An investigation of student teachers' teaching of difficult ideas in chemistry

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ABSTRACT

It is not surprising that, in view of the conceptual and theoretical nature of chemistry, there are many ideas in chemistry that pupils find difficult. A review of the work in this area shows an extensive body of literature in which pupils' misunderstandings of key ideas in chemistry in the 12 – 15 age range are documented. However, much of this research does not give any assistance in terms of the development of teaching strategies or implementation of intervention packages. In fact, it appears from the literature that comparatively little research has been carried out into how student teachers teach ideas in those areas of chemistry where misunderstandings arise.

This study investigated how student teachers draw on the guidance they are given in their training course about dealing with pupils' misunderstandings in chemistry. The project is a case study of practice in one institution and is also characterised by aspects of an action research project. A baseline study was carried out to establish a benchmark of current practice among student teachers. This was followed by the development and implementation of an Intervention Package to assist a second group of student teachers in teaching these difficult ideas. Data were gathered by means of classroom observation, questionnaires, interviews and analysis of lesson plans.

A theoretical framework was developed to assist in the analysis of the baseline data and the post-intervention data. Models of educational evaluation were used to develop a strategy for assessing the effectiveness of the Intervention Package. The results of this assessment indicate that the Intervention Package was successful in a number of areas, e.g. increasing the awareness of the student teachers of the problems involved in teaching difficult ideas, encouraging the student teachers to use particular types of resources in their teaching, helping them to develop new teaching strategies and encouraging them to foster a greater climate of understanding in the classroom. The attitude of the student teachers towards the material covered in the Intervention Package was found to be very positive since they viewed this material as a practical strategy to help their teaching of difficult ideas in chemistry.

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Declan Kennedy
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Author's Declaration

This is to declare that this work is an original study, carried out by the undersigned, which is being presented to a University for the first time as the requirement for the award of a PhD degree.

Declan Kennedy

Signed by the author

CHAPTER 1

INTRODUCTION

1.1 The background and origins of the research question

This research study emerged out of an attempt to improve aspects of the training course for science teachers in a university teacher-training course in Ireland. The research question was formulated as an outcome of a need perceived by the researcher in his transition from teaching science for 23 years in a secondary school to his appointment as lecturer in science education at university level. There is growing concern in Ireland at the fall-off in the number of pupils taking science beyond the age of 15 (Department of Education and Science, 1998 ;Regan and Childs, 2003). Whilst science is not a compulsory subject in the secondary school system in Ireland, about 98% of pupils in the 12 – 15 age group take science for the Junior Certificate examination in the third year of their second-level education. This is a national examination set by a government agency called the *State Examinations Commission.* After the completion of the Junior Certificate course, pupils must study seven subjects for their Leaving Certificate examination. Of these seven subjects, four are compulsory; Irish language, English, Mathematics and a modern language. Unfortunately, the number of pupils who opt to take science subjects has been steadily declining and, of the 50 000 approximately who take Junior Certificate science, only 23 000 opt for biology, 9000 opt for physics and 7000 opt for chemistry. In research carried out to determine the reasons for this decline, one of the most common reasons cited by pupils was that science was a "difficult" subject (Department of Education and Science, 1998 p. 60). It is not surprising that, in view of the conceptual and theoretical nature of various aspects of science, many pupils find difficulty with understanding many areas of science.

Some research evidence (discussed in Chapter 2) indicates that a contributory factor to the persistence of misunderstandings is the way in which such ideas are taught. Science teachers may not always teach in ways that challenge or acknowledge misunderstandings. Therefore, pupils' grounding in some of the key ideas that underpin science may be poor and contribute to the idea that science is "difficult". In fact, persistent misunderstandings may act as significant impasses to the development of accurate understanding of science ideas. Thus, acknowledgement and resolution of these ideas will contribute positively to pupils' learning at all stages.

In terms of chemistry, there is an extensive body of literature documenting pupils' misunderstandings of key ideas at secondary level. Research discussed in Chapter 2 suggests that these misunderstandings are widespread among pupils and are quite resistant to change. However, given the nature and extent of the literature on these misunderstandings, there is a great dearth of research into how teachers teach ideas in those areas of science where these misunderstandings arise.

A great deal of the research into pupils' misunderstandings of ideas in science relies on a constructivist approach based on theories about how children learn rather than how teachers teach. Much of the research appears to be characterised by detailed work documenting misunderstandings in specific areas with relatively little follow up in terms of development of teaching strategies or intervention packages for implementation in schools.

The circumstances described above point to a desirability of carrying out research into how student teachers teach difficult ideas in chemistry. This study therefore addresses the following research question: ***How do student teachers draw on the guidance they are given in their training course about dealing with pupils' misunderstandings in chemistry?***

It is hoped that the research carried out into how student teachers teach difficult ideas in chemistry will assist in the development of strategies to try to overcome pupils' misunderstandings of key ideas in science.

1.2 Initial teacher training in Ireland

In Ireland, after completing their undergraduate degree, student teachers must obtain the qualification of the Higher Diploma in Education (H.Dip.Ed) in order to be recognised as qualified to teach in second-level schools. This is a one-year course, entry to which is highly competitive. In general, only graduates with a first or second class honours degree are offered places on the H.Dip.Ed course. The course is a full time one in which the student teachers spend their mornings in local schools and their afternoons at the university. The student teachers must undertake teaching practice in schools within a thirty-mile radius of the university. Each student teacher is supervised at least five times during the academic year by his/her own supervisor and by a visiting supervisor. The two supervisors decide on a teaching practice grade to be awarded to the student teacher at the end of the academic year. A sample of the student teachers is also visited by an external examiner.

Students who wish to qualify as science teachers undertake the "science methodology" component of the course. (All students study core subjects like the psychology of education, sociology of education, history of education and philosophy of education.) As part of the science methodology component of the course, student teachers attend lectures, tutorials, practical sessions, micro-teaching workshops and ICT in science teaching sessions. The science methodology course is assessed by means of a project carried out by the students. The overall grade awarded is based on their teaching practice grade, their project mark and the marks obtained in three written examination papers.

All of the student teachers who participated in this study are Higher Diploma in Education students undertaking the science methodology component of the course.

1.3 What is in each chapter?

Chapter 2 presents a review of the literature with regard to the difficulties that pupils encounter in their study of science. It discusses the reasons why pupils in secondary schools find some ideas in science difficult and describes key features of research into pupils' misunderstandings of selected ideas in chemistry that appear to present pupils with difficulties. It also discusses the implications for teaching and learning that arise out of research into pupils' misunderstandings and examines the key features of research into how beginning teachers teach difficult ideas in science.

Chapter 3 describes the mechanism by which a theoretical framework was developed to assist in the analysis of the data collected. The development of the theoretical framework by surveying the literature for other related theoretical frameworks is outlined. The usefulness of this framework in terms of the provision of a detailed map of various factors relating to the way student teachers teach, particularly in relation to their teaching of difficult ideas, is discussed. Finally, the potential application of the framework map as a useful frame of reference for identifying changes in practice (if any) as a result of the Intervention Package is summarised and discussed.

Chapter 4 outlines the nature of the research methodology employed in this study and describes the various research tools used to gather data: classroom observation, semi-structured interviews, questionnaires and lesson plan analysis.

Details are also given of the methodology used to analyse the data collected as well as the steps taken to ensure the reliability and validity of the data collection tools and the data analysis.

Chapter 5 considers the strategy to assess the extent to which the Intervention Package has been successful in achieving its aims. Some key research projects in the area of curriculum innovation are first examined in order to produce a model to examine the extent to which the aims of the Intervention Project have been achieved. The findings from these research projects are then used to establish the model within which the evidence gathered in this study may be analysed and discussed.

Chapter 6 reports and discusses the analysis of the data gathered in the baseline study. Details are given of the method by which the items arising from the baseline data are mapped on to the various categories developed in the theoretical framework. Based on the results of this analysis, a detailed picture of the teaching of difficult ideas by the student teachers in the baseline study is outlined.

Chapter 7 discusses the assessment of the Intervention Package using three themes synthesised from various models for educational evaluation. The post-intervention data are analysed by means of the same framework used to analyse the baseline data and the results discussed in terms of the extent to which the aims and outcomes of the Intervention Package have been achieved. The picture that emerges of the teaching of difficult ideas by the student teachers in the post-intervention study is then discussed.

Chapter 8 summarises the main findings of the study by considering those areas where the Intervention Package appears to have had significant impact. It also examines those areas where the Intervention Package appears to have had little impact and discusses some possible reasons for this. In addition, some of the limitations of the study are identified and discussed. Finally, the significance of this research project in terms of how the study adds to current knowledge is reviewed and discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

As most science teachers are aware, the study of science is a struggle for many pupils. The learning outcomes that follow from the teacher's instruction can often be very disappointing in terms of how much the pupils are able to remember, how well the pupils understand the material and how much of the material they are able to apply in their everyday lives. Why do pupils encounter such difficulty in learning science?

Most of the work that has been done this area was carried out relatively recently - mainly in the 1980s and 1990s. The science education literature of these two decades contains numerous studies of the difficulties that second-level pupils have in coming to terms with various scientific phenomena (Driver et al., 1994; Schofield et al., 1989). These studies clearly show that pupils' conceptions are often inconsistent with the scientific concepts that they are expected to learn (Driver, 1989; Gilbert, Osborne and Fensham, 1982). A survey of the literature shows that these concepts are referred to using terms like *alternative frameworks*, *misconceptions*, *alternative conceptions* and *misunderstandings* (Driver and Easley, 1978; Driver et al., 1994; Erduran, 2003; Gilbert and Swift, 1985; Johnstone, 2000; Novak, 1988; Taber, 2003). In this study we will use the term ***misunderstanding*** when we refer to any concept that differs from the commonly accepted scientific meaning of the term.

Research has also shown that these misunderstandings influence subsequent learning and can be highly resistant to change (Novak, 1988; Nussbaum and Novick, 1982; Barker, 1994). Thus, these misunderstandings have major implications for both practitioners and researchers in the area of science education. Particular attention must be paid to the method used to teach certain concepts in science – especially those concepts that are known to cause difficulties for pupils. Thus, the main purposes of this chapter may be summarised as follows:

- To discuss the reasons why pupils in secondary schools find some ideas in science difficult – particularly in the area of chemistry.
- To describe key features of research into pupils' misunderstandings of selected ideas in chemistry that appear to present pupils with difficulties.
- To discuss the implications for teaching and learning that arise out of research into pupils' misunderstandings.
- To discuss the key features of research into how student teachers teach difficult ideas in science.
- To discuss how the above areas of research have determined the shape of this research study and the methodology adopted.

2.2 What is learning science all about? Why do problems often arise?

The literature on children's learning is very extensive. The main aim of most of this research is to try to construct a model of the process of learning so that this model may be used by those involved in curriculum development and also used by practising teachers in developing more effective teaching approaches. It is not appropriate to this work to give a detailed critique of the huge volume of written material in the area of how children learn. However, it is necessary to give a brief overview of the major contributions to our knowledge in this area – particularly with regard to those whose theories have been used in an attempt to comprehend children's understanding of specific ideas and concepts in science.

In the late 1960s and early 1970s there was considerable interest in Piaget's model of learning (Piaget and Inhelder, 1974). The model proposed that children passed through four main stages of psychological development. The first two stages can be identified in children up to about the age of seven. These first two stages are called *sensory-motor* and *pre-conceptual.* However, at around the age of seven, children begin to show that they are capable of ***concrete operational*** thought. This is developed in relation to objects that can be seen or felt or easily visualised. For example, when a ball of Plasticene is moulded into a new shape and then rolled back into a ball, the child may realise that the amount and weight of Plasticene remains unchanged through the cycle. Important characteristics of concrete operations are that they can cope with only a limited number of variables and that they allow the child to *describe* situations but not to *explain* them. The fourth stage in Piaget's model is called **formal operational** thinking. Formal operational thinking is associated with the use of hypothetical models for the purpose of explaining things. It is characteristic of situations involving several variables and also of the use of the mathematical notions of ratio and proportion. In this stage the child is able to handle abstract ideas and, when carrying out scientific investigations, appreciate that many factors may be influencing a situation. The child would understand that to investigate one of these factors, the others must be held constant.

The significance of Piaget's work for science teachers is that it would appear that some form of learning cannot be achieved until children reach the formal thinking stage. Piaget's experimental work led him to believe that formal thinking can take place in 12-year old children (Scaife, 2000). However, subsequent research (Shayer et al. 1976, Lawson and Renner, 1978) indicates that most children develop formal thinking much later than this and some do not develop it at all. Piaget's model was used to try to explain why children were encountering difficulties learning school science and it was suggested that the model could be used as a basis for constructing more appropriate learning materials. It has been argued (Shayer and Adey, 1981) that familiarity with the idea of Piaget's stages of cognitive development gives teacher a better insight into devising approaches to developing science curricula. Shayer and his co-workers were major advocates of Piaget's model and used it to explain why pupils found it difficult to understand some ideas in science and why some practical science activities were difficult to carry through to expected conclusions. This work has lead on to the development of interesting research in the area of cognitive acceleration (Adey, 1989; Adey et al., 1995; Moran and Vaughan, 2000; Simon, 2002) where intervention materials have been designed to promote cognitive development.

Learning science involves coming to terms with and being able to use the various concepts of the scientific community. In reaching this understanding, the pupil is involved in trying to make sense of the scientific view of the world against a background of the pupil's own existing ways of thinking about everyday phenomena. The perspective on learning that draws attention to the active role of the learner and examines the interplay between the pupil's own knowledge and the material being taught, is referred to as a constructivist view of learning (Driver and Oldham, 1986). This view of learning has its origins in the work of the "personal construct theory" of the American psychologist George Kelly (Kelly, 1971). From his work as a school psychologist, Kelly gained an insight into the process of learning and proposