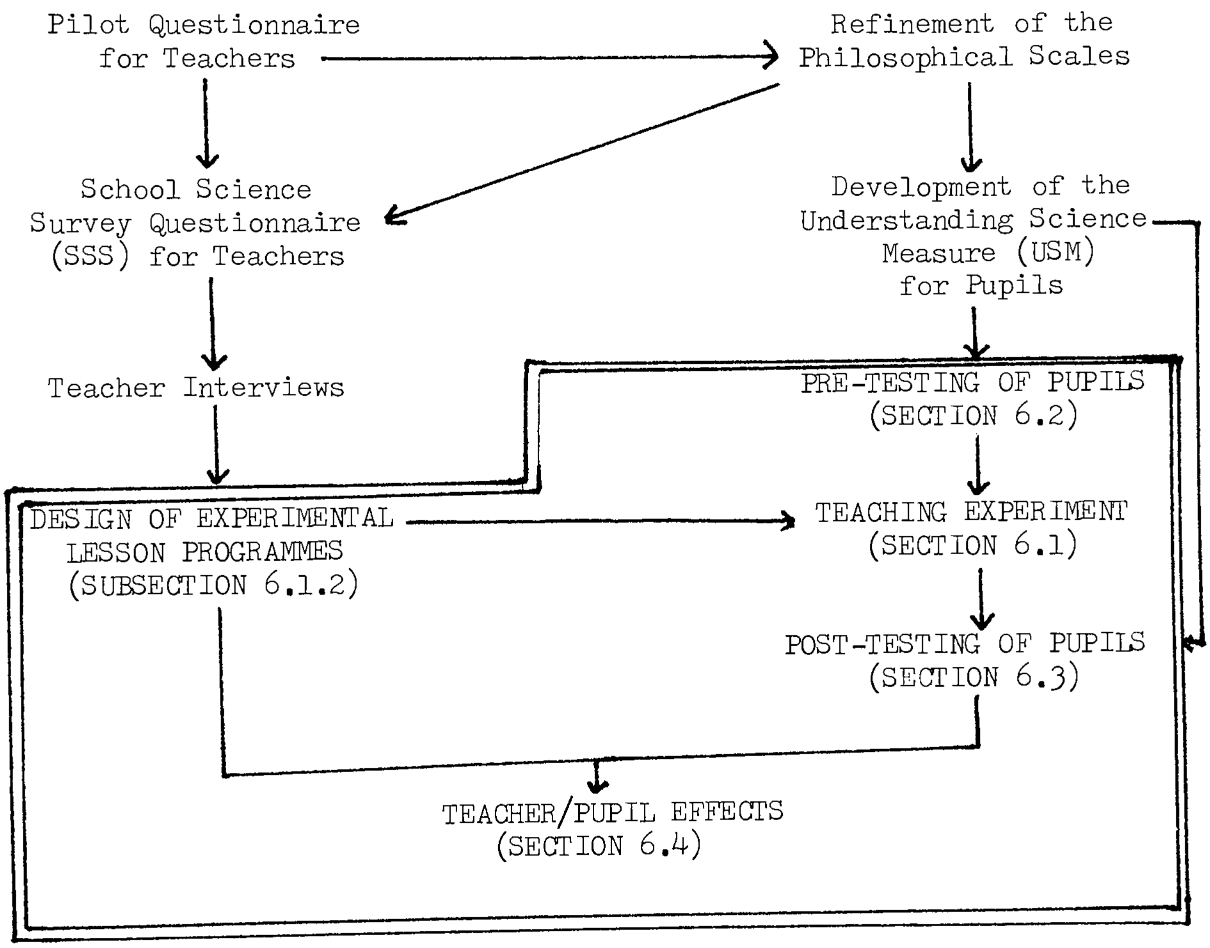
O types: no discernible philosophical beliefs.

Two individuals of each type were interviewed six months after the completion of the survey. The interviews confirmed the findings of the questionnaire and showed that there was some connection between the philosophical beliefs held by the teachers and the ways in which they planned to conduct their lessons.

Details of the teaching styles of the extreme H, I and V type teachers were noted from their interviews as a basis for planning the teaching experiment which was to follow.

CHAPTER 6:

PUPILS' UNDERSTANDING OF THE PHILOSOPHY OF SCIENCE



6.1 The Experimental Situation

6.1.1 Organisation of the Experiment

In the experimental phase of the investigation, five normal science classes were subjected to biased teaching styles in some of their science lessons during a period of several months. The teaching methods used were based on those reported by the extreme H, I and V type teachers in the interviews described in the previous chapter. An attempt was made to assess the effect of these teaching styles on the pupils' understanding of the philosophy of science by using the Understanding Science Measure (see subsection 4.2.4).

During the time when this research was being done, the author was teaching in a 13-18 comprehensive high school for boys. The classes used for the experiment were normal third form groups with pupils in the 13-14 age group. All pupils in this year group followed a common science course and each class had a 70 minute double period of each of the three main sciences (biology, chemistry and physics) every week. As far as possible the normal arrangement in the school was for a team of three teachers to cover all science lessons for this year group. In those circumstances, any effect of bias in teaching style would be the same for all classes.

As the author was the chemistry teacher in the team, it was planned that he should vary his teaching style to provide a consistent bias throughout the period of the experiment for the classes involved. No attempt was made to change the normal approach of the biology or physics teachers who also taught the experimental groups.

Pupils at the school entered from four middle schools, but ex-pupils of all four feeder schools were mixed in all teaching groups so that differences between groups were not likely to be due to any variety of experience of science teaching in the pupils' previous schools. When they entered the school, the pupils were sorted into two broad ability bands on the basis of gradings (A-E) from the middle schools and tests administered by the high school itself. Three tests were given to the pupils in their first two days in the school before the final allocation to teaching groups was made. One test was the Gapadol Reading Comprehension Test (McLeod & Anderson 1973), which uses the cloze technique and gives standardized scores for the reading age range 8-17+. The second test was the Vernon Graded Arithmatic-Mathematics Test (Vernon & Miller 1976) and the third was a factual recall test devised by the head of science department and intended to check what pupils remembered from their middle school science work.

Once these broad bands had been agreed, each department in the school was free to divide the half year groups in any convenient way for teaching purposes independently of other subject departments. The normal practice of the science department in the school was to divide the upper ability band (the A band) into three parallel groups which, as far as possible, contained a range of pupils of similar ability and attainment. In the lower (B) band the remedial pupils were formed into one teaching group and the remainder of the pupils were placed in two parallel groups. The pupils in the 'remedial' group were those who had been graded E by their middle schools plus a few who achieved very low scores on the Gapadol test.

The remedial group of about twenty pupils was excluded from this study for several reasons: it would not have been possible to compare it with another similar group taught in a different manner; there would have been difficulties in testing the pupils' understanding of science because of their low reading ability; some topics in the science syllabus were modified for this group; and this group had a different chemistry teacher from all the other classes in the year group.

As the E grading was used by middle schools for only the bottom 10% of the ability range, the teaching experiment was conducted with groups covering nearly 90% of the ability range of the pupils entering the school. A more symmetrical experimental design would have been possible if three parallel groups had been available in each of the two ability bands. In the case of the three A band groups, each was treated in a different fashion. One group was to be taught as an extreme hypothetico-deductivist (H type) teacher might conduct his lessons; one was to be taught in an inductivist (I type) manner, and the third in a verificationist (V type) style. In the B band, it was possible to contrast only two teaching styles and a decision had to be made concerning the one to be omitted.

As the information from the School Science Survey questionnaire had shown that the V type teacher was the single most common type and that there was also a number of H types in the sample of teachers tested, the H and V teaching styles must be used in some form in a number of schools. The existence of HI types and the comparative rarity of the extreme I type had suggested the strength of the H/V dichotomy. For this reason the two B band groups were given H and V treatment respectively. The experimental design thus allowed for a comparison of all three teaching styles and their effects upon pupils in the upper band, and for a study of the effects of the H and the V treatments across the widest possible ability range.

The three top band classes were labelled AH, AI and AV; the two lower band groups were BH and BV. The A and B labels indicated the band and the H, I or V label the style of teaching used with the group. These labels were not known by the children or by any of the other staff teaching the groups. The treatment to be given to each group by the experimenter in the chemistry lessons was decided in an arbitrary way before he met any of the groups. As the one variable which could not be controlled was the time of the week at which a group presented itself for a chemistry lesson, this variable was used as the public label for each group. The groups were known by the name of the teacher followed by the day of the week and the period numbers in the eight period day on which each group had its chemistry lesson each week. The relationship between the experimental and public labels of groups is shown in Table 6.1.

Table 6.1 Labels of Experimental Groups

EXPERIMENTAL LABEL	PUBLIC LABEL
AH	Mon 7,8
AI	Tue 3,4
AV	Thur 3,4
BH	Tue 7,8
BV	Wed 7,8

All five groups taking part in the experiment were taught physics by the same teacher and all except the BV group had the same biology teacher. Group BV was taught biology by the experimenter who used the same teaching technique as he used when taking the group for chemistry. The chemistry lessons, which made up the experimental treatment, were all taught by the same person in the same laboratory for all groups. The experimenter had no control over the composition of the groups. This was determined by the head of science department, a physicist not involved in teaching any classes in the experiment. It was his normal policy to make groups within a band as similar as possible and he was not aware at the time he was allocating pupils to groups that the groups would be treated differently. It must be assumed that the groups within each band were as alike as any two or more classes can be within a normal school situation.

Much educational reseach is done in an artificial experimental situation. The experimental treatment may take place in an unusual room with a specially selected group of pupils and be carried out by researchers who are not members of staff normally teaching the pupils involved in the experiment. It is also unusual for a teaching experiment to last for more than a relatively short period of time. In this case, the situation was so normal that the pupils were not aware than an experiment was taking place. As far as they were concerned, they were simply participating in their normal chemistry lessons throughout the experimental period. The teacher involved was the one normally timetabled for these classes and those with older brothers in the school would have known that they had also been taught chemistry and/or biology by him. The content of the lesson was the same for all groups and was the chemistry syllabus used in the school for some years. Apparatus used by pupils and teacher, the experiments and demonstrations done in the lessons, and the order of lessons through the year was the same for all five groups. Every attempt was made to ensure that pupils who discussed lessons with those from other groups or with older brothers would find that the work covered was in no way out of the ordinary.

The experiment was designed to assess some effects of different teaching styles within a normal school environment, while hiding from the participating pupils the fact that an experiment was taking place.

6.1.2 Course Content and Teaching Styles

The scheme of work that formed the basis of the chemistry course for all five groups in the experiment was the same and there was no difference in the number or type of practical lessons for any of the groups; if a demonstration or a class practical was used, it was the same for all groups. The basic content of the scheme of work was as follows:

1. Safety in the laboratory.
2. Basic chemistry apparatus and where to find it.
3. Three states of matter - solid, liquid, gas. Class practical: melting ice and boiling water.
4. Purification of rock salt by filtration and evaporation - class practical.
5. Investigation of ink - simple class experiment on distillation. Demonstration of Liebig condenser and ascending paper chromatography.
6. Fractional distillation of crude oil. Demonstration because of smell.
7. Electrolysis of water - demonstration. Introduction of simple chemical equations.
8. Differences between elements, mixtures and compounds. Use of 'ball and stick' models.
9. Testing flame for production of carbon dioxide and water. Simple gas tests.
10. Burning in air - Phlogiston Theory. Demonstration of burning magnesium. Class practical: heating copper in air.
11. Explaining gain in weight of copper heated in air - class experiment. Demonstration of gas syringe method.
12. Reduction of copper oxide. Extraction of metals from ores. Demonstrations of reduction of lead ore and electrolysis of copper sulphate.
13. Electrons and the flow of electricity. Demonstration of maltese cross tube. The Plum Pudding Hypothesis.
14. The Rutherford/Bohr atomic model.
15. Periodic table, ionic bonding and valency.
16. Reactivity of metals. Demonstrations of reactions with cold water. Class practical: reactions with dilute acids.
17. Class experiment: displacement reactions. Demonstration of displacement in the halogens.
18. Preparation and properties of hydrogen - class practical.
19. Preparation and properties of carbon dioxide - class practical.
20. Rates of chemical reaction. Demonstrations of effects of particle size and temperature; class practical on effect of concentration.
21. Preparation and properties of oxygen (use of catalysts) - class practical.
22. Preparation of chlorine - class practical. Demonstration of properties.

The scheme represents about two term's work. The third form examinations were held soon after the start of the third term to make it possible for results to be obtained and reports written before choices were made concerning fourth and fifth form courses. The experimental post-test was given to the pupils during the same period as they were sitting their school examinations, when they would be thinking about their work because of revision for the examinations.

In the summer term they were given lessons on solubility and were introduced to quantitative work starting with simple acid/alkali titrations, but these topics did not influence the experimental results as they were taught after the administration of the post-test. The third form physics course was an introduction to heat, light, sound, electricity and magnetism. The biology course included topics on cells, classification, nutrition, respiration, blood systems, movement, sense organs and reproduction. Sections on ecology and evolution were taught after the administration of the post-test. No attempt was made to change the teaching approach of those teaching physics or biology. The experimental treatment consisted in the variety of teaching styles adopted with the chemistry content. The differences involved the way in which each lesson and any practical work was introduced to the classes.

The teaching style in each case was based on what the extreme type teachers had described as their own methods in the teacher interviews. With the V groups, theoretical concepts were taught first in each lesson and then the practical work was introduced. Although titles beginning 'To prove ...' were avoided, the implicit approach was that of using practical work or demonstration to confirm what the class had already been told. With the I group, practicals were performed as often as possible before class discussion. In the discussion which followed the practical work or demonstration, the pupils were asked to describe what they had noticed and they were encouraged to draw wider ranging conclusions from the experimental data. In the teaching style adopted with the H groups discussion preceeded the experiment in each case with pupils being encouraged to speculate about what results they might obtain before they set up the apparatus to begin work. These classes were encouraged to make several predictions about each experiment when this was possible so that some at least would be shown to be incorrect.

With all groups it was suggested that science is different from other subjects studied in the school curriculum but that biology, chemistry and physics are related in that they make use of similar methods and standards. In discussion, examples from biology and physics were sometimes used to illustrate points being made. All the tests given during the experimental period and the chemistry examination set in the summer term were identical for all groups. As far as possible everything was done in such a way as to make the chemistry lessons appear to the pupils as a part of their normal programme of science teaching in the school. It is therefore likely that the pupils reacted to their chemistry lessons in the way that normal children would in a non-experimental situation.

The content of the chemistry course was not unusual. It introduced pupils to basic separation techniques, the periodic table and valency, the chemistry of combustion, the reactivity series of metals, and the preparation and properties of gases. In the normal course of events, most teachers would probably use a variety of types of lesson during such a course, varying the order of practical and theory work in the lesson according to the topic being covered. In the experimental situation and attempt was made to be consistent with each group even if, under other circumstances, the teacher might have taught a particular lesson in another way.

To illustrate the differences in approach used with H. I and V groups, lesson plans follow for two of the lessons used in the course: the first is the demonstration of the fractional distillation of crude oil; the second involves a class experiment to prepare carbon dioxide.

Lesson 6: FRACTIONAL DISTILLATION OF CRUDE OIL

Previous work: melting and boiling, filtration, evaporation, simple distillation.

a) H APPROACH:

INTRODUCTION: Class discussion about useful things obtained from crude oil. Building up a list, from pupil suggestions, of main oil products. Discussion of problem of how to obtain these from crude oil. As most are liquids, the pupils eventually realise filtration or simple distillation will not be effective. Pupil (or teacher, if necessary with less able groups) suggests that if water boils at 100°C other liquids may boil at different temperatures. Could this idea be used to divide crude oil into petrol, diesel oil, etc.?

APPARATUS: Class help to design simple apparatus to heat oil gently, gradually raising temperature, collecting liquids boiling at different temperatures.

METHOD: Using apparatus (teacher demonstration because of unpleasant smell), a sample of crude oil is distilled to produce five fractions boiling at different temperatures. A sixth fraction is left in the apparatus.

RESULTS: Class asked to guess what each fraction is on the basis of its colour, viscosity and smell and to make predictions about how, if at all, it will burn. These ideas are then tested and the results recorded.

b) <u>I APPROACH:</u>

INTRODUCTION: Class told they are going to investigate crude oil using the kind of apparatus they have used before for distillation. They are asked to note appearance and smell of crude oil before the experiment begins.

APPARATUS: Distillation apparatus assembled. It is drawn by pupils.

METHOD: Class gather round teacher for the demonstration and told to watch what happens. They note vapour rising, bubbling and temperature changes as well as the colour and viscosity of distillate formed after each temperature rise.

RESULTS: After class has written descriptions of the fractions collected, the teacher burns a sample of each. Pupils note colour and size of flame, ease of ignition, amount of smoke and residue and use this information to identify fractions.

c) <u>V APPROACH:</u>

INTRODUCTION: Pupils told that petrol, paraffin, diesel oil, lubricating oil, fuel oil and bitumen are main components of crude oil and that these can be separated by using information about the different boiling points of these substances.

APPARATUS: Pupils draw and label apparatus.

METHOD: Teacher demonstrates distillation, stressing that fractions are being collected in order of ascending boiling points as stated in introduction.

RESULTS: Teacher demonstrates that fractions are indeed as stated by burning samples for the class to see the differences.

d) <u>HOMEWORK:</u> In all three aproaches pupils are required to take notes and to write a report of what happened in the lesson under the four subheadings used in the above lesson plans. Extension work is to find out about the use of the fractionating column in oil refineries and to note any differences between this and the method used in the lesson.

Lesson 19: PREPARATION AND PROPERTIES OF CARBON DIOXIDE

Previous work: reactivity of metals and the displacement of hydrogen from dilute acids by metals in the upper part of the series; simple gas tests.

a) H APPROACH:

INTRODUCTION: Discussion about reactions with acids. Do things other than metals react with acids? Pupils quickly test a range of powders (chlorides, carbonates, nitrates and sulphates) with dilute acids. Although some dissovle, only carbonates fizz to give a gas. What is this gas? Two or three (at least) ideas suggested: the gas is hydrogen from the acid or, as only carbonates react, it could be oxygen or carbon dioxide from the carbonate. Discuss the need to produce enough of the gas to collect in test tubes and test.

APPARATUS: Decide to use same apparatus as in previous lesson when making a quantity of hydrogen.

METHOD: Working in pairs, pupils assemble apparatus, prepare gas and test with lighted splint.

RESULTS: As lighted splint test shows gas is not hydrogen, second suggestion tested using glowing splint. As gas does not allow splints to burn, it is nitrogen or carbon dioxide, probably the latter. Test using lime water. Discussion of properties of carbon dioxide - demonstration of solubility in water to produce acid solution and of pouring on to lighted candle. Will anything burn in carbon dioxide? Test idea that it depends on reactivity by putting burning magnesium into carbon dioxide.

b) I APPROACH:

INTRODUCTION: Pupils issued with chemicals and dilute acids and asked to record what happens when acid added. This leads to the general observation that only carbonates 'fizz' when acid is added.

APPARATUS: Normal gas preparation apparatus given to each pair of pupils so that they can collect enough gas to test.

METHOD: Pupils prepare gas, collect over water and test with lighted splint.

RESULTS: Evidence from lighted splint and from teacher demonstration of tests with limewater, with litmus after dissolving in water, with burning candle and with magnesium suggests general rule that acid plus carbonate gives the gas known as carbon dioxide.

c) V APPROACH:

INTRODUCTION: Teacher informs class that carbon dioxide is prepared by action of acid on carbonates. The class is allowed to prove that only carbonates react with dilute acids by quickly testing a variety of labelled chemicals. Teacher gives instructions for collecting a larger sample of the gas.

APPARATUS: Gas preparation apparatus issued for pupils to work in pairs.

METHOD: Pupils pour acid onto marble chips, which they are told are made of calcium carbonate. They collect gas by displacement of water and test with lighted splint.

RESULTS: Teacher outlines and demonstrates properties: heavier than air, test with limewater, test with litmus after dissolving in water, burning magnesium.

d) HOMEWORK: All groups set homework asking them to write up their notes on the lesson and to write about the uses of carbon dioxide.

Although the class experiments performed by the pupils and the demonstrations used by the teacher were the same for all groups, there were differences in the way that the practical work was introduced and in the relationship between the practical work and the exposition or discussion part of the lessons. In theory lessons with no practical work it was still possible to preserve the differences in approach by references to historical examples and by the way in which evidence described by the teacher was related to the concepts being taught.

For example in the lesson concerned with atomic structure (lesson 14), the H approach was to consider possible theories about the shape and structure of atoms such as the 'plum pudding hypothesis' before proceeding to a description of Rutherford's gold leaf experiment as a test of such theories. In the I approach, the experiment itself was used as the starting point and Rutherford's results used as evidence upon which generalizations about atomic structure could be made. For the V approach, the lesson began with a simplified description of the Rutherford/Bohr atomic model and then the data from the experiment was used as proof that atoms are in fact like this.

The methods adopted in conducting the experimental teaching phase of the investigation were designed to make it as close as possible to the real situation in schools where several teachers with differing teaching styles may be following the same syllabus. As the factual content of the course was the same for all groups, common tests and a common end of year examination could be used as was normal in other subjects in the school. As well as giving the appearance of normality to the pupils and to teachers not directly involved in the experiment, this also made it possible to assess whether any of the teaching styles affected the ability of the pupils to recall the factual content of the course in the examination situation. As a comparison, scores obtained by the same pupils in the biology and physics examinations were also recorded.

6.1.3 Possible Criticisms

There is a variety of factors which can jeopardize the validity of teaching experiments. A comprehensive list of these factors is given by Campbell and Stanley (1963). The effects that such factors may have had on the present experiment are considered below.

The first variable mentioned by Campbell and Stanley is history, the events occurring between pre-test and post-test in addition to the experimental variable. In this experiment, as all the pupils belonged to the same school and were, with the one exception noted above, taught biology and physics by the same teachers, it would be difficult to assign any differences discovered to other specific events in their school careers. In particular, it should be borne in mind that the pupils were grouped differently for all the non-science subjects, so that whole groups could be affected only by what happened in the science lessons or what happened to all pupils in the year group.

The second variable to be considered is that of maturation, factors operating as a function of the passage of time. In so far as it is possible to assess these, such factors would be consistent for all the experimental groups. The pupils in all groups were members of the same year group and the length of time between pre-test and post-test was the same for all groups. In any case maturation is not likely to be an acceptable explanation for some groups improving on a test while others receive lower marks on retest.

The effects of the third extraneous variable are more difficult to assess. It is possible that being exposed to a pre-test could sensitize a subject so that he becomes more aware of the correct answers in a second testing. However Campbell and Stanley (op.cit.) point out that there is some evidence that subjects may do less well on retesting in some cases and that most of the evidence for a practice effect comes only from the use of tests of IQ or verbal reasoning. In this study, the pre-test was presented to the pupils as just one of a series of tests given them within the first week of joining the school. No more or less emphasis was placed upon it than might be given to any other twenty item multiple choice test they were given in other subjects or at other times, so there was little reason to suppose that it would have a particular sensitizing effect. As all the groups were given the same test at both pre-test and post-test stages, differences between groups could not be due to a sensitivity or practice effect. The sensitivity effect could have been serious if the experimental period had been a matter of minutes or hours rather than months, but with the length of time between pre-test and post-test the effect would in practice be small or absent.

Other factors also had little effect. There was no variation in the test or in the scoring used for pre-test and post-test so instrumentation is not a factor to be considered. Nor need problems of statistical regression or differential selection be regarded as a cause for concern as the groups were not selected on the basis of the pre-test scores. Experimental mortality was non-existent and could not be the reason for any differences between groups. The question of whether it is possible to generalize from the results of the experiment must remain open, particularly as only a single teacher was involved in the teaching. Nevertheless, the effects obtained were the result of a teacher taking normal classes in a school and the lesson content was unexceptional. If the differences reported below are accepted as being due to the different teaching approaches adopted by the experimenter with the five groups, then it is likely that the experiment has some direct relevance for classroom teachers.

6.2 The Pre-test Results

Within the two ability bands, pupils had been allocated to groups in such a way as to attempt to make the groups as similar as possible. The initial grouping was done on the basis of middle school gradings (Table 6.2) and also took into account the middle school of origin (Table 6.3). Final placings were confirmed after the pupils had been

Table 6.2 Distribution of Middle School Grades in Experimental Groups

GROUP	GRADE: A	B	C	D	TOTAL
AH	5	10	12	0	27
AI	5	10	12	0	27
AV	5	10	11	0	26
BH	0	0	14	14	28
BV	0	0	16	12	28
TOTAL	15	30	65	26	136

Table 6.3 Breakdown of Groups by Middle School of Origin

GROUP	MIDDLE SCHOOL: C	L	M	N	TOTAL
AH	8	10	4	5	27
AI	7	9	5	6	27
AV	9	9	1	7	26
BH	7	10	3	8	28
BV	7	10	3	8	28
TOTAL	38	48	16	34	136

tested on entry to the school. Three tests were given: the Gapadol Reading Comprehension Test (McLeod & Anderson 1973), the Vernon Graded Arithmatic-Mathematics Test (Vernon & Miller 1976) and an internally devised science test based on the content of the middle schools' science courses. Table 6.4 shows how the groups compared on these three tests. Comparisons of the test marks with the middle school gradings showed that there were strong positive correlations, all significant at the 0.001 level of probability, between the four measures of ability, but comparisons between the groups within each band revealed no significant differences.

Table 6.4 Entry Test Scores for Experimental Groups

GROUP	READING MEAN	READING PROB.	MATHEMATICS MEAN	MATHEMATICS PROB.	SCIENCE MEAN	SCIENCE PROB.
AH	43.4	0.29 ns	50.9	0.78 ns	36.8	0.28 ns
AI	41.0		50.4		35.2	
AV	40.2		49.3		34.6	
BH	25.6	0.38 ns	36.7	0.47 ns	28.5	0.88 ns
BV	27.9		38.0		28.8	
OVERALL	35.4	-	44.9	-	32.7	-

Although the five experimental groups were evenly matched within the bands by middle school gradings and had no significant differences in scores on the reading, mathematics and science tests, it was decided to pre-test all the pupils taking part in the experiment on the instrument to be used to assess their understanding of science at the end of the experimental teaching period. This was done to make possible a comparison for each group of the scores obtained before and after the experimental period. Without a pre-test it would have been necessary to assume that all groups would have equal scores before the teaching treatment was given. The test instrument was the Understanding Science Measure (USM), the development of which is described above in subsection 4.2.4. The complete test is printed in Appendix 7 and the pupil responses to the test items were scored as shown in Tables 4.20 and 4.21.

Scale OT was made up of the ten unchanged items from SUM (Coxhead & Whitfield 1975) and the PH, PI and PV scales were derived from the responses to the ten philosophical questions. The scores obtained by the groups on these four scales in the pre-test are shown in Table 6.5. If all the groups had been evenly matched, there would have been no significant differences between their scores on any of the four

Table 6.5 Pre-test Scores on USM

GROUP	SCALE OT MEAN	SCALE OT PROB.	SCALE PH MEAN	SCALE PH PROB.	SCALE PI MEAN	SCALE PI PROB.	SCALE PV MEAN	SCALE PV PROB.
AH	5.70	0.92 ns	3.44	0.22 ns	4.37	0.23 ns	1.81	0.002 **
AI	5.81		3.67		4.00		1.81	
AV	5.62		2.88		3.61		3.00	
BH	4.07	0.43 ns	2.25	0.31 ns	3.86	0.62 ns	3.00	0.93 ns
BV	4.43		2.64		3.64		3.04	
OVERALL	5.11	-	2.97	-	3.90	-	2.54	-

USM scales. There were no significant differences between the scores obtained by the two B band groups but group AV did score significantly higher on the PV scale than either of the other two A band groups. The mean score for group AV on this scale was similar to that obtained by the B band groups and such a finding illustrates the importance of conducting a pre-test, making it possible to detect changes which occur during an experimental period in spite of an unexpected difference present at the beginning between supposedly similar groups.

Two factors may have contributed towards the occurrence of this difference in scores on the pre-test. Although the three A band groups were apparently well matched for ability, taking into account the middle school gradings and the three tests given to pupils on entry to the school, group AV had a slightly lower mean on all measures. Correlations between the USM scales and the measures of ability (Table 6.6) showed that, while scales OT and PH were positively correlated, scale PV was negatively correlated with all the ability measures. It was possible that slight differences in ability had contributed to the unexpected group AV score on scale PV. The other factor was that group AV happened to have slightly more pupils from middle schools N and C but fewer from school M than did the other A band groups. Mean scores for school N pupils were consistently lower on all the tests of ability than for those from other schools although not significantly

Table 6.6 Correlations between Pre-test Scales

	SCALE OT	SCALE PH	SCALE PI	SCALE PV
GRADE	0.38***	0.14 ns	0.17 *	-0.25**
READING	0.44***	0.19 *	0.12 ns	-0.26**
MATHEMATICS	0.31***	0.26**	0.07 ns	-0.28***
SCIENCE	0.37***	0.20 *	0.09 ns	-0.25**

so. Thus the difference could have been a school effect either due to pupils receiving a different style of teaching in one school or to the school's grades not being exactly comparable with the grades from the others.

The difference between group AV and the other A band groups does not invalidate the experiment as the final results obtained by the groups on USM were compared with the pre-test results. Changes in the mean score of a group thus indicated that the experimental programme had either reinforced the views of those already biased, convinced those who were previously uncommitted, or converted those who had previously held other views.

6.3 The Post-test Results

6.3.1 Statement of Results

At the end of the experimental teaching period of just over two school terms, the five groups were retested using the same version of the Understanding Science Measure (USM) which had been used eight months earlier as a pre-test. The post-test was administered to the pupils during the period when they were taking their normal internal school examinations.

The main hypothesis being tested in the experimental teaching situation was Hypothesis 5 (see page 70). This hypothesis would lead to the predictions that:

a) there would be no significant differences in scores on scale OT between groups in the same band, but

b) there would be marked differences in the scores on the PH, PI and PV scales depending on the teaching methods that had been used with each group.

Table 6.7 Post-test Scores on USM

GROUP	SCALE OT		SCALE PH		SCALE PI		SCALE PV	
	MEAN	PROB.	MEAN	PROB.	MEAN	PROB.	MEAN	PROB.
AH	6.70	0.53 ns	5.63	0.001 ***	2.96	0.001 ***	1.22	0.001 ***
AI	7.11		2.19		6.44		1.22	
AV	6.65		2.73		3.23		3.69	
BH	4.54	0.06 ns	4.79	0.001 ***	2.86	0.72 ns	1.75	0.001 ***
BV	5.36		2.39		3.00		4.07	
OVERALL	6.05	-	3.55	-	3.69	-	2.39	-

The post-test scores on the four USM scales are shown in Table 6.7. These results did seem to conform to the predicted pattern. The differences in scores on scale OT were not significant, although that between groups BH and BV narrowly missed being significant at the 0.05 level. This difference was possibly due to slight variation in the ability composition of the groups (see Tables 6.2 and 6.4). The overall difference in mean between the A band and the B band indicated that scores on scale OT were related to ability.

The differences in scores within each band on the philosophical scales were highly significant. In both bands the group with the highest score on scale PH was the one which had received the hypothetico-deductivist teaching treatment. Similarly, the groups taught in the verificationist style had the highest scores on scale PV. Only one group, AI, had been given the inductivist treatment and this was the only group to score significantly higher than the others on scale PI.

However, as there had been a significant difference in the A band scale PV scores at the pre-test stage,a more careful analysis of these results was necessary. To establish that the post-test differences were due to the teaching programme it was necessary to show that there had been a change in scores over and above anything that could be accounted for by original dissimilarity between the groups.

6.3.2 Analysis of Variance

An analysis of variance and covariance was performed on the data using the ANOVA subprogram available as a part of SPSS. This method allows one to control for initial differences between groups when assessing the amount of variance due to a main variable. In this way it becomes possible to detect differences which might otherwise be masked by greater initial differences between groups exposed to an experimental treatment. In this case the main variable was the style of teaching treatment given to each group during the two term period of the experiment.

There was one complication in analysing the results of the teaching experiment. This was due to there being five groups and three treatments. Whereas there was an H group and a V group in each ability band, only the A band contained a group receiving the I type treatment. When analysing the results, it was possible to compare the effects of all three teaching treatments on the more able children, but only a comparison of the H and V treatments was possible over the full ability range.

Table 6.8 shows the results of using the SPSS ANOVA subprogram to analyse the sources of variance in the scores of the A band groups. The scores obtained by the pupils on scale OT in the pre-test had been

Table 6.8 Sources of Variance in USM Post-test Scores for A Band Groups

(showing percentages of variance and significance)

SOURCES OF VARIANCE	SCALE OT	SCALE PH	SCALE PI	SCALE PV	df
COVARIATES:					
Pre-test OT Score	7.3% *	1.4% ns	1.4% ns	1.0% ns	1
Pre-test P Score	-	6.4% ***	0.0% ns	29.7% ***	1
INDEPENDENT VARIABLE:					
Treatment	1.3% ns	53.6% ***	61.6% ***	27.1% ***	2
RESIDUE:	91.4%	39.4%	37.7%	41.4%	75

found to be positively correlated with all the measures of ability used to compare the groups, yet differences in the pre-test scores on this scale had no effect on the final scores on the philosophical scales over and above the effect of the pre-test scores on the philosophical scales themselves. As there had been some differences in the scores on the philosophical scales in the pre-test, particularly group AV scoring higher on scale PV and lower on scale PH than the other two groups, it was necessary to take these into account when looking at the post-test scores. Table 6.8 shows that differing pre-test philosophical scores was indeed a significant factor in determining the post-test scores on scales PH and PV. However, when this effect was allowed for by treating the initial differences as a covariate, the treatment effect on the post-test scores was still highly significant.

Table 6.9 Adjusted Means on USM Scales for A Band Groups

GROUP	SCALE OT	SCALE PH	SCALE PI	SCALE PV
AH	6.71	5.60	2.96	1.38
AI	7.09	2.10	6.44	1.37
AV	6.68	2.86	3.26	3.39
A BAND	6.83	3.53	4.23	2.03

Table 6.9 shows the adjusted means for each scale. The highest mean score for each of the philosophical scales is underlined. These means were adjusted to eliminate all the effects which could be attributed to initial differences in ability or in the pre-test philosophical scores. All the differences in mean score which remain can be attributed to the main variable, the teaching treatment.

Whereas the differences between the mean scores of the three groups on scale OT were small, on the philosophical scales the differences were marked. On scale PH the group which had received the H teaching treatment, group AH, had a much higher mean score than either of the other two parallel groups. The highest score on scale PI was achieved by the group given the I treatment, and group AV did best on scale PV. These results were in accord with the hypothesis that pupil understanding of the philosophy of science is affected by the philosophy of science implied by the teaching style adopted by their science teachers.

The teaching treatment appeared to have no effect on the group scores on the philosophical scales not related to the teaching method used. For example, if the scores of the AI and AV groups on scale PH are compared by an appropriate t-test, as described in Kirk (1968, pp 471-472), the difference is not significant. This is also true for comparisons between AH and AV groups on scale PI, and AH and AI groups on scale PV (t_{75} values are between 0.03 and 1.54). The more able pupils who made up the A band were able to recognize the responses to USM questions which corresponded to the philosophy of science implied by their teacher's approach to his lesson content.

A similar analysis was carried out to check the effect of a wider range of ability by considering the scores achieved by the H and V groups in both ability bands. The results of this analysis, shown in Table 6.10, indicate that scores obtained in the pre-test on scale OT

Table 6.10 Sources of Variance in USM Post-test Scores for H and V Groups

(showing percentages of variance and significance)

SOURCES OF VARIANCE	SCALE OT		SCALE PH		SCALE PV		df
COVARIATES:							
Pre-test OT Score	16.3%	***	0.4%	ns	0.0%	ns	1
Pre-test P Score	-		2.2%	*	16.0%	***	1
INDEPENDENT VARIABLES:							
Treatment	0.9%	ns	40.7%	***	32.7%	***	1
Band	11.6%	***	0.7%	ns	0.2%	ns	1
Treatment x Band	1.0%	ns	0.2%	ns	0.1%	ns	1
RESIDUE:	70.2%		55.1%		50.1%		103

did not have a significant effect on the post-test scores on either of the philosophical scales over and above the effect of the pre-test scores on the corresponding philosophical scales. However there was clearly a relationship between pre-test and post-test scores on scale OT itself. Even after adjusting for this relationship, it was the difference in ability as reflected in the banding of the pupils which accounted for most of the variation in the post-test scores on scale OT. The residual effect of the teaching treatment on this score was small and not statistically significant.

The reverse of that situation applied to the post-test scores on the PH and PV scales. Once the differences due to pre-test OT scores and to pre-test philosophical scale scores had been adjusted for, it was the effect of the teaching treatment that was significant. The band effect on the scores on the two philosophical scales was not significant. Most of the differences in scores on the PH and PV scales can be accounted for by the effects of the teaching treatment, irrespective of the pupils' ability band.

Table 6.11 Adjusted Means on USM Scales for H and V groups

CATEGORY	SCALE OT	SCALE PH	SCALE PV
H GROUPS	5.61	<u>5.20</u>	1.59
V GROUPS	5.97	2.56	<u>3.79</u>
A BAND	<u>6.49</u>	4.09	2.58
B BAND	5.12	3.70	2.77
ALL	5.79	3.89	2.68

As can be seen from the adjusted means in Table 6.11, there was little difference in scores on scale OT between pupils who had received the H or V teaching treatments, but the differences in scores on the philosophical scales are striking. The H groups had high scores on scale PH and low scores on scale PV. In contrast, the V groups had high PV scores and low PH scores. These differences were much greater than any effect which could be attributed to variation in ability between pupils in the two bands. As these means have been adjusted to take account of pre-test differences in both scale OT and the philosophical scales, the variation in scores shown in Table 6.11 cannot be attributed to those factors. In the case of the scores on scales PH and PV, the differences in mean scores are best explained by the teaching treatment received by the groups during the experimental period.

6.3.3 Interpretation of Results

The analysis of variance and covariance showed clearly that the differences between groups in the scores they obtained on the USM philosophical scales in the post-test were due mainly to the treatment they had received during the teaching experiment rather than to any initial dissimilarity between the groups. This was true both of the three-way comparison of groups in the A band and the comparison between the H and V groups across the whole ability range.

It could be argued that some of the changes which occurred during the experimental period had other causes: maturation; increased contact time with specialist science teachers; watching science-orientated television programmes recommended by teachers. Changes in score on scale OT from pre-test to post-test were not attributable to the experimental treatments and therefore could be due to such factors. All groups showed an increase in score on this scale of about one point out of the maximum of ten. The overall increase in mean score on the scale was from 5.11 on the pre-test to 6.05 on the post-test. This increase was somewhat greater than that reported by Powell (in preparation, see subsection 4.2.4 above) as the difference between year groups in his school. This would suggest factors other than maturation were involved with the experimental groups. In comparison with Powell's groups the post-test scores cannot be said to be unusually high; rather the pre-test scores were low. This might indicate that their science experience in the middle schools had placed the pupils in the experimental groups at some disadvantage because they had not been taught by graduate scientists until entering the high school at the age of 13+. After two terms of being taught by specialist science teachers their awareness of what science is had increased so that they were then achieving scores on scale OT comparable with those who had transferred to the secondary sector at an earlier age.

The changes in the scores on the philosophical scales cannot be explained in this way. They could not be due simply to maturation or to an increased awareness of 'things scientific'. Although the change on the PV scale for groups AV and BV amounted to an increase of one point or less on average, in the H and I groups the increase was over two points and always in the expected direction. As the adjusted means in Tables 6.9 and 6.11 show, all groups achieved their highest scores on the scale which corresponded to the style of teaching they had experienced. The pattern of results is striking, particularly as Table 6.11 shows the effect occurred throughout the ability range.

An increase in scores on any of the philosophical scales must be accompanied by a corresponding decrease in scores on the other two philosophical scales. The experimental groups were influenced in different ways during the period of the teaching experiment and this produced changes in the way the groups responded to the philosophical questions on USM. Groups given the H treatment achieved higher PH, and lower PI and PV, scores on the post-test than they had obtained on the pre-test. For those subjected to the V treatment it was the PV scores that increased while PH and PI scores declined. Only the group receiving the I treatment showed an increase in its mean score on scale PI. While some groups showed an increase in their mean scores on a particular philosophical scale, other groups exhibited a declining score on the same scale. As the scores of the groups changed in different directions on the three philosophical scales, and the direction of any increased always corresponded to the teaching style experienced by the groups, the simplest explanation which accounts for the changes is that the experimental treatment did have the predicted effect on their responses to the questions in the post-test.

Another way of showing the effect of the teaching treatment on the way pupils respond to USM is to compare the internal consistency reliability estimates for the four scales in the pre-test and the post-test. In all cases the reliability was higher for the post-test than for the same scale on the pre-test (Table 6.12). There was some increase in the reliability of scale OT, which consisted of the non-philosophical items retained unchanged from SUM, but this was not great and can be taken as a base line for assessing the increases in the reliabilities of the other three scales. The increases in the

Table 6.12 Reliability Coefficients for USM Scales

SCALE	PRE-TEST	POST-TEST
OT	0.37	0.42
PH	0.27	0.57
PI	0.22	0.54
PV	0.28	0.55

reliability estimates for the three philosophical scales far exceeded that for scale OT. The relatively low coefficients obtained for the philosophical scales in the pre-test show that many pupils were incapable of selecting a set of coherent answers and may even have been answering at random. The higher internal reliability estimates obtained from the post-test results show that the pupils at that stage were more consistent in their responses to questions and were more likely to accept, or to reject, a coherent set of responses to the philosophical questions.

This increase in the coherence of pupil responses can be seen as another measure of the effect of the teaching treatments. Giving groups a variety of treatments polarised their viewpoints so that at the end of the experiment they were more able to recognize a response as belonging to a certain view of science or to reject it as being inappropriate.

6.4 Some Other Effects

6.4.1 Effects on School Examination Results

When the experimental teaching situation was planned, it was decided that the main measure of pupil understanding of the philosophy of science was to be the USM and this was to be used in both the pre-test and the post-test. It was also a possibility that the teaching treatments might affect performance in the school's science examinations and it was therefore planned to monitor the pupils' marks in biology, chemistry and physics at the end of the year to see if this was the case.

The mean scores obtained by the groups in their end of year science examinations are shown in Table 6.13. As might be expected, the pupils in the A band achieved consistently higher marks in the

Table 6.13 End of Year Science Examination Marks

GROUP	NUMBER IN GROUP	MEAN PERCENTAGE SCORES: BIOLOGY	CHEMISTRY	PHYSICS
AH	27	49	59	56
AI	27	54	60	56
AV	26	53	61	55
BH	28	31	42	44
BV	28	40	52	43
A BAND	80	52	60	55
B BAND	56	35	47	43
ALL	136	45	55	50

examinations than did those in the B band. One would not normally expect large differences between groups within the bands, but there did appear to be differences between the biology and chemistry scores of the B band groups which were significant ($p=0.007$ and $p=0.002$ respectively).

Three possible explanations suggested themselves for these differences: group BV had a different biology teacher from all the other groups; group BV was initially a slightly better group; the V style of teaching was more effective in conveying factual information. The first explanation alone would not explain the differences in both biology and chemistry marks, and was for that reason rejected. However the biology teacher of group BV was the experimenter and he used the V teaching style with that group both in his biology and in his chemistry lessons with the group. The normal biology teacher used an approach more akin to the I style, so the difference was more likely to be due to teaching style rather than to the group having a different teacher per se.

There had been some differences between the groups in the scores they obtained on the original measures of ability and so an analysis of variance and covariance was carried out on the science examination marks using the scores on the original reading, mathematics and science tests as the covariates. When the results for the A band groups were analysed alone all the variation in the end of year examination marks seemed to be attributable to initial differences in ability, particularly those on the mathematics and science tests. The teaching treatment appeared to have no discernible effect. A rather different result was obtained when the results of the H and V groups across the full ability range were analysed (Table 6.14).

Table 6.14 Sources of Variance in Science Marks for H and V Groups

SOURCES OF VARIANCE	BIOLOGY	CHEMISTRY	PHYSICS
COVARIATES:			
Reading Score	p=0.001***	p=0.005 **	p=0.26 ns
Mathematics Score	p=0.02 *	p=0.008 **	p=0.001***
Science Score	p=0.006 **	p=0.005 **	p=0.001***
INDEPENDENT VARIABLES:			
Treatment	p=0.001***	p=0.001***	p=0.46 ns
Band	p=0.75 ns	p=0.32 ns	p=0.90 ns
Treatment x Band	p=0.77 ns	p=0.47 ns	p=0.46 ns

Apart from the reading score not having a significant effect on the physics examination marks, the variation in initial ability did account for some of the differences in scores on the science examinations. Once the ability measures had been taken into account, there was no residual effect due to the banding but there was a significant effect due to the teaching treatment for both biology and chemistry. The absence of effect on the physics scores is explained by there having been only one teacher involved in the physics teaching. In biology, the experimenter had taught one of the groups concerned using a style of teaching different from the teacher of the other groups. In chemistry, the teaching style was changed for each group. This analysis seemed to indicate that the teaching treatment could have some effect on marks in science examinations after allowance had been made for initial variations in ability between the experimental groups. Furthermore it appeared to be the groups which had received the V treatment that had the advantage (Table 6.15).

Table 6.15 Adjusted Means on Science Examinations for H and V Groups

CATEGORY	BIOLOGY	CHEMISTRY	PHYSICS
H GROUPS	39.5	49.6	49.4
V GROUPS	46.7	57.3	48.3
ALL	43.1	53.4	48.9

This is not as surprising as it might at first appear. School examinations tend to be content orientated and V type teaching stresses the course material itself rather than the scientific processes used to establish the factual content. Indeed other workers (e.g. Lynch 1978) have shown that there is no relationship between the amount of practical work experienced by pupils and their subsequent examination grades.

Before the start of the experiment, the author had feared that pupils might suffer because of the teacher not being free to adopt what he might consider to be the best teaching technique for each topic in the course. Overall, however, the chemistry examination marks were slightly higher than had been the case in previous years, when the same examination had been used. Both the biology and physics marks were lower than previous years. It would not appear that the pupils did suffer in terms of examination marks by being participants in the experiment, which could affect only the content of the chemistry lessons.

The fear that those pupils given the V treatment would be at a disadvantage was certainly unfounded. The adjusted means shown in Table 6.15 indicate that, after initial differences are allowed for, strong V type teaching may be more effective when the final examination consists mainly of factual recall questions.

6.4.2 Effects on Pupils' Vocabulary

The three science examinations were content based with a high proportion of recall type questions. The biology and physics papers consisted entirely of multiple choice and short answer questions, but the chemistry paper also included some questions requiring longer answers. In answering these questions, pupils had to describe experiments they had performed or seen demonstrated earlier in the year. In a few answers to these questions an interesting effect was noted. Most of the pupils answered the examination questions in an impersonal way by using the passive mood but a few, particularly the less able, wrote in a narrative style. It was the second type of answer which revealed interesting differences between pupils who had been taught in the H, I or V style.

Pupils who had been given the H treatment sometimes began their accounts of experiments by stating a problem. Three examples of this follow:

> We have a problem on our hands and that is ...
> We have got a problem about how to ...
> The problem is to separate all the components.

The teacher's way of introducing practical work seemed to have influenced the way in which these pupils thought about the experimental situation and the vocabulary they used to describe it. Thus pupils from the H groups referred to the need for having a hypothesis to direct their experiments even though they did not know the word itself:

> Before we do enthing (sic) we make a prediction ...
> We have come up with an idea of how to do this.
> Well, we had an idea.
> We thought of many ideas for this experiment.

The last example above showed an awareness of the possibility of having more than one solution to a problem and of having to decide on the best one. There was therefore some awareness of experiments being used as a test of ideas:

> Conclusion: My idea for the experiment worked.

In contrast to the style of writing noted above, the pupils who had been in the V groups seemed to adopt a more matter-of-fact style of writing:

> When we buy a bottle of ink we are really paying for a lot of water, because all ink is, is a coloured dye (either blue, black, green or red) added with some water. This experiment will show you how to split up those colours in ink ...

The V type pupils also saw results as leading to definite conclusions. It can be seen that they expected experimental results to prove something:

> To prove that carbon dioxide was produced we placed some limewater in the test tube ... the limewater went milky - carbon dioxide was produced.
>
> This experiment proves that ink is not a single substance.
>
> The above experiment proves that CO_2 is heavyer (sic) than air and also that it doesn't support combustion.
>
> ... so we proved that we had carbon dixide (sic).

The third group of pupils, those who had experienced the I style of teaching, seemed in some cases to be less certain of what their evidence proved but they were at pains to write about their actual observations. Also to be noticed in their accounts was the absence of any prior expectations. What they observed seemed always to take them by surprise:

> We saw that water was beginning to rise up the blotting paper and was taking the ink with it ... We noticed the different colours had separated into all different colours as it rose.
>
> You will find bits of salt on the filter paper.
>
> After a long time the liquid had gone down and steam was coming off vigourously (sic). At the end of the heating we found we were left with pure salt.

Only the descriptions of experiments by pupils who had been in the I group expressed this sense of wonder or surprise at seeing fairly routine things.

The way in which pupils wrote about experiments they had done earlier in the year could have been influenced by the way they had been taught, in particular by the way in which the experiments had been introduced. The H groups had been faced with problem solving situations and encouraged to think of more than one possible answer. The I group had been told to look carefully at what happened in any experiment, while the V groups were more likely to have been told that things were 'really like this'. When writing their examination answers the pupils knew these would be marked by the teacher who had taught them and it was possible that they wrote in a style which they believed he would find acceptable.

Even though it was a strong possibility that pupils were merely trying to please their teacher another explanation for their styles of writing about experiments was considered. This was the possibility that the teaching treatment had produced a more wide ranging effect on the vocabulary used by the pupils when describing scientists or scientific activities. From the limited evidence in the answers to questions in the chemistry examination, it might be predicted that pupils from the H groups would be more likely to use words such as 'problem', 'idea' or 'test' when describing the activities of scientists than would pupils from the other groups. Those from the I group might more often refer to scientists looking at or observing things and then noting them down. With pupils from the V groups one might expect extensive use of the words 'proof' and 'prove' together with the inclusion of more factual information for its own sake.

The testing of these predictions concerning differences in vocabulary was attempted with the cooperation of an English teacher who taught some of the pupils involved in the experiment. The pupils were given the chance to write a science fiction story. They were given no guidance about plot but were asked to make the scientists in the story behave as would real scientists if faced with the situations described.

Over a half of the pupils in the experiment wrote stories, many of which were based on characters or plots from television series, so there was little evidence that science lessons in school had affected the kind of stories they chose to write. A simple count of the number of times certain words or phrases appeared in the stories revealed some interesting differences between pupils who had received the three teaching styles in the experiment (Table 6.16).

Pupils who had been exposed to the H style of teaching used words such as 'idea', 'think', 'thought', 'problem', 'question', 'test', 'testing', 'check' and 'clues' more often than did those who had been in the I or V groups. Pupils from the I group seemed to favour words such as 'record', 'recording', 'noted', 'sample', 'specimen', 'notice', 'look', 'observations', 'information', 'discovery', 'theory', 'pattern' and 'conclusion'. They also mentioned the use of computers and scientists needing months or years of research to complete their work. All mentioned experiments frequently but pupils from the V groups more often said that they 'prove' something. They also mentioed 'measurement', often with numbers quoted, and more often described and named fictional apparatus. The mention of specific chemicals by name was three times more common in the stories of pupils from the V groups.

Table 6.16 Word Use Frequency in Science Fiction Story Writing

WORD OR PHRASE	H GROUP N=27	I GROUP N=26	V GROUP N=25
Experiment(s)	11	10	12
Idea/think/thought	20	6	-
Test(ing)/check	17	17	6
Problem/question	10	4	-
Clues	4	-	-
Observations	-	16	-
Notice/look	-	9	-
Conclusions	-	5	-
Record(ing)/noted	-	18	2
Pattern	-	6	-
Information	-	5	1
Discovery/theory	2	8	1
Evidence	-	3	-
Computers	4	14	8
Sample/specimen	3	8	3
Months or years of work	1	5	-
Prove/proof	2	3	7
Measurement/number/figures	9	7	15
Apparatus (usually by name)	12	10	22
Chemical by name	9	11	32

These results provided some support for the evidence obtained from the chemistry examination scripts. As the frequency of use of certain words varied in the science fiction essays outside the context of science lessons, this suggests that the effects of a teaching technique may extend beyond the immediate context of a single subject and teacher. The varaiation in word use frequency in the stories could not be explained by pupils trying to please a particular teacher. Rather it seemed that the teaching style to which they had been exposed during the experiment had changed their conceptions of what it is a scientist does and how it is that he does it.

It cannot be said that this effect, if indeed it exists, was investigated systematically. Nor were the results from the story writing analysed carefully. The groups writing the stories did not contain all the pupils from the teaching experiment and were not matched for ability, so no great reliability is claimed for these findings. Nevertheless the differences found were of interest and point to and area worthy of further research.

6.4.3 Effects on Pupils' Subject Choice

The results concerning changes in pupils' vocabulary suggested that the teaching experiment might have affected the way in which pupils viewed the activities of scientists. This in turn could have had an effect on the pupils' attitude towards their school science subjects, particularly chemistry as this was the subject in which they had experienced the biased teaching styles.

In this country there is a relatively simple way of assessing pupils' attitudes towards a school subject. At the age of fourteen, they are usually given some choice of subject courses to be followed for the two years leading up to their GCE or CSE examinations taken at the age of sixteen. They may be influenced in this choice by examination marks and advice from parents, friends or careers teachers, but one factor which undeniably affects their choice is their own view of the subject itself. If a pupil has enjoyed the lessons and the way in which a subject is presented previously, then he is more likely to continue studying the subject than if the reverse is true.

A study was made concerning the subject preferences of the pupils who had taken part in the teaching experiment. In the school where the experiment was conducted, all pupils had to follow two science courses chosen from the following: Biology, Rural Science, Chemistry, Physical Science, Physics and General Science. As no pupil could study three sciences, those who wished to do so were advised to choose Biology and Physical Science, the latter being a combined chemistry and physics course. Soon after the publication of the school science examination marks, the pupils were asked to state their preferences by indicating which two courses they would have chosen had a decision been needed at once. An indication of the effect that different styles of teaching may have can be seen in the numbers stating a preference for Chemistry or Physical Science as a possible course for their next two years in the school. Table 6.17 shows the number of pupils in each group expressing a preference for these subjects at the end of the experimental period.

Table 6.17 Subject Preferences in Experimental Groups

GROUP	NUMBER IN GROUP	NUMBER WANTING TO STUDY CHEMISTRY	NUMBER WANTING TO STUDY PHYSICAL SCIENCE	TOTAL WANTING EITHER COURSE (%)
AH	27	17	6	85%
AI	27	14	8	81%
AV	26	7	7	54%
BH	28	3	5	29%
BV	28	10	4	50%

As the science examination marks show (Table 6.13), there was no reason for pupils in group AV to feel that they were any less able to continue their study of chemistry than pupils in the other A band groups. A possible explanation for fewer pupils in the AV group wanting to continue with chemistry is that they failed to find the teaching method stimulating.

It was not surprising to find that chemistry was less popular with pupils in the B band as it tends to be a subject which appeals more to able children. The difference between the two B band groups is harder to explain, but it could be due to differences in their examination results. Group BV had better mean chemistry marks than group BH and, if these pupils were not doing well in most subjects and did not particularly like any of them, they might have been influenced to choose a subject in which they had obtained slightly better marks.

Almost certainly the opinions given by the pupils at this stage represented their personal preferences, but they were then subjected to pressure from the school and from their parents to choose combinations of subjects appropriate for their abilities and careers intentions. Such pressures can change a pupil's choice of courses radically and the extent to which a pupil is able to resist these pressures may be seen as a measure of the strength of his original preferences. For this reason it seemed desirable to compare the original preferences of the pupils with the subjects they eventually selected. As shown in Table 6.18, the final choice of subjects was very similar to the preferences stated earlier by the pupils.

Table 6.18 Numbers Choosing Fourth Form Science Courses

GROUP	BIOLOGY OR RURAL SCIENCE	CHEMISTRY	PHYSICAL SCIENCE	PHYSICS	GENERAL SCIENCE	% CHOOSING CHEMISTRY OR PHYSICAL SCIENCE
AH	12	16	6	20	-	81%
AI	13	14	8	19	-	81%
AV	15	8	8	21	-	62%
BH	21	6	2	22	5	29%
BV	20	8	4	20	4	43%

Biology and Rural Science are shown together in Table 6.18 as no pupil could follow both courses. The higher numbers for these courses in the B band are due to the popularity of the Rural Science course with the less academic pupils. The General Science course was also intended for lower ability pupils. Physics, because of its supposed career inportance, had a strong appeal across the full ability range. The only unusual aspect of the pattern of final choices was the small number of pupils from group AV choosing Chemistry. The differences between other groups were reduced because of the similarity of advice given to all pupils.

Although most of the observed differences were not great enough to be judged significant when subjected to a chi-squared test, that which was found between the preferences expressed by groups AH and AV was significant at the 0.05 level of probability. While it must be said that the numbers involved were small and the teacher used a style of teaching which might be more extreme than that experienced by most pupils, this does provide some evidence that V type teaching deters more able pupils from continuing with a subject.

The School Science Survey questionnaire showed that V type teachers were the most common extreme type. In their interviews they made it clear that they used this style of teaching, particularly with the more able pupils, in order to cover the requirements of the examination syllabus. It is possible that the very approach adopted by teachers seeking to produce the greatest number of pupils with science qualifications may also be the one likely to drive them away from the subject entirely. If these longer term effects concerning pupils' attitudes to science and their willingness to continue studying it do exist as these results suggest, they are of greater practical significance than the immediate effects measured by use of USM and may therefore merit further investigation.

SUMMARY OF CHAPTER 6:

Five groups of pupils were given chemistry lessons by a teacher who used three different extreme teaching styles:

H type teaching: hypothetico-deductivist problem solving style, using practical work to test predictions and pupils' ideas.

I type teaching: inductivist enquiry based style, using practical work to encourage pupil observation.

V type teaching: verificationist style based on transfer of factual information, using practical work to demonstrate truth of factual content.

The Understanding Science Measure (USM) was used to test pupils before and after the two term experimental period. Pupil scores on the philosophical scales of USM changed from pre-test to post-test. In all cases a group's highest mean post-test score was on the scale corresponding to the teaching style used with the group. This effect was not dependent on ability or pre-test scores and indicates that pupils' understanding of the philosophy of science can be influenced by their teacher's implied philosophy of science.

Some evidence was also found that teaching style could affect:

a) pupils' performance in science examinations,

b) the vocabulary they use to describe scientific activities, and

c) their subsequent decisions about continuing to study science.

It was suggested that these effects might deserve further study.

CHAPTER 7:

REVIEW AND DISCUSSION

This study began with definitions of three distinct philosophical standpoints relating to the methodology and nature of science. One was the hypothetico-deductivist position outlined in the published writings of Karl Popper (1968, 1969, 1972). The second was the inductivist view of science, based on the Novum Organum of Francis Bacon published in 1620, a viewpoint of some antiquity which has led to many attempts to provide a logical justification of the inductive process of generalization. Lastly, the verificationist standpoint was derived from, although not perhaps identical with, that advanced by the logical positivists (e.g. Ayer 1971) who saw the verification of scientific knowledge by sense data as being the basic kind of proof on which any guarantee of the truth of scientific facts must rest. These three philosophical standpoints were termed the H, I and V positions respectively.

Initially the three views of science were advanced on purely theoretical grounds with no evidence that they corresponded to sets of opinions or attitudes actually held by anyone involved in science education. However two hypotheses were advanced (see section 3.3) which related to science teachers and their views on the philosophy of science:

Hypothesis 1: Science teachers in schools have some understanding of the philosophy of science.

Hypothesis 2: Teachers differ in the philosophy of science to which they subscribe.

As a first attempt to collect some evidence relating to these hypotheses, a pilot questionnaire was circulated to a small group of science teachers. Two sections in this questionnaire (see Appendix 1) probed the teachers' beliefs about the nature of scientific activities and their views about the use of practicals and demonstrations as teaching techniques. Factor analyses of the patterns of responses to these two sections (see subsection 4.1.2) gave some support to the threefold model originally proposed as patterns of responses corresponding to the three divergent philosophies emerged both in the section dealing with the use of practical work in the teaching situation and in the section investigating the teachers' more overt understanding of the philosophy of science.

Further development and refinement of the test instruments followed and it became clear that the investigation required the use of tests different in kind from those previously published. TOUS (Cooley & Klopfer 1961) and SUM (Coxhead & Whitfield) are well known and widely used to test understanding of science, and both are scored on the assumption that the hypothetico-deductivist philosophy is the correct one. An underlying assumption of the second hypothesis in this investigation was that some people would hold other philosophies to be equally or more acceptable. The reliability of the tests being developed seemed low in comparison with TOUS and SUM. It was thought that this could be because respondents found it especially difficult to select a coherent set of answers when the alternatives represented different philosophical viewpoints. It was considered that the high reliabilities of published tests could be due in part to their unidimensional nature.

At this point in the investigation it seemed necessary to test a subsidiary hypothesis of limited scope:

Hypothesis 6: It is possible to construct a test to measure understanding of the inductivist philosophy of science.

In testing this hypothesis, SUM was modified so that in the ten philosophical questions inductivist 'correct' answers were substituted for the usual hypothetico-deductivist ones. This modified version of SUM was called the Understanding Science Test (UST) and was administered to school children of secondary age. The results showed it was possible for an inductivist test to have an internal consistency reliability estimate which compared well with tests such as SUM or TOUS. As it is unlikely that the children who completed UST were all confirmed inductivists while all those who were involved in the trials of SUM were hypothetico-deductivists, the results obtained made it clear that a unidimensional test would not serve the purposes of this investigation.

As the three views of science are not strict logical alternatives but represent distinct perspectives upon basically similar events, the assumption that teachers would fit tidily into predetermined categories was abandoned and it was accepted that many would lack a clear and coherent philosophy of science that was based on careful thought or wide reading. The teacher questionnaire was therefore redesigned to sample opinions rather than to test knowledge. The format adopted for the final version of the School Science Survey questionnaire (see Appendix 4) did not prevent those with extreme views from selecting a set of opinions corresponding to one of the three defined philosophical positions, but it also allowed the uncommitted to remain so rather than forcing them to make choices they did not recognize as valid.

The third of the main hypotheses underlying this investigation was:

Hypothesis 3: It is possible to identify teachers who subscribe to the extreme philosophical positions.

By use of the School Science Survey questionnaire, a small number of teachers was selected on the basis of their pattern of responses. The questionnaire allowed considerable freedom to respondents in selecting a pattern of statements which corresponded to their own views. Two teachers of each extreme type were selected for interview. In each interview, the views expressed by the teacher about his philosophy of science corresponded to those that would have been predicted from his pattern of responses on the questionnaire. Although the total number of interviews was small, they did provide some support for the belief that it would be possible to identify teachers with certain extreme philosophical viewpoints by using questionnaire techniques.

The interviews also provided evidence which had some bearing on the fourth hypothesis:

Hypothesis 4: The teaching style of an individual who holds an extreme view of the philosophy of science is affected by this.

As a part of the interview, each of the selected teachers was asked to describe his normal teaching methods. In particular the question of how the teachers related theory and practical work was of interest. Although the sample size was small, it was nevertheless stiking that all those interviewed described teaching styles which could be said to correspond to their philosophical beliefs. This finding was of great interest because of the lack of previous evidence connecting teaching method with underlying philosophical beliefs.

The threefold classification of teachers which had been proposed on theoretical grounds and which found some support in the questionnaire and interview results had an interesting parallel. By use of the Science Teacher Observation Schedule or STOS (Eggleston et al. 1975), Galton and Eggleston (1979) came to the conclusion that science teachers fell into three groupings or 'types' which were sharply differentiated from each other by having distinct teaching styles. Their three styles of teaching may be summarized as follows:

Type I: Problem Solvers - used a teacher dominated style of teaching, asking questions that had to be answered by constructing hypotheses, stating problems but putting little emphasis on informational aspects of science. These teachers put the emphasis on science as a problem solving activity.

Type II: Informers - did not ask many questions except those demanding recall or applications of facts and principles. These teachers made many statements of fact, introduced problems requiring convergent thinking and had a non-practical teaching bias.

Type III: Enquirers - used a highly child-centred approach with much pupil-initiated and maintained behaviour directed towards experimental work.

Although the classification used here does not correspond exactly to that proposed by Galton and Eggleston (1979), the similarities are sufficient to suggest that further work in this field might be profitable. The problem solvers may adopt an approach which corresponds to that of the H type teachers in encouraging pupils to put forward hypotheses as possible solutions to problems which have to be subjected to experimental testing. The similarity between the informers and the V type teachers lies in the emphasis on factual content and their non-practical bias. Although the parallel is less close, there may be some correspondence between the enquirers and the I type teachers. Both adopt a less teacher dominated style with more pupil control of activities, the I type teacher in particular avoiding the introduction of hypotheses to focus and direct the observations of the pupils.

Extreme I type teachers were found to be rare in the sample studied and Galton and Eggleston (op.cit.) also report that their Type III style of teaching was not used by a high proportion (18%) of the group they investigated. It is possible that the 'enquirers' category would include those teachers who would have been classified as HI (or not-V) in the present study (see pp 142-143). These may adopt a process-orientated approach, rather than a fact-laden one, without being extreme H or I types.

It is possible that the philosophical basis of this study would also provide a rationale for understanding the observed differences in teaching styles of science teachers. However the present investigation followed a somewhat different line. Although it has been claimed (Steller 1977) that pupils have some intuitive knowledge of scientific method, it is clear that training in enquiry techniques can improve this understanding (Peterson 1978, Bluhm 1979, Pappelis et al. 1980). What may not always be realised is that teachers could affect pupils' views on the philosophy of science without a conscious intention so to do. There is little doubt that pupils do believe that there is a connection between what they do in science lessons and what is done by real scientists in spite of warnings that teachers should not set out to mislead them into believing that they are carrying out scientific investigations when they are simply learning about science (Kyle 1980). This line of thought led to the last of the five main hypotheses in this study:

Hypothesis 5: Pupil understanding of the philosophy of science is determined by their teacher's implied philosophy of science.

Other studies of the effects of differing teaching styles (e.g. Heaney 1971) have been complicated by the differences between schools and the variety of pupil backgrounds. Rather than study the effects of extreme H, I and V type teachers on their own pupils, the experimenter attempted to duplicate their teaching styles himself within one school so that as many variables as possible, including the personality of the teacher conducting the lessons, could be kept constant for all pupils taking part.

It must be admitted that this choice of experimental design may have resulted in a somewhat exaggerated effect as the teacher, knowing himself to be in an experimental situation, adopted a more consistent approach to his subject matter than is probably the case in reality even with the naturally extreme individuals identified by the School Science Survey questionnaire. Even so, the techniques adopted in the lessons during the experimental period were not so extreme as to be beyond the range of what has been reported when other workers (Galton & Eggleston 1979, Hacker et al. 1979) have observed science teachers at work in their own classrooms in a non-experimental situation. Nor were the approaches used anything other than those described by the extreme H, I and V type teachers themselves in their interviews.

Previous research has concentrated on the effects of teaching style on pupil attitudes or attainment rather than looking for possible effects on their beliefs concerning the philosophy of science. The main original contribution of this study has been to provide some evidence that a teacher may affect his pupils' views of science not by teaching a philosophy of science to them in an explicit fashion but by implying that he holds certain philosophical beliefs by the way in which he teaches the subject matter in a normal school science course. The results obtained with the Understanding Science Measure (USM) at the end of the teaching experiment showed that effects of this kind can be produced by variations in teaching style which could be within the range that occurs in normal science lessons.

For those who regard science as providing a useful source of knowledge for technological application, this concern about pupils' understanding of the philosophy of science may seen inappropriate or unimportant but a lack of understanding can have more far reaching consequences. Throughout this study an attempt has been made to regard the three philosophies as real alternatives but informed opinion would be that the verificationist view with its emphasis on fact is naive and simplistic, the inductivist view underplays the role of theory in guiding future research and that the hypothetico-deductivist view is nearest to being an accurate representation of the scientific method. Even this representation may be merely of limited application and part of another alternative view (Kuhn 1970). The real cause for concern is that an inadequate or outdated view of science may have serious practical consequences. The philosophical misunderstanding in such circumstances may serve to explain other, apparently unconnected, observations.

It is a cause of some concern that pupils in this country find science subjects difficult and in some cases cease studying science long before completing the compulsory stage of education. Even the curriculum reforms which have taken place in the last twenty years do not seem to have had the desired effect of producing new generations of children more committed to science. If the connection between the philosophical bases of teaching styles and pupil beliefs about the philosophy of science is accepted then it may have some bearing on this problem and may give rise to some suggestions which would affect aspects of the science education policy of the future.

The first formal teaching of science that pupils receive is the most important in determining their interest in, and attitudes towards, the subject (Harvey & Edwards 1980), and yet the Dainton Report (1968) noted the concentration of graduate teachers

> ... on the later years of the course (and hence on pupils already committed to science) while at the same time critical decisions for or against science and technology (whether articulated or not) are made in the early years between the ages of 10 and 13. Much of the science teaching to which pupils are exposed in these crucial years would appear to be done by non-graduate teachers and to some extent by teachers not qualified in science. (op.cit. p 46)

Whether one sees science mainly as a contribution to the cultural background of future citizens (Koelsche & Morgan 1964) or as a basis for the training of future engineers and technologists, as did the Dainton Report, the concern over pupils giving up the study of science remains. The evidence from the teaching experiment (see Chapter 6) may provide a reason for suggesting that the teacher's level of qualification in science may not be the only factor which influences the pupils' reactions to his lessons.

Perhaps headteachers and heads of department should pay more attention to the teaching style of staff teaching the younger pupils and be less concerned about the factual content of their schemes of work. One problem is that teachers usually practise their craft in isolation from their colleagues and tend to resent any criticism of the teaching style they adopt. There is certainly disagreement about the main reasons for the use of practical work in science courses. Many teachers, particularly those classified here as V types, use practicals to reinforce practical knowledge (Gonzalez & Gilbert 1980), but there is little doubt that pupils expect to carry out experiments partly as means of finding out how scientists work (Hofstein et al. 1980). Differences in views about the use of practical work between the H, I and V type teachers do seem to have an effect upon their pupils' perception of the nature of science and the activities of scientists. Without a conscious intention to do so, science teachers determine whether pupils see science as an interesting and ongoing activity or as a mainly static body of knowledge.

In the sample of teachers studied the extreme I type was rare. It is therefore the H/V spectrum of opinion and practice that must give rise to the greatest concern. By placing cognitive objectives highest in importance (Schibeci 1981), many teachers leave the determination of pupil attitudes to science as well as their beliefs about the philosophy of science to chance. It is suggested here that an important factor involved in the determination of attitudes as well as beliefs is the philosophy of science implied by the the teaching style adopted.

The numbers of pupils continuing to study chemistry by choice after completion of the teaching experiment was used as an approximate guide to the effect of the three teaching styles on the attitudes of the pupils towards science. Although the results were only just significant, they did indicate that more able pupils might be discouraged from further study by a strong V type teaching style. This result highlights another similarity between the V type approach and that of the 'informers' in the Galton and Eggleston (1979) study. They found that pupils taught by this type of teacher

> ... were invariably the ones with the poorest attitudes at the post-test,

and they state that

> there were grounds for suggesting that the teacher-directed, didactic approach of the 'informing style' was by far the least effective of all the three types. (op.cit. p 82)

Such results seem to suggest that the V type teacher not only gives his pupils a distorted view of the nature of science but also is a cause of them rejecting what they believe science to be. The problems highlighted in the Dainton Report may need to be resolved in ways other than that of producing more science grauates and encouraging them to enter teaching. The problem may involve the retraining of teachers and graduates entering teaching to make them see science in a different light. The prevalence of the V type teacher, the commonest of the three extreme types found by the teacher questionnaire, may lead one to conclude that a high proportion of those who continue to study science successfully must be those who are willing to accept this view of science and then pass it on to yet another generation of pupils if they become teachers.

Attempts to break this cycle by the introduction of new curriculum materials have met with limited success. Galton and Eggleston (1979) raise, but do not answer, the question of why so many teachers adopt a style of teaching which appears to run counter to the philosophy inherent in the material of the curriculum projects they use. It is possible that this mismatch is due to the lack of philosophical understanding possessed by many teachers. Those who are strongly prejudiced towards a V type philosophy would be inclined to judge a new curriculum project in terms of its factual content alone. This is a characteristic of their viewpoint. They might be influenced by the familiarity, the novelty, the modernity or the relevance of the informational content of a course, but would be oblivious to the philosophical assumptions underlying any proposed teaching method in the curriculum package. In such circumstances they would see no contradiction in their adopting the course content and continuing to teach it in their normal fashion. This is why it was not uncommon when the Nuffield schemes were first published to hear teachers saying that they 'could never cover all that material in the number of periods' they had for teaching the science course as if it was the factual content implied by the suggested pupil investigations that was all that was of importance in the courses.

A greater philosophical awareness is required by all those involved in the training or appointment of science teachers if this situation is to change. Textbook writers and chief examiners may also have a part to play. Although the use of a set textbook appears to be less common than in the past, it is possible to speculate upon the effect of denying V type teachers the use of fact-laden textbooks. Such teachers may be more likely to use books than teachers of other types. If all books explicitly projected the H, or HI, philosophy in their style and content, this might provide some small counter balance to the teacher effect in determining the pupils' view of science. A change in the syllabuses and the style of examinations might also serve as a way of forcing teachers in post to reconsider what they do at present. The V type teachers interviewed were much more conscious of examination requirements than were the other extreme types. If a change in their approach is seen to be desirable, control of the examination syllabuses they are so inclined to follow should be considered as a possible weapon. If a more common curriculum is introduced into schools as has been proposed recently (DES 1981, Schools Council 1981), this might be regarded as an opportunity not only to reinforce the unity of science but also to remove the factual emphasis in the present curriculum.

In the present circumstances there is some justification for the informational approach of the V type teacher. In the science examinations which followed the teaching experiment, some of the marks showed that pupils given the V treatment might do better in content based examinations. Other workers (e.g. Raghubir 1979b) report similar findings and it can be argued that the V approach is common, both in this and other countries (Lynch 1978), and this has not prevented the continued production of new scientists. If the V approach has an advantage in increasing factual recall, this may be outweighed by other factors, including its effect in discouraging more able pupils from further study of science. The greatest difference in examination scores seemed to be with the pupils in the lower band and this is to be expected. Bady (1979) found that the ability to understand the logic of hypothesis testing was related to scholastic ability. He claimed that less than half of the ability range can be expected to realise that hypotheses can be tested only by attempted falsification and that the less able are more likely to have 'a simplistic and naively absolutistic view' of scientific method, believing that hypotheses can be 'proven by verification'. If this is the case, lower ability pupils would find the V approach more in accord with their natural view of science and be doubly inclined to accept it as it also makes fewer intellectual demands upon them.

In spite of evidence (Raghubir 1979a) that a freer and less directed approach produces gains in ability to formulate hypotheses, design experiments and analyse results, this is less likely to apply to below average pupils who are so used to failing in school that they do not have the confidence to succeed without the teacher's support. There was no evidence that the V approach caused the pupils in the B band to give up further study of chemistry or that the H approach produced better motivation to continue.

On balance however it must be concluded that the relatively common occurrence of the V type is a cause for concern. In spite of possible advantages of this type of teaching in producing slightly improved scores on content based examinations, the harm which can be done by its giving false ideas about science to the more able pupils is much more serious. It is this effect which may lead to a proportion of able children ceasing to study science subjects and to a subsequent shortage of scientists, engineers and technicians.

If further research confirms the main conclusions of this study, it should become a matter of policy to ensure adequate training in the philosophy of science for all those involved in science education. If teachers are made aware of the philosophical implications of their teaching styles and the beliefs and attitudes that these may engender in their pupils, then they may be persuaded of the need for change. Only such a concerted effort on the part of science teachers, teacher trainers, textbook writers and those who draw up examination syllabuses is likely to succeed in breaking the continuing cycle of misunderstanding.

SUMMARY OF CHAPTER 7:

The main hypotheses which form the basis of this study are reviewed, together with some of the evidence which relates to them. This evidence is discussed in the light of other recent work in this

field and certain recommendations are made concerning future science education policy. These are:

1. Training for science teachers and all new entrants to the profession in the philosophy of science, to include training in recognizing the philosphical implications inherent in different teaching styles.
2. Editorial control of writers of school science textbooks to ensure a reasonable balance between content relating to the processes and philosophy of science and that concerned with transmission of factual information.
3. Revision of examination syllabuses to remove pressure on teachers to cover certain factual content and also the increase the emphasis on testing for understanding of the processes of science.
4. Greater care in selecting teachers, particularly those who will teach younger pupils, giving attention to their teaching styles as well as to their knowledge of science.

CHAPTER 8:

SUMMARY OF CONCLUSIONS

The main conclusions which can be drawn from this investigation may be briefly summarized as follows:

1. It is possible to classify teachers of science according to their views about the philosophy of science. The main categories are:

   H type: hypothetico-deductivists having a problem solving approach to their teaching of science.

   I type: inductivists having an observational approach to the teaching of science.

   V types: verificationists with a factual or informative approach to teaching science.

   O types: teachers with no discernible philosophy of science affecting their teaching style.

   Although some teachers have views combining aspects of more than one of the above categories (e.g. HI types), those who hold coherent extreme viewpoints can be identified by their responses to questionnaire items. Follow-up interviews of a small sample of teachers showed that questionnaire responses correspond with the views expressed by teachers in extended personal interviews.

2. Teachers of the first three extreme types not only have more clearly formulated views about the philosophy of science, but are influenced by their views when planning their lessons. The ways in which they describe their teaching styles and report using practical work in their lessons shows a strong positive relationship between these and their beliefs concerning the philosophy of science.

3. Pupil understanding of the philosophy of science can be measured by a short test consisting of multiple choice items. The test developed

for use in this investigation allows for a determination of pupil bias towards any of the three main philosophical positions to be made.

4. Pupils' views about the philosophy of science are influenced by the way in which they are taught science even if their teacher does not attempt to do so explicitly. The teaching style used implies that the teacher holds a certain philosophy, and this implicit philosophy can have effects upon the pupils. Pupils taught in different ways exhibit a different pattern of responses on the specially designed measure of science understanding. Pupils given H type teaching achieve significantly higher scores on the scale measuring agreement with the hypothetico-deductivist philosophy. Pupils who have received I type or V type teaching obtain their highest scores on the inductivist and verificationist scales respectively.

5. Pupils who are given extreme V type teaching may do slightly better than others in school examinations requiring factual recall.

6. The style of teaching given to pupils can affect their willingness to continue studying a subject. In particular, the V type of teaching may deter more able pupils from continuing to study a science subject.

7. Different teaching styles have an effect on the vocabulary used by pupils to describe scientists and their activities.

8. The effects of teachers' implied philosophies of science on their pupils may be serious enough to prompt consideration of changes in future policies concerning science education.

APPENDICES

Note: Material reproduced in Appendices 1, 2, 3, 4, 5, and 7 has been photo-reduced and is half original size.

APPENDIX 1

PILOT SURVEY QUESTIONNAIRE

a) Covering letter to Heads of Science Departments.

THE UNIVERSITY OF ASTON IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021.359 3611 Ex 6165/6230

The Department of Educational Enquiry

Professor of Education and Head of Department:
Professor R C Whitfield BSc, PhD, MA, MEd, FRIC

Dear

At the suggestion of Neil Stears, I am writing to ask if you could possibly help me pilot a questionnaire into science practical work. In the last few years, science teachers have been encouraged to make greater use of class practicals. There is also a greater emphasis on teaching'scientific method' rather than concentrating on some of the factual material that was included in traditional science courses.

However, teachers have not always been consulted about the changes and may not be happy about them. The present survey is designed to find out from a large number of science teachers in Midland schools what their views are about 'scientific method'; how they see practical work contributing to the teaching of their pupils, especially those in the 11-14 age range; how familiar they are with published projects, such as Nuffield and SCISP; and the criteria they use in selecting textbooks for use in their schools. For example, do teachers agree that there is one scientific method as assumed in some projects? Do teachers agree about the value of practical work in promoting the aims of science teaching? How do teachers decide which books to adopt? How much freedom of choice is there? Can we really look at how good a book is or are most of us limited by cost?

In its final form, this questionnaire will be shorter, but we would be most grateful to you for filling it in as it is so that we can find the most effective questions in each section before we shorten it for administration to teachers in other education authorities. Your co-operation in this pilot study is most appreciated.

We believe that the results will be useful to a variety of groups - publishers, administrators, science advisers, headteachers - because they will reflect the views of those actually teaching science.

Thank you in advance for giving your time and opinions. As we need as large a sample as possible, a number of spare questionnaires are enclosed, which you may care to give to colleagues in your department to fill in. A stamped, addressed envelope is enclosed for the return of the questionnaire. Please note that all the information collected will be treated in the strictest confidence.

Yours sincerely,

David Dibbs
Peter Coxhead

Telex 336997

Appendix 1: Pilot Survey Questionnaire

b) Covering letter to other teachers.

THE UNIVERSITY OF ASTON IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021.359 3611 Ex 6165/6230

The Department of Educational Enquiry

Professor of Education and Head of Department:
Professor R C Whitfield BSc, PhD, MA, MEd, FRIC

Dear Colleague,

In the last few years, science teachers have been encouraged to make greater use of class practicals. There is also a greater emphasis on teaching 'scientific method' rather than concentrating on some of the factual material that was included in traditional science courses.

However, teachers have not always been consulted about the changes and may not be happy about them. The present survey is designed to find out from a large number of science teachers in Midland schools what their views are about 'scientific method'; how they see practical work contributing to the teaching of their pupils, especially those in the 11-14 age range; how familiar they are with published projects, such as Nuffield and SCISP; and the criteria they use in selecting textbooks for use in their schools. For example, do teachers agree that there is one scientific method as assumed in some projects? Do teachers agree about the value of practical work in promoting the aims of science teaching? How do teachers decide which books to adopt? How much freedom of choice is there? Can we really look at how good a book is or are most of us limited by cost?

In its final form, this questionnaire will be shorter, but we would be most grateful to you for filling it in as it is so that we can find the most effective questions in each section before we shorten it for administration to teachers in other education authorities. Your co-operation in this pilot study is most appreciated.

We believe that the results will be useful to a variety of groups - publishers, administrators, science advisers, headteachers - because they will reflect the views of those actually teaching science.

Thank you in advance for giving your time and opinions. A stamped, addressed envelope is enclosed for the return of the questionnaire. Please note that the information collected will be treated in the strictest confidence.

Yours sincerely,

David Dibbs
Peter Coxhead

Telex 336997

Appendix 1: Pilot Survey Questionnaire

c) The Questionnaire.

SCHOOL SCIENCE SURVEY

Completing the questionnaire should take about 30 mins. We are grateful to you for giving your time and your opinions. Please return the completed questionnaire in the envelope provided. All your personal details and individual opinions will be treated in strictest confidence.

SECTION 1: Background

NAME --- MALE/FEMALE

SCHOOL -- POSITION -------------------

No. of years teaching science ( )

No. of years in present school ( )

SCIENCE SUBJECTS TAUGHT AT PRESENT:

Biology	YES/NO	If Yes, age range(s) --------------
Chemistry	YES/NO	--------------
Physics	YES/NO	--------------
General, combined or integrated sciences	YES/NO	--------------

QUALIFICATIONS: (Please tick any that apply)

Higher degree in science subject ( )

Good hons. degree in science ( )

Degree in science subject(s) ( )

Graduate equivalent ( )

Non-science degree ( )

B.Ed. degree ( )

Cert. Ed. or P.G.C.E. ( )

Advanced Dip. Ed. ( )

Other (please specify) --

Main subject(s) of qualifications --

Details of any experience other than teaching:

Appendix 1: Pilot Survey Questionnaire

SECTION 2: Curriculum Development Projects and Books in Use

COMMENT	NUFFIELD						
	Biology O level 11-16	Chemistry O level 11-16	Physics O level 11-16	Combined Science 11-13	Secondary Science 13-16	Schools Council 5-13	SCISP 13-16
Adopted the course							
Teach a modified version							
Use some of the material							
Prefer not to use it							
Not familiar with the material							
Do not teach this material							

Please list below any books you have for use by pupils in the 11-14 age range (secondary years 1-3). In the comment section please say why you chose the book or continue to use it. If you have no choice in the textbooks you use, please say why you don't like any you have to use. If there is notenough space please continue on the back of this page.

TITLE	AUTHOR	COMMENT

Appendix 1: Pilot Survey Questionnaire

SECTION 3: Practical Work in Science Teaching. 3

For each statement about practical work, please say if you strongly agree (SA), agree (A), are undecided (U), disagree (D), or strongly disagree (SD) by ticking in one column. There are no correct anwers; we want your honest opinions, but hope that you are not undecided about too many statements.

A previous survey showed that teachers often see practical work as having different value for pupils of different age groups. If you teach a wide age range, please try to bear in mind the pupils in the 11-14 age group (years 1-3 in a secondary school) when deciding whether or not you agree with any statement. If you teach only older pupils please indicate below the age group you have in mind when answering this Section. Also please indicate if you teach only one of the separate sciences whether you think the answers you give apply to all sciences or just to your specialism.

Age group: 11-14 ( )

Other ( ) Please say which____________________

Do your opinions about practical work apply to

all science subjects ( )

Biology ( )

Chemistry ( )

Physics ( )

	Please tick one: SA	A	U	D	SD
1. Doing experiments makes learning science more enjoyable.					
2. In practicals pupils develop manipulative skills.					
3. Pupils would get a false idea of science if they did no practical work.					
4. Learning to pool the results of all class experiments is important.					
5. Experiments help pupils to learn facts and recall them more easily.					
6. Pupils are often capable of designing valid experiments.					
7. Pupils need clear instructions about practical procedures.					
8. Practical work is good for illustrating scientific principles.					
9. It is difficult to get enough practical work done to give pupils experience of making their own generalizations.					
0. Practicals teach pupils the importance of having evidence for their opinions.					
1. Practical work can be used to test predictions made by pupils.					
2. Observation of many different examples is an important practical experience.					

SECTION 3 (cont.)	SA	A	U	D	SD
13. Practicals give pupils first-hand experience of scientific concepts they have been taught.					
14. Practical work gives pupils an idea of how difficult it is to discover something new.					
15. Doing practical work helps pupils to practice careful recording.					
16. Doing practicals promotes scientific methods of thought.					
17. Careful measurement and recording is necessary if pupils are to find the regularities in nature.					
18. Practical work encourages accurate observation.					
19. Practical work is an integral part of pupils' scientific investigations.					
20. Doing practical work keeps pupils usefully occupied.					
21. Conflicting results are useful for leading on to discussion after a practical.					
22. Pupils ought not to be taught scientific laws until they have observed a regular pattern themselves.					
23. Pupils get a sense of achievement when they obtain the right results.					
24. Doing experiments teaches pupils to handle apparatus skillfully.					
25. The 'discovery method' works if pupils have enough time to explore possible uses of experimental apparatus themselves.					
26. Learning facts by doing practicals is better than just reading a book.					
27. Pupils should not know the results to expect before they begin an experiment.					
28. Doing practical work is a way of showing pupils that what I say is true.					
29. Demonstrations are better than class practicals because there is less opportunity for messing about.					
30. Doing experiments teaches pupils to test their ideas.					
31. Demonstrations are often better than class practicals because the results are more reliable.					
32. Repeating experiments a number of times is necessary to establish general patterns.					
33. In practicals pupils should know from the beginning all the steps they will perform.					
34. Practical work is useful in verifying facts taught in theory lessons.					

SECTION 3 (cont.)

	SA	A	U	D	SD
35. Practical investigations should always be open ended.					
36. Pupils can learn to choose their own experimental apparatus.					
37. Practical work arouses interest in pupils.					
38. Doing practical work provides training in problem solving.					
39. Pupils should collect experimental observations themselves before being taught theoretical principles.					
40. Doing an experiment is a good way of answering questions raised by pupils in class.					

If there are any other comments you would like to make about the usefulness or importance of practical work, please use this space or continue on a separate piece of paper.

Appendix 1: Pilot Survey Questionnaire

SECTION 4: Your View of Science 6

Please tick the best answer for each question. Do not tick more than one. In each case, decide on the best answer even if more than one seems to fit.

1. Which of the following is the best statement about scientific knowledge?
   - A. Scientific knowledge is a systematic collection of facts. ( )
   - B. Data and ideas from the past contribute to today's scientific knowledge. ( )
   - C. Scientific knowledge depends on large numbers of factual observations. ( )
   - D. Statements are not accepted as scientific knowledge unless they are absolutely true. ( )

2. The principal function of a scientific society is to:
   - A. Inform non-scientists of important scientific discoveries. ( )
   - B. Ensure that newly discovered facts are available to researchers. ( )
   - C. Promote the exchange of ideas. ( )
   - D. Check that no research findings are published unless they are true. ( )

3. The principal aim of science is to:
   - A. Prove that our knowledge of the physical world is true. ( )
   - B. Provide people with the means to live better lives. ( )
   - C. Discover, collect and classify facts about nature. ( )
   - D. Explain natural phenomena in terms of principles and theories. ( )

4. Most important scientific discoveries come about as a result of:
   - A. A set of carefully designed and executed experiments. ( )
   - B. The interactions of ideas and experiments in the solution of problems. ( )
   - C. The dedication of one man to the collection of many observations. ( )
   - D. An interaction between a chance observation and an alert mind. ( )

5. A scientific law is:
   - A. An exact report of many observations of scientists. ( )
   - B. A generalized statement of relationships among natural phenomena. ( )
   - C. A theoretical explanation of natural phenomena. ( )
   - D. Always supported by so much evidence that it could not be proved wrong. ( )

6. When a scientist has established a theory, he has:
   - A. Developed new ideas and understanding. ( )
   - B. Uncovered one of the laws of nature. ( )
   - C. Moved mankind nearer to knowledge of absolute truth. ( )
   - D. Discovered new experimental evidence. ( )

7. In deciding whether to accept a proposed theory, scientists make a decision on the basis of:
   - A. Whether or not the theory is true. ( )
   - B. Whether or not the theory can be expressed in mathematical form. ( )
   - C. The evidence supporting the theory and their personal ideas. ( )
   - D. The experimental and observational evidence available. ( )

Appendix 1: Pilot Survey Questionnaire

8. Experiments and tests are used by scientists to:
   A. Improve their knowledge by trial and error. ( )
   B. Prove the regularity of natural phenomena. ( )
   C. Inquire into the mysteries of nature. ( )
   D. Check predictions made from their observations and ideas. ( )

9. Which of the following is the best description of the methods used by scientists?
   A. Observation and experiment - collection and classification of data - looking for general laws or patterns. ( )
   B. Observation and experiment - comparing results with established scientific fact - publication of newly discovered facts. ( )
   C. Identification of problem - thinking of possible answers - testing them by experiment - comparing results with original ideas. ( )
   D. Reading about previous research work - designing better experiments - publishing any new experimental results or observations. ( )

10. Most scientists agree that scientific theories are:
   A. Explanations that may be revised or improved. ( )
   B. Final explanations of natural phenomena. ( )
   C. Descriptions of the world as it really is. ( )
   D. Truths that will not be disproved in the future. ( )

11. Which of these activities is most typical of science?
   A. Making experimental measures more accurate. ( )
   B. Checking through the work of other scientists. ( )
   C. Testing ideas by observation and experiment. ( )
   D. Careful and systematic collection of experimental data. ( )

12. After doing an experiment carefully, a scientist gets a result different from the one he had expected. He ought to think:
   A. I should not have made a prediction before doing the experiment. ( )
   B. I will improve the experiment to get the correct result. ( )
   C. If I had practised longer, I would have got the result I expected. ( )
   D. If I did the experiment properly, there was something wrong with my prediction. ( )

13. A Scientist is open-minded if he:
   A. Thinks up many new ideas for experiments. ( )
   B. Is always searching for new observational data. ( )
   C. Considers hypotheses which go against his own. ( )
   D. Is always ready to learn new scientific facts. ( )

14. In scientific investigations, a hypothesis:
   A. Prevents scientists looking at natural phenomena objectively. ( )
   B. Is an indispensible guide to future experiments. ( )
   C. Is an idea which has no experimental proof. ( )
   D. May be interesting to theorists, but does not help in the search for truth. ( )

15. When new evidence does not fit a current scientific theory, scientists:

A. Throw out the theory as the new evidence does not support it. ( )

B. Look for much more evidence both for and against the theory. ( )

C. Question the new evidence as it does not agree with previously established facts. ( )

D. Suspend judgement until a better theory is proposed. ( )

Please use the space below if you would like to make any comment on your views about scientific methods and activities not covered in the questionnaire.

APPENDIX 2

PHILOSOPHICAL SCALES USED IN TRIALS

a) Multiple Choice Version.

YOUR VIEW OF SCIENCE: Name: ....

Please tick the best answer for each question. Do not tick more than one. In each case decide on the best answer even if more than one seems to fit.

1. Which one of the following is the best statement about scientific knowledge?
   a. Scientific knowledge is a systematic collection of facts. ( )
   b. Data and ideas from the past contribute to today's scientific knowledge. ( )
   c. Scientific knowledge is based on a large number of factual observations. ( )

2. Most important scientific discoveries come about as a result of
   a. a set of carefully designed and executed experiments. ( )
   b. the interactions of ideas and experiments in the solution of problems. ( )
   c. interactions between chance observations and an alert mind. ( )

3. A scientific law is
   a. an exact report of many observations of scientists. ( )
   b. a generalised statement of relationships among natural phenomena. ( )
   c. a theoretical explanation of natural phenomena. ( )

4. When a scientist has established a theory, he has
   a. developed new ideas and understanding. ( )
   b. uncovered one of the laws of nature. ( )
   c. discovered new experimental evidence. ( )

5. Experiments and tests are used by scientists to
   a. prove the regularity of natural phenomena. ( )
   b. inquire into the mysteries of nature. ( )
   c. check predictions made from their observations and ideas. ( )

6. Which of the following is the best description of the methods used by scientists?
   a. Observation and experiment - collection and classification of data - looking for general laws or patterns. ( )
   b. Reading of previous research work - designing better experiments - comparing results with established facts-publishing new experimental results or factual data. ( )
   c. Identification of problem - thinking of possible answers - testing them by experiment - comparing results with original ideas. ( )

(Please turn over)

7. After doing an experiment carefully, a scientist gets a result different from the one he expected. He ought to think:
   a. I should not have made a prediction before doing the experiment. ( )
   b. I will improve the experiment to get the correct result. ( )
   c. If I did the experiment properly, there was something wrong with my prediction. ( )

8. A scientist is open minded if he
   a. is always searching for new observational data. ( )
   b. considers hypotheses which go against his own. ( )
   c. is always ready to learn of new scientific facts. ( )

9. When new evidence does not fit a current scientific theory, scientists
   a. change the theory as the new evidence does not support it. ( )
   b. question the new evidence as it does not agree with previously established facts. ( )
   c. look for much more evidence before proposing a better theory. ( )

10. In deciding whether to accept a proposed theory, scientists make a decision on the basis of
   a. the truth of the evidence supporting the theory. ( )
   b. the evidence supporting the theory and their personal ideas. ( )
   c. the amount of experimental and observational evidence available. ( )

Please use the space below if you would like to make any comment on your views about scientific methods and activities not covered in the questionnaire.

Appendix 2: Philosophical Scales used in Trials

b) Paired Statements Version.

YOUR VIEW OF SCIENCE. Name: ....

From each pair of statements, please tick the one you think more closely reflects what science is and/or what scientists do. You may think that both are wrong, but still try to chose the one you think best.

1.	Data and ideas from the past contribute to today's scientific knowledge. ( )	Scientific knowledge is based on a large number of factual observations. ( )
2.	Scientific theories are based on impressive amounts of confirming factual evidence. ( )	Our scientific theories may need to be revised or improved in the future. ( )
3.	Hypotheses prevent scientists from looking at natural phenomena objectively. ( )	Hypotheses are ideas with no experimental proof. ( )
4.	A scientific law is supported by so much evidence that it could not be proved wrong. ( )	A scientific law is a generalised statement of our present state of knowledge in some field. ( )
5.	The main aim of science is to discover and classify facts about nature. ( )	The main aim of science is to look for general patterns in natural phenomena. ( )
6.	Scientific societies and journals exist to promote the exchange of ideas. ( )	Scientific journals ensure that new results and discoveries are available to researchers. ( )
7.	Most scientific discoveries result from the dedication of scientists to the collection of many observations. ( )	New scientific discoveries must be confirmed by experimental evidence. ( )
8.	Experiments are used by scientists to prove the regularity of natural phenomena. ( )	Experiments are used by scientists to check predictions from their observations and ideas. ( )
9.	A typical activity of scientists is careful and systematic collection of data. ( )	A typical activity of scientists is testing ideas by observation and experiment. ( )
10.	Experimental evidence is needed to establish the truth of scientific statements. ( )	Experimental and observational evidence is the basis of scientific generalisations. ( )
11.	In scientific investigations, a hypothesis is an indispensible guide to future experiments. ( )	In scientific investigations, a hypothesis can prevent one from making objective generalisations. ( )
12.	Scientific theories are accepted if supported by confirming factual evidence. ( )	Scientific theories are summaries of large amounts of observational data. ( )
13.	Scientific knowledge is a systematic collection of facts. ( )	Scientific knowledge has arisen from the ideas and data of past scientists. ( )
14.	Scientific laws are general statements based on observations of natural phenomena. ( )	Scientific laws have been confirmed by so much evidence they will never be proved wrong. ( )

(Please turn over)

15.	The principal aim of science is to explain natural phenomena in terms of principles and theories. ( )	Looking for general patterns in natural phenomena is the main aim of science. ( )
16.	The main function of a scientific society is to check no research findings are published unless they are true. ( )	The principal function of a scientific society is to promote the exchange of ideas. ( )
17.	Scientists use experiments to test their predictions and ideas. ( )	Scientists use experiments in the search for regularies in nature. ( )
18.	Scientific discoveries are confirmed by carefully designed and executed experiments. ( )	Scientific discoveries are aresult of the interaction of ideas and experiment in the solution of problems. ( )
19.	If new results do not fit current theory they must be questioned as they do not agree with facts already established. ( )	If new evidence does not fit a current theory, the theory must be discarded or modified. ( )
20.	Testing ideas by observation or experiment are typical scientific activities. ( )	Making experimental measures more accurate is a typical activity of scientists. ( )
21.	Scientists decide whether to accept a proposed theory on the observational and experimental evidence available. ( )	Scientists decide whether to accept a proposed theory on the basis of the evidence supporting the theory and their personal ideas. ( )
22.	Statements of scientific knowledge are true. ( )	Statements of scientific knowledge are generalisations. ( )
23.	Hypotheses may be interesting to theorists, but do not help in the search for truth. ( )	Hypotheses are necessary if one is to decide what experiments to do next. ( )
24.	Scientists aim to prove that our knowledge of the physical world is factually correct. ( )	Scientists aim to explain natural occurences in theoretical terms. ( )
25.	A scientific law points to our present theoretical explanation of certain phenomena. ( )	A scientific law is a generalised statement of relationships among natural phenomena. ( )
26.	Scientific journals contain useful records of observations and most experimental results. ( )	Scientific journals inform people of new discoveries and the experiments confirming them. ( )
27.	New evidence may lead a scientist to question a widely held theory he previously accepted. ( )	New evidence is always welcomed by scientists as it helps to establish new theories. ( )
28.	The most typical activity of a scientist is checking the work of others for accuracy. ( )	The most typical activity of scientists is the collection and systematization of new data. ( )
29.	Experiments are a way of increasing the variety of data available to scientists. ( )	Experiments are used to prove the truth of scientific statements. ( )
30.	Important discoveries are the result of interactions between the ideas of scientists and their experiments. ( )	Important discoveries arise as a result of the dedication of many scientists to the collection of experimental observations. ( )

APPENDIX 3

UNDERSTANDING SCIENCE TEST (INDUCTIVIST VERSION)

a) Instructions for administering the test.

UNDERSTANDING SCIENCE TEST.

Instructions for administering the test:

1. Explain to pupils the difficulty in devising a test which can be used to test understanding of science because pupils in different schools, or in different classes of one school, may be taught different things in different ways or in a different order. This test is designed to be a measure of understanding irrespective of what type of science course has been followed. Please point out to the pupils that, in filling it in, they are taking part in a scientific experiment themselves.

2. Write sample question on blackboard:

   The main thing that scientists do is to
   A. collect scientific books. ( )
   B. build pieces of apparatus. ( )
   C. give lectures about science. ( )
   D. carry on scientific research. (✓)

3. Explain that answer D. is correct because, although several answers are partly correct, the answer D. is the 'main thing' that scientists do, and so it is the best answer. In doing the test, the pupils should tick the best answer. They must be told to:

   i. tick the best answer.
   ii. tick only one answer for each question.
   iii. leave no blanks (a guess can be a tick, a blank is always wrong).
   iv. ask if they cannot understand a word.

4. Check that the pupils understand the instructions. Give out papers. Tell them to put their <u>names</u> and <u>form</u> at the top and to begin at once. This is not a speed test but all pupils should finish in less than 30 minutes. When about half appear to be finished, remind the class that they can check through to make sure that they have ticked the best answer to each question.

5. If pupils ask for the meaning of any word in the test, explain briefly at the level you would normally expect to use when teaching that class.

6. When all have finished, check that name and form have been written at the top and collect papers. Completed papers should be returned to me at the end of the lesson. Please <u>do not</u> discuss the answers to specific questions with the class as this would prevent us using the test in future years to see if pupils improve.

M.J.N. 1979.

Appendix 3: Understanding Science Test (Inductivist Version)

b) Understanding Science Test (based on SUM, with philosophical questions modified to contain inductivist answers).

UNDERSTANDING SCIENCE TEST NAME....................

1. A scientist expected to get a certain result for an experiment. When he did the experiment carefully the result was different from what he had expected. He ought to think
   - A. "I should not have made a prediction before doing the experiment" ( )
   - B. "I will improve the experiment to get the result I expected" ( )
   - C. "If I had practised longer, I would have got the result I expected" ( )
   - D. "I should not have made a prediction until I had made many more observations" ( )

2. All of the following play some part in scientific discovery. Which one of them is more typical of science than the others?
   - A. Careful observation and recording results. ( )
   - B. Making experimental measure more accurate. ( )
   - C. Checking through the work of earlier scientists. ( )
   - D. Measurement and calculation. ( )

3. Science may help with all of these EXCEPT
   - A. improving our standard of living. ( )
   - B. growing more beautiful flowers. ( )
   - C. showing that lying is wrong. ( )
   - D. making clothes more hard wearing. ( )

4. Which of these could science NEVER do without?
   - A. Well-trained assistants. ( )
   - B. Large sums of money for equipment. ( )
   - C. People who are observant. ( )
   - D. Specially built laboratories. ( )

5. Are biology, chemistry and physics related or not? They are
   - A. not related, because biologists, chemists and physicists study very different things. ( )
   - B. related, because careful observation and recording of experimental results are important to all of them. ( )
   - C. related, because they all use mathematics. ( )
   - D. related, because all three are taught as science subjects at schoo . ( )

6. Most scientists think that scientific theories are
   - A. based on large amounts of evidence. ( )
   - B. final explanations of things. ( )
   - C. descriptions of the world as it really is. ( )
   - D. truths that can't be changed. ( )

7. The people and government of this country today affect science
   - A. not much because scientists are isolated from the rest of society. ( )
   - B. not much because scientists are not interested in what the people or the government think. ( )
   - C. a great deal because the education and support given to scientists depends on how the people feel about science. ( )
   - D. a great deal because most scientists have to do what the government tells them. ( )

8. Which of the following is the BEST list of what scientists study?
   - A. atoms, molecules and stars. ( )
   - B. rockets, satellites and space travel. ( )
   - C. plants, animals and diseases. ( )
   - D. matter, energy and living things. ( )

9. Scientists are in NO way responsible for
   - A. the colours of out clothes. ( )
   - B. the colours of the rainbow. ( )
   - C. the pollution of rivers. ( )
   - D. the world food problem. ( )

10. Scientists today agree about many ideas of how the natural world works. Most likely, these ideas will
    - A. not be changed because they are based on so much evidence. ( )
    - B. be changed to keep up with fast-moving world events. ( )
    - C. be changed, but not for a long time. ( )
    - D. not be changed because they are true. ( )

11. The most important thing that biology, chemistry and physics have in common is that they
    - A. involve working in laboratories. ( )
    - B. need very intelligent people. ( )
    - C. rely on results of experiments and observations. ( )
    - D. involve long periods of study at a University. ( )

12. Potassium, nitrogen and phosphorus are three chemicals. Experiments are planned to learn something about the effect of potassium on the growth of a plant. Nitrogen and phosphorus are already known to be necessary. One group of plants is grown in soil containing nitrogen and phosphorus but without potassium. A second group should be grown in soil containing
    - A. potassium only. ( )
    - B. nitrogen and potassium, but no phosphorus. ( )
    - C. potassium and phosphorus, nut no nitrogen. ( )
    - D. nitrogen, phosphorus and potassium. ( )

13. In the past, important scientific discoveries were made by people who worked on science as a hobby, for example statesmen or business men. Why is this less true today?
    - A. People are less interested in science than they used to be. ( )
    - B. Most scientific research today requires many years of special preparation and training. ( )
    - C. No important discovery can be made today without expensive equipment which only scientists possess. ( )
    - D. Only scientists have the abilities needed to make important discoveries. ( )

14. If an astronomer (a scientist who studies stars) is asked by another scientist, who is not an astronomer, to explain why some stars seem to be brighter than others, his answer will most likely involve
    - A. complicated mathematical formulae and equations. ( )
    - B. lists of stars which are brighter than others. ( )
    - C. a theory that the universe may be expanding. ( )
    - D. scientific principles based on observations. ( )

15. A doctor says that 90 out of a 100 of his patients who had colds recovered in one day when they used a brand new medicine. This should be accepted as important evidence only if

A. the doctor had been trained for several years as a research scientist. ( )
B. the year before only 3 patients out of the same 100 had recovered from their colds in a day. ( )
C. the new medicine was already known to be good for curing other illnesses. ( )
D. the doctor had at least another 100 patients who did not have colds. ( )

16. Modern scientists can solve more complicated problems than scientists of the past because they

A. have much more evidence than earlier scientists. ( )
B. have more accurate measuring instruments. ( )
C. have shown that many of the theories of earlier scientists were wrong. ( )
D. receive a better education than earlier scientists. ( )

17. The most important reason for doing experiments when we are learning science is that

A. experiments give us practice in careful observation. ( )
B. experiments enable us to learn more easily. ( )
C. experiments make learning more interesting. ( )
D. it is important to learn to handle apparatus skilfully. ( )

18. Before proposing a new theory about the way mountains were built up, a geologist (a scientist who studies the Earth) would first

A. rule out all previous attempts to explain mountain-building. ( )
B. see if it explains the known facts about mountain-building. ( )
C. study a geological map of all the mountains in the British Isles. ( )
D. see if his theory would be useful to mining engineers. ( )

19. The results of scientific discoveries are

A. always good, because they help mankind. ( )
B. usually good, because scientists always tell the truth. ( )
C. sometimes bad, because scientists are no better than people in other jobs. ( )
D. usually bad, because they help to destroy nature. ( )

20. Other scientists completely ignored the results of Mary Jones' experiments. This was NOT because

A. she is dishonest. ( )
B. she did the wrong sort of experiment. ( )
C. she got the results mixed up. ( )
D. she is a woman. ( )

D.R.D. 1979.

APPENDIX 4

SCHOOL SCIENCE SURVEY

a) Covering letter to secondary and high school headteachers.

THE UNIVERSITY OF ASTON IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021.359 3611 Ex 6165/6230

The Department of Educational Enquiry

Professor of Education and Head of Department:
Professor Richard C Whitfield BSc, PhD, MA, MEd.

Dear Headteacher,

SCHOOL SCIENCE SURVEY

Please find enclosed for your information a copy of a questionnaire which is being sent to all those teaching science subjects in middle and secondary schools in the Dudley area as part of a wider survey of opinion and practice among science teachers.

We are grateful to Mr. Lambert, the General Inspector of Schools responsible for Science, for his support in circulating the questionnaires to schools, and we hope that you will encourage your science staff to complete and return them to us as soon as possible.

Although replies from individual teachers will be treated in strictest confidence, we shall be happy to send you a copy of the results of the survey if you request one.

Yours sincerely,

David R. Dibbs,
and Peter Coxhead.

Telex 336997

Appendix 4: School Science Survey

b) Covering letter to middle school headteachers.

THE UNIVERSITY OF ASTON IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021.359 3611 Ex 6165/6230

The Department of Educational Enquiry

Professor of Education and Head of Department:
Professor Richard C Whitfield BSc, PhD, MA, MEd.

Dear Headteacher,

SCHOOL SCIENCE SURVEY

Please find enclosed three copies of the School Science Survey questionnaire. As a part of a wider survey of opinion and practice among science teachers and with the support of Mr. Lambert, the General Inspector of Schools responsible for Science, copies of the questionnaire are being sent to all science teachers in the Dudley secondary and high schools.

However, to form a clear picture of the views of science teachers in the Borough it is essential that those teaching science in the middle schools also have the opportunity to complete the questionnaire. Therefore, we would be grateful if you could give the enclosed questionnaire to those of your staff teaching science and encourage them to complete and return the questionnaires to us as soon as possible.

Although replies from individual teachers will be treated in strictest confidence, we shall be happy to send you a copy of the results of the survey if you request one.

Yours sincerely,

David R. Dibbs,
and Peter Coxhead.

Telex 336997

Appendix 4: School Science Survey

c) Covering letter to science teachers

THE UNIVERSITY OF ASTON IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021.359 3611 Ex 6165/6230

The Department of Educational Enquiry

Professor of Education and Head of Department:
Professor Richard C Whitfield BSc, PhD, MA, MEd.

Dear Colleague,

<u>SCHOOL SCIENCE SURVEY</u>

In the last few years, science teachers have been encouraged to make greater use of class practicals. There is also a greater emphasis on teaching 'scientific method' rather than concentrating on some of the factual material that was included in traditional science courses.

However, teachers have not always been consulted about the changes and may not be happy about them. The present survey is designed to find out from a large number of science teachers in Midland schools what their views are about 'scientific method'; how they see practical work contributing to the teaching of their pupils, especially those in the 11-14 age range; how familiar they are with published projects, such as Nuffield and SCISP; and the criteria they use in selecting textbooks for use in their schools. For example, do teachers agree that there is one scientific method as assumed in some projects? Do teachers agree about the value of practical work in promoting the aims of science teaching? How do teachers decide which books to adopt? How much freedom of choice is there? Can we really look at how good a book is or are most of us limited by cost?

With the support of Mr. Lambert, the General Inspector of Schools responsible for Science, copies of the questionnaire are being sent to all those teaching science in the Dudley middle and secondary schools. Obviously the results will be of the greatest value if the questionnaire is completed by all those who receive a copy.

We believe that the results will be useful to a variety of groups - publishers, administrators, science advisors, headteachers - because they will reflect the views of those actually teaching science.

Thank you in advance for giving your time and opinions. A stamped, addressed envelope is enclosed for the return of the questionnaire. Please note that your answers to the questionnaire will be treated in the strictest confidence and will not be seen by anyone else in your school or education authority. The information about your background is necessary only to help in the analysis of results. We need your name only in case we wish to speak to a few individuals later about any interesting opinions they have expressed. However, if you would like to receive a copy of the survey results, please fill in your name and address on the enclosed sticky label and we will forward one later.

Yours sincerely,

David R. Dibbs

David R. Dibbs,
<u>and Peter Coxhead.</u>

Telex 336997

d) Follow-up letter to Heads of Science Departments.

THE UNIVERSITY OF ASTON IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021 359 3611 Ex 6165/6230

The Department of Educational Enquiry

Professor of Education and Head of Department:
Professor Richard C Whitfield BSc, PhD, MA, MEd.

Dear Colleague,

SCHOOL SCIENCE SURVEY.

About three weeks ago you and all the members of your department will have received copies of the School Science Survey questionnaire through your Local Education Authority post. If the results of the survey are to be of value it is important that we receive as many replies as possible from all the schools in the area.

In spite of the problems we are having with the postal services at present and knowing that it is probably a busy time of the year for you, I should be grateful if you could remind those of your colleagues who have not yet completed the questionnaire and ask them to return it to me before the end of term so that we can carry out the computer analysis during the summer.

Thank you for your help with the Survey.

Yours sincerely,

David R. Dibbs.

Appendix 4: School Science Survey

e) The Survey Questionnaire.

SCHOOL SCIENCE SURVEY

Section 1: Background.

NAME .... MALE/FEMALE ....

SCHOOL ....

POSITION ....

No. of years teaching science (   )

No. of years in present school (   )

SCIENCE SUBJECTS TAUGHT AT PRESENT:

Biology	YES/NO	If yes, age range(s) ....
Chemistry	YES/NO	....
Physics	YES/NO	....
General, Combined or Integrated Science	YES/NO	....
Environmental or Rural Science	YES/NO	....

QUALIFICATIONS:

(Please tick any that apply, and state main subject of qualification).

Degree or graduate equivalent	( )	Subject: ....
Cert. Ed. or P.G.C.E.	( )	Subject: ....
Taught higher degree or diploma	( )	Subject: ....
Higher degree by research	( )	Subject: ....

Section 2: Curriculum Projects and Books

A: For each curriculum development project, please put one tick into the most appropriate box

Project:	Usually enter pupils for the project exam.	Use some material from the course	Prefer not to use it	Do not teach this subject or age group
Nuffield Biology O Level 11-16				
Nuffield Chemistry O Level 11-16				
Nuffield Physics O Level 11-16				
Nuffield Combined Science 11-13				
Nuffield Secondary Science 13-16				
Schools Council 5-13				
SCISP 13-16				

B: Please list below any book you regard as being particularly suitable for use as a textbook by pupils in the 11-14 age range (years 1-3 in a secondary school).

Title	Author(s)

Appendix 4: School Science Survey

C: Please indicate by one tick on each line whether or not you consider each criterion as important in choice of books for 11-14 year-old pupils. Try to rate each criterion on the following scale:

0 = Not important at all
1 = Only slightly important
2 = Fairly important
3 = More important
4 = Very important indeed

	0	1	2	3	4
Level of reading difficulty					
Quality of illustrations					
Qualifications of authors					
Suggestions in book for pupil investigations					
Inclusion of data from which pupils can draw conclusions					
Emphasis on 'scientific method' in text					
Emphasis given to applications of science in present society					
Accuracy of factual information					
Logical organisation of concepts introduced					
Inclusion of alternative theories					
Emphasis on problem solving as a scientific activity					
Inclusion of historical aspects of science					
Size and shape of book					
Price and value for money					
Strength of binding and cover					
Inclusion of past examination questions					
Coverage of topics in examination syllabus					

Please use the space below to mention anything else which you think is important to consider when selecting textbooks for your pupils:

Appendix 4: School Science Survey

Section 3: Practical Work in Science Teaching

For each statement about practical work, please say if you strongly agree (SA), agree (A), are undecided (U), Disagree (D), or strongly disagree (SD) by ticking in one column. There are no correct answers; we want your honest opinions, but hope you are not undecided about too many statements.

A previous survey showed that teachers often see practical work as having different value for pupils of different ages. If you teach a wide age range, please answer with reference to the pupils in the 11-14 age group (years 1-3 in a secondary school) when deciding whether or not you agree with any statement.

	SA	A	U	D	SD
1. Doing experiments makes learning science more enjoyable					
2. In practicals pupils develop manipulative skills					
3. Pupils would get a false idea of science if they did no practical work					
4. Pupils need clear instructions about practical procedures					
5. Practical work is good for illustrating scientific principles					
6. Practicals teach pupils the importance of having evidence for their opinions					
7. Practical work can be used to test predictions made by pupils					
8. Observation of many different examples is an important practical experience					
9. Practicals give pupils first-hand experience of scientific concepts they have been taught					
10. Practical work gives pupils an idea of how difficult it is to discover something new					
11. Doing practicals promotes scientific methods of thought					
12. Careful measurement and recording is necessary if pupils are to find the regularities in nature					
13. Practical work encourages accurate observation					
14. Practical work is an integral part of pupils' scientific investigation					
15. Doing practical work keeps pupils usefully occupied					
16. Pupils get a sense of achievement when they obtain the right results					
17. Doing experiments teaches pupils to handle apparatus skillfully					
18. Pupils should not know the results to expect before they begin an experiment					

Section 3 continued...

	SA	A	U	D	SD
19. Doing practical work is a way of showing pupils that what I say is true					
20. Doing experiments teaches pupils to test their ideas					
21. Demonstrations are often better than class practicals because the results are more reliable					
22. Repeating experiments a number of times is necessary to establish general patterns					
23. Practical work is useful in verifying facts taught in theory lessons					
24. Practical work arouses interest in pupils					
25. Doing an experiment is a good way of answering questions raised by pupils in class					

Appendix 4: School Science Survey

Section 4: Your View of Science

People disagree about what makes science different from other activities of mankind, and about what the methods are that scientists really use. As in the previous section, please use a tick against each statement to show how strongly you agree or disagree with it. Again, we want your honest opinions but hope you are not undecided about too many statements.

	Please tick one				
	SA	A	U	D	SD
1. Making experimental measures more accurate is a typical activity of scientists.					
2. Scientific knowledge must be based on a large number of factual observations.					
3. A scientific law is merely a statement of our present state of knowledge in some field.					
4. The main function of a scientific society is to ensure that no research findings are published unless they are true.					
5. Experiments, like observations, are just a way of increasing the variety of data available to scientists.					
6. Hypotheses are essential if one is to decide what experiments to do next.					
7. Scientific discoveries are confirmed by carefully designed and executed experiments.					
8. The main function of scientific journals is to ensure that records of observations and experimental results from the past are available to researchers.					
9. Testing ideas by observation or experiment is the most typical of scientific activities.					
10. Scientific theories are accepted only if supported by confirming factual evidence.					
11. Most scientific discoveries result from the dedication of scientists to the collection of many observations.					
12. Contrary evidence should lead a scientist to question even a widely held theory he had previously accepted.					
13. Scientists aim to prove that our knowledge of the physical world is factually correct.					
14. Scientific theories are simply generalisations derived from large amounts to observational data.					
15. Experiments are only useful to scientists who have prior predictions and ideas to test.					
16. Scientific laws have been confirmed by so much evidence that they could never be proved wrong.					

Appendix 4: School Science Survey

	SA	A	U	D	SD
17. Looking for general patterns in natural phenomena is the main aim of science.					
18. It is ideas from the past which make the greatest contributions to today's scientific knowledge.					
19. Having a hypothesis before starting a scientific investigation can prevent one from making generalisations objectively.					
20. Our scientific theories may need to be revised or improved in the future.					
21. Hypotheses may be interesting to theorists, but they do not help in the search for truth.					
22. New evidence is welcomed by scientists as it may help to establish new generalisations.					
23. Statements of scientific knowledge are true.					
24. The principal aim of science is to explain natural phenomena in terms of principles and theories.					
25. If new evidence does not fit current theories, it must be questioned as it does not agree with facts already established.					
26. A typical activity of scientists is the careful and systematic collection of observational data.					
27. Scientific discoveries are the result of the interaction of ideas and experiment in the solution of problems					
28. Scientific societies and journals exist to promote the criticism and exchange of ideas.					
29. Experiments are used to prove the truth of scientific statements.					
30 A scientific law is a generalized statement of relationships among natural phenonema.					

Please use the space below if you would like to make any comments on your views about scientific methods and activities not covered in the questionnaire. Thank you for your help.

APPENDIX 5

SURVEY REPORT

Copies of this report were made available to officers of the Local Education Authority involved and to any of the participating teachers or headteachers who requested it.

SCHOOL SCIENCE SURVEY - DUDLEY

REPORT TO PARTICIPATING TEACHERS

Introduction

Copies of the questionnaire were circulated to all schools designated as Middle, Secondary or High School in the Dudley Metropolitan Borough. Some of the Middle Schools cater for the 8-12 age range, while those in the Halesowen district are 9-13. Some of the Secondary/High schools take pupils at 11+, some at 12+ and some at 13+. It was hoped to obtain a representative sample of all those teaching science to the 11-14 age group.

The questionnaire was sent by name to all science teachers in the Secondary/High schools through the LEA internal post. Three copies were sent to the Head of each Middle School with a request to give a copy to everyone teaching science in the school. As the total number of science teachers in the Middle Schools is not known it was not possible to calculate the return rate for that group of teachers.

School Type	Middle	Sec/High	Not known
No. of Science Teachers	-	162	-
No. Completing Questionnaire	20	74	1
%Return Rate	-	46	-

The Teachers

Section 1 of the questionnaire concerned the background of the teachers who responded. (All figures quoted in the following tables are percentages).

Sex:	Male	Female	Not Known
	74	25	1

Position:	Head	2
	Deputy Head	8
	Pastoral/Admin. Post.	5
	Head of Science	30
	Head Bio./Chem./ Phys. etc.	20
	Teacher of Science	35
Subject:	Biology	30
	Chemistry	25
	Physics	23
	General Science	4
	Rural Science	2
	Not Science	16
Qualifications:	Cert. Ed.	36
	B.Ed.	12
	Untrained Graduate	19
	Degree + P.G.C.E.	33

In addition 8% had obtained a higher degree, usually involving some experience of research.

The proponderance of male science teachers among the respondents is not surprising as there are more male than female science teachers in the population as a whole. The spread of position, from Headmasters (still teaching science classes) at the one extreme to part-time temporary teachers at the other was pleasing as it suggested the results of the survey will reflect the views of all those involved in science teaching rather than a sub-group. Respondents ranged from those in their probationary year to those with 30+ years experience of teaching science. The average number of years experience for the teachers as a whole was 12. The presence of a large proportion of untrained graduates (nearly one fifth of the total) reflects D.E.S. policy to allow entry to the profession in shortage subjects of those who leave not trained specifically for teaching.

It was hoped that the survey would reflect the views of those teaching science as most schools do not teach the various science disciplines as separate subjects to the 11-14 age group. However, almost all teachers have been trained in one or two of the specialist disciplines and very few see themselves as having had a training in science as such. As one's own discipline could affect one's approach to teaching a general science course, it seemed reasonable to ask if there was a difference in the distribution of subject specialists between Middle and Sec./High Schools.

School Type:	Middle	Sec/High
Subject:		
Biology/Rural Science	18	35
Chem/Gen. Sci. Phys. Sci.	18	32
Physics	0	30
Not Science	64	3
Total:	100	100

It seems clear from these figures that pupils who have their first introduction to science in a Middle School are almost twice as likely to be taught by a non-scientist (a teacher who did not study a science as his or her main subject at university or college) as they are to be taught by someone with a scientific training. In a Secondary or High school they are extremely unlikely to be taught science by a non-scientist. Even more noticable is the fact that none of the Middle school teachers who replied had studied physics as a main subject, whereas in the Secondary sector approximately a third of the science teachers had done so. These differences are very important if they truly represent the state of affairs in the schools. Since at least one reply was received from 25 of the 26 Secondary/High schools approached, the picture we have obtained of this situation there is probably fairly accurate. In the Middle school sector, replies were received from 13 of the 28 schools approached so the picture there may be incomplete. However, as it is probably that schools with a science specialist, or who have someone with an interest in science, are more likely to reply than others, the percentage of those with science training may be even lower than our results indicate.

Although it is undeniable that these differences exist, they would be important only if it can be shown that the absence of say physics graduates in middle schools is disadvantageous to the pupils. It is possible that the reverse is the case!

Curriculum Projects and Books

Section 2 of the survey was concerned with the use teachers make of published materials. Very few teachers have adopted the Nuffield O'level schemes in their entirety (i.e. taking pupils through to the appropriate examinations) but a larger percentage use some of the material from these courses. Bearing in mind we were concerned mainly with the 11-14 age range, where most schools do not offer separate sciences, it is not surprising that Nuffield Combined Science, together with some material from Secondary Science, proved the most commonly used source.

Percentage of teachers who:

PROJECT	ADOPTED THE COURSE	USE SOME MATERIAL
Nufffield Biology	0	21
Nuffield Chemistry	3	21
Nuffield Physics	0	19
Nuffield Combined Science	0	40
Nuffield Secondary Science	0	31
Schools Council 5-13	0	18
SCISP	0	11

However, it is clear that none of these projects individually is very popular with the teachers who responded. Even Combined Science is only used by 40% of the teachers. SCISP, which is intended for pupils aged 13-16 and therefore could be used from the third form onwards as a source for teaching material, is only used by 11% of the teachers overall; removing Middle schools where it is inappropriate only raises this figure to 14%. As the projects listed represent the main products of the curricular review movement of the 1960s, it might have been expected that a higher percentage of teachers would at least draw on them to some extent.

It was clear that most teachers have difficulty finding suitable books for the 11-14 age range. A few wrote that they preferred not to use books at all and some said that they simply could not afford books for pupils of this age.

No. of Books Recommended	% of Teachers
0	50
1	26
2	17
3	3
4	2
5	1
6	0
7	1

Most of the books mentioned were listed by only one or two teachers. Those mentioned by more than three respondents were:

TITLE	AUTHOR	NO. OF TEACHERS LISTING BOOKS
Science for the 70s	Mees et al.	15
General Science	Windridge	8
Nuffield Biology Texts	-	6
Exploring Physics	Duncan	5

The last two show that the Nuffield movement has some influence while the second indicate that the traditional approach to science teaching is still valued by some. Two teachers mentioned that that they prepared and duplicated their own work cards rather than use any published materials.

As teachers find it difficult to obtain really suitable books for their pupils it is relevant to ask what they hope to find in a book and what their priorities are.

The survey questionnaire listed seventeen criteria which teachers might consider important when choosing books. Each criterion was given a score depending on the number of teachers regarding it as having a high level of importance. Thus it was possible to rank the criteria from most to least impor ınt. For example, 'Accuracy of factual information' was rated 'very important indee l' by 82% of teachers and nobody thought it of no importance. At the other extreme 'Qualifications of authors' was regarded as 'not important at all' by 47% of respondents and only 1% regarded this as of great importance. The 10 most important criteria were:

RANK:	CRITERION	SCORE
1	Accuracy of factual information	372
2	Level of reading difficulty	346
3	Price and value for money	341
4	Quality of illustrations	330
5	Logical organization of concepts introduced	320
6	Emphasis given to applications of science in present society	309
7	Strength of binding and cover	298
8	Emphasis on 'scientific method' in test	265
9	Inclusion of data from which pupils can draw conclusions	
10	Emphasis on problem solving as a scientific acitivity	250

Obviously teachers value highly both the accuracy of textbooks and their value for money. With books being so expensive, one which is durable and not overpriced has a decided advantage over one less well produced.

A statistical technique called "factor analysis" was applied to the responses, since it shows whether certain criteria are connected in that teachers responded to them in similar ways. Two of the low-ranked criteria (concerned with inclusions of examination questions and coverage of examination syllabus) were strongly linked with each other but with nothing else. Similarly "price and value for money" was linked with "strength of binding and cover".

"Level of reading difficulty" and "logical organisation of concepts introduced" were positively related but both were strongly negatively related to "qualifications of authors', perhaps reflecting a concern that some authors, who may be well qualified in science, are unable to write books which communicate successfully to the younger or less able pupil.

The factor analysis also showed a strong link between five other criteria. These were:

Suggestions in book for pupil investigations
Inclusion of data from which pupils can draw conclusions
Emphasis on 'scientific methods' in text
Inclusion of alternative theories
Emphasis on problem solving as a scientific activity.

Although not all teachers rated these criteria high in importance, those who did may represent a group who demand that a book should not merely be factually accurate but also present science as an ongoing activity which may be distinguished from other human activities by its distinct methodology.

If one regards this as a desirable attribute of science teachers, it is interesting to note that there were significant differences in the response to these criteria by teachers with different subject backgrounds, the highest positive response being from those with a non-science background. As most of the non-science trained teachers are in the Middle schools, this also produced a significant difference between the two types of school. It appears therefore that pupils who are introduced to science in a Middle school are more likely to be given books which emphasise science as a process rather than a collection of factual information to be learned in isolation from the methods used to establish it.

Practical Work

Section 3 of the survey was concerned with the opinions of teachers about the value of practical work and their reasons for giving pupils practical experience in lessons.

The statement which provoked the strongest agreement from respondents was 'Pupils need clear instructions about practical procedures'. Obviously teachers want the practical lessons to achieve something rather than just be enjoyable in their own right.

The next few statements are given in their rank order according to the strength of positive reaction they received.

Rank	Statement
2	Doing experiments makes learning science more enjoyable.
3	Practical work is an integral part of pupils' scientific investigation.
4	Practical work arouses interest in pupils.
5	In practicals pupils develop manipulative skills.
6	Practical work is good for illustrating scientific principles.
7	Pupils would get a false idea of science if they did no practical work.
8	Practicals teach pupils the importance of leaving evidence for their opinions.
9	Practicals give pupils first-hand experience of scientific concepts they have been taught.
10	Pupils get a sense of achievement when they obtain the right results.

Overall it seems that teachers include practical work to increase pupil interest, enjoyment and feelings of participation (2, 4, 8 and 10 above) as well as to promote skill learning (5). There is a strong feeling that science cannot be taught properly unless at least some practical work is included (3 and 7), but an important reason for introducing practical work is to reinforce the material taught in theory lessons (6 and 9) even if teachers do not always explicitly accept this. (The strongest negative reaction was against the statement 'Doing practical work is a way of showing pupils that what I say is true!').

Again it was possible to employ statistical techniques to discover whether the statements could be grouped together. This suggested that the most coherent group of statements were those concerned with using practicals so that pupils are actually involved in an open-ended investigation themselves, although these statements were not rated very highly overall. Thus there is probably a substantial minority of teachers who do feel this use of practicals is important. Other coherent groups of statements concerned including practical work to give a true picture of science and improving practical techniques.

We could not find any systematic differences between teachers who rated one group of statements higher than another, so it would seem that a teacher's reasons for using practical work are personal, perhaps related to his own teaching philosophy or his philosophy of science, rather than being related to the type of school he works in or his educational background.

Philosophy of Science

The last section of the questionnaire was concerned with the tea :ers' view of science as an activity. Books on the philosophy of science (such as Kar Popper's book 'The Logic of Scientific Discovery') propose that science should be seen as an ongoing human activity, just as liable to failure as any other activity we indulge in, rather than as a definitely and permanently established body of factual knowledge. Ranking responses to statements in this section showed that the majority of teachers are aware of this.

Rank	Statement
1	Contrary evidence should lead a scientist to question even a widely held theory he had previously accepted.
2	Our scientific theories may need to be revised or improved in the future.
3	Scientific knowledge must be based on a large number of factual observations.
4	Hypotheses are essential if one is to decide what experiments to do next.
5	Scientific societies and journals exist to promote the criticism and exchange of ideas.
6	Scientific discoveries are the result of the interaction of ideas and experiment in the solution of problems.

Clearly these statements are supportive of the view that scientific knowledge is open to continual change. Indeed the statement provoking the strongest negative response was 'Scientific laws have been confirmed by so much evidence that they could never be proved wrong'.

As in the previous section it is possible to group similar questions; the major group expressed the view that science is a process rather than an established body of knowledge. There was a statistically significant difference in relation to this view, between men and women teachers, with men more likely to see science as a process. There were no significant differences between teachers trained in Biology, Chemistry or Physics, but those trained in subjects other than the sciences were more likely to see science as a body of knowledge. Although the difference between Secondary/High school teachers and Middle school teachers was noticeable, it was not great enough to be regarded as statistically significant - the higher proportion of non-science trained teachers and women teachers in Middle schools probably accounts for the differences observed.

Teachers who saw science as a process tended to be those who valued practical work for giving pupils experience of scientific investigation, whereas teachers who incline to the view that science is an established body of knowledge tended to be those who used practical work to reinforce theory work in lessons.

Summary of Conclusions

1) Teachers were more inclined to use material from several published sources than adopt a curriculum project in its entirety.

2) The books actually available to teachers do not, in general, satisfy the perceived needs of science pupils in the 11-14 age range.

3) Middle and Secondary school teachers do not judge books by identical criteria.

4) Most teachers use practical work mainly to improve pupil interest and to reinforce material taught in theory lessons.

5) The personal 'philosophy' of teachers as regards the nature of science varies greatly and affects the way in which they use practical work in their lessons.

APPENDIX 6

TEACHER INTERVIEW SCHEDULE

1. How often do you include some kind of practical work in your lessons?
2. Where do you fit the practical into your typical lesson plan? Do you have separate practical lessons?
3. Why do you do it this way? Have you always done it this way, or have you tried different approaches?
4. Do you prefer to use teacher demonstration or a class practical? Give reasons.
5. What are your main reasons for including practical work?
6. Do you think pupils benefit from practicals? In what ways?
7. How do you introduce a practical to a class?
8. Do you use discussion with classes, either before or after practical work?
9. Why do you think science should be taught in school at all? What does it contribute to the curriculum?
10. Is science different from other subjects?
11. Does science differ from other subjects only in factual content or are its methods different as well?
12. Do you think it makes sense to talk of <u>one</u> scientific method?

Note: The points listed above were not asked as direct questions, but were taken as the basis for a discussion. Although the order varied, all the points were covered in some way with all of the teachers interviewed.

APPENDIX 7

UNDERSTANDING SCIENCE MEASURE

This measure is based on SUM with the philosophical questions modified to contain H, I and V alternative answers.

THIRD FORM UNDERSTANDING SCIENCE MEASURE.

DO NOT WRITE ON OR MARK THIS QUESTION PAPER IN ANY WAY.

1. A scientist expected to get a certain result from an experiment. When he did the experiment carefully the result was different from what he expected. He ought to think
   A. I should not have made a prediction before doing the experiment.
   B. I will improve the experiment to get the correct result.
   C. If I did the experiment properly, there was something wrong with my prediction.
   D. I should have made more observations before making a prediction.

2. Most important scientific discoveries come about as a result of
   A. carefully done experiments and accurate measurement.
   B. the bright ideas of scientists, tested by experiment.
   C. careful observation and recording of natural events.
   D. scientists searching for the truth.

3. Science may help with all of these EXCEPT
   A. improving our standard of living.
   B. growing more beautiful flowers.
   C. showing that lying is wrong.
   D. making clothes more hard wearing.

4. A scientist is open-minded if he
   A. is always trying to find more observations.
   B. listens to the ideas of people who disagree with him.
   C. is always ready to learn new scientific facts.
   D. believes everything he is told.

5. Which of the following is the <u>best</u> description of the methods used by scientists?
   A. Observing carefully and looking for general patterns.
   B. Using experiments to discover more facts about the world we live in.
   C. Trying to improve the accuracy of measurements.
   D. Thinking of possible answers and then testing them.

6. When a scientist has established a new theory, he has
   A. developed new ideas and understanding.
   B. uncovered a true law of nature.
   C. collected a lot of evidence in support of the theory.
   D. not done anything that is very important.

7. The people and government of the country affect science
   A. not much because scientists are isolated from the rest of society.
   B. not much because scientists are not interested in what the people or the government think.
   C. a great deal because the education and support given to scientists depends on how people feel about science
   D. a great deal because most scientists have to do what the government tells them.

8. Which of the following is the <u>best</u> list of what scientists study?
   A. atoms, molecules and stars.
   B. rockets, satellites and space travel.
   C. plants, animals and diseases.
   D. matter, energy and living things.

9. Scientists are in NO way responsible for
   A. the colour of our clothes.
   B. the colours of the rainbow.
   C. the pollution of rivers.
   D. the world food problem.

10. Which one of the following is the <u>best</u> statement about scientific knowledge?
   A. Scientific knowledge is made up of all the facts we know about the universe.
   B. Scientific knowledge is based on the ideas and experimental results of earlier scientists.
   C. Scientific knowledge is the only kind of knowledge we can be sure is true.
   D. Scientific knowledge is based on very large amounts of experimental evidence and observation.

11. The most important thing that biology, chemistry and physics have in common is that they
   A. need very intelligent people with University training.
   B. involve learning large numbers of facts.
   C. rely on making a lot of careful observations.
   D. depend on ideas and experimental testing.

12. Potassium, nitrogen and phosphorus are three chemicals. Experiments are planned to learn something about the effect of potassium on the growth of a plant. Nitrogen and phosphorus are already known to be necessary. One group of plants is grown in soil containing nitrogen and phosphorus but without potassium. A second proup should be grown in soil containing
   A. potassium only.
   B. nitogen and potassium, but no phosphorus.
   C. potassium and phosphorus, but no nitrogen.
   D. nitogen, phosphorus and potassium.

13. In the past, important scientific discoveries were made by people who worked on science as a hobby, for example statesmen or businessmen. Why is this less true today?
   A. People are less interested in science than they used to be.
   B. Most scientific research today requires many years of special preparation and training.
   C. No important discovery can be made today without expensive equipment which only scientists possess.
   D. Only scientists have the abilities needed to make important Discoveries.

14. In deciding whether to accept a new theory, scientists take a decision of the basis of

A. whether or not the theory is true.
B. the amount of evidence there is to support the theory.
C. their personal ideas as well as the evidence for the theory.
D. the reputation of the scientist proposing the new theory.

15. A doctor says that 90 out of 100 of his patients who had colds recovered in one day when they used a brand new medicine. This should be accepted as important evidence only if

A. the doctor had been trained for several years as a research scientist.
B. the year before only 3 patients out of the same 100 had recovered from their colds in a day.
C. the new medicine was already known to be good for curing other illnesses.
D. the doctor had at least another 100 patients who did not have colds.

16. When new evidence does not fit a scientific theory, scientists should

A. question the theory as the new results do not support it.
B. question the new evidence as it does not agree with facts that are already accepted as true.
C. look for much more evidence before doing anything.
D. ignore it and carry on as before.

17. Experiments and tests are used by scientists to

A. prove that what they say about the world is true.
B. inquire into the mysteries of nature.
C. provide large amounts of evidence observed in controlled conditions.
D. checking predictions made from their observations and ideas.

18. Before proposing a new theory about the way mountains were built up, a geologist (a scientist who studies the Earth) would first

A. rule ou all previous attempts to explain mountain-building.
B. see if it explains the known facts about mountain-building.
C. study a geological map of all the mountains in the British Isles.
D. see if his theory would be useful to mining engineers.

19. The results of scientific discoveries are

A. always good, because they help mankind.
B. usually good, because scientists always tell the truth.
C. sometimes bad, because scientists are no better than people in other jobs.
D. usually bad, because they help to destry nature.

20. Other scientists completely ignored the results of Mary Jones's experiments. This was NOT because

A. she is dishonest.
B. she did the wrong experiment.
C. she got the results mixed up.
D. she is a woman.

[illegible] 1979

APPENDIX 8

ABBREVIATIONS

1. Scales from Questionnaires and Tests:

S: from Section 3 of teacher questionnaire, indicates how much a teacher regards practical work as generally useful in science lessons.

T: from Section 3 of teacher questionnaire, measures teacher belief that teaching practical technique is important as an end in itself.

H: from Section 3 of teacher questionnaire, measures teacher inclination to use practical work in science lessons as a test of predictions or of pupils' ideas.

I: from Section 3 of teacher questionnaire, measures teacher inclination to use practical work in science lessons mainly to increase the range of observations available to pupils.

V: from Section 3 of teacher questionnaire, measures teacher inclination to use practical work in science lessons to demonstrate the truth of material previously covered in theory lessons.

PH: a) from Section 4 of teacher questionnaire, measures strength of agreement with the hypothetico-deductivist philosophy.

b) from Understanding Science Measure, pupil equivalent of above.

PI: a) from Section 4 of teacher questionnaire, measures strength of agreement with the inductivist philosophy.

b) from Understanding Science Measure, pupil equivalent of above.

PV: a) from Section 4 of teacher questionnaire, measures strength of agreement with the verificationist philosophy.

b) from Understanding Science Measure, pupil equivalent of above.

BH: from Section 2 of teacher questionnaire, indicates how important teacher rates the methodological content of science textbooks.

OT: from Understanding Science Measure, consists of the unmodified non-philosophical questions from SUM.

HTOT: total score obtained by adding an individual's deviations from the mean on scales H' and PH'.

ITOT: total score obtained by adding an individual's deviations from the mean on scales I' and PI'.

VTOT: total score obtained by adding an individual's deviations from the mean on scales V' and PV'.

Note: Scales H', I', V', PH', PI' and PV' are derived from scales H, I, V, PH, PI and PV respectively by applying 'correction' formulae as given in Table 4.8.

2. Types of Teacher:

H type: supports hypothetico-deductivist philosophy and uses practicals in science lessons to test his predictions and the ideas of pupils; has a problem-solving teaching style.

I type: supports inductivist philosophy and uses practicals in science lessons mainly to increase the range of observations available to pupils; has an enquiry based teaching style.

V type: supports verificationist philosophy and uses practicals in science lessons to demonstrate the truth of theoretical concepts previously taught; has a teaching style based on transfer of factual information.

O type: has no discernible philosophy of science and uses practical work often to increase pupil enjoyment or as a visual aid.

3. Groups in Teaching Experiment:

AH: group of above average ability receiving H type teaching.

AI: group of above average ability receiving I type teaching.

AV: group of above average ability receiving V type teaching.

BH: group of below average ability receiving H type teaching.

BV: group of below average ability receiving V type teaching.

4. Tests and Examinations:

SSS: School Science Survey: the questionnaire used with teachers both in the pilot and, with modifications, in the main surveys; contains four sections: 1. Background, 2. Curriculum Projects and Books, 3. Practical Work in Science Teaching, 4. Philosophy of Science.

USM: Understanding Science Measure: twenty item multiple choice test made up of ten philosophical questions and ten other questions copied from SUM; philosophical questions rewritten in such a way as to include answers corresponding to the hypothetico-deductivist, the inductivist and the verificationist philosophies.

UST: Understanding Science Test: twenty item multiple choice test made up of ten philosophical questions and ten other questions copied from SUM; philosophical questions rewritten to provide inductivist answers in place of the hypothetico-deductivist answers in SUM.

Appendix 8: Abbreviations

SUM: Science Understanding Measure (Coxhead & Whitfield 1975).

TOUS: Test on Understanding Science (Cooley & Klopfer 1961).

FAST: The Facts about Science Test (Stice 1958).

NOSS: Nature of Science Scale (Kimball 1967).

SPI: Science Process Inventory (Welch & Pella 1967).

ISTS: Inquiry into Science Teaching Strategies (Lazorowitz & Lee 1976).

STOS: Science Teaching Observation Schedule (Eggleston et al. 1975).

GCE: General Certificate of Education: single subject examination taken at age of 16+ by about top 20% of ability range; also known as O level (ordinary level). There are also GCE A level (advanced level) examinations taken at 18+. University places are usually given on the basis of A level results.

CSE: Certificate of Secondary Education: single subject examination taken at 16+ and intended for the 40% of the ability range below that taking GCE examinations. A grade 1 CSE pass is regarded as equivalent to a GCE O level pass.

IEA: International Association for the Evaluation of Educational Achievement (Comber & Keeves 1973).

5. Curriculum Projects:

BSCS: Biological Science Curriculum Study: Grobman A.B., University of Colorado/National Science Foundation; started by American Institute of Biological Sciences, 1958.

CBA: Chemical Bond Approach: Strong L.E., Earlham College/National Science Foundation; started at Reid College, Oregon, 1957.

CHEM Study: Chemical Education Materials Study: Pimental G.C., University of California/National Science Foundation; started at Harvey Mudd College, California, 1959.

PSSC: Physical Science Study Committee: Zacharias J.R., Educational Services Inc./National Science Foundation; started at Cambridge, Massuchusetts, 1956.

HOSC: History of Science Cases Instructional Method: Klopfer L.E. and Cooley W.W. 1963.

SCISP: Schools Council Integrated Science Project: Hall W.C. and Mowl B.S., Chelsea College/Schools Council; started at Chelsea College, University of London, 1969.

6. Significance:

*	significant at the 0.05 (5%) level of probability.
**	significant at the 0.01 (1%) level of probability.
***	significant at the 0.001 (0.1%) level of probability.
ns	not significant, could be due to chance.

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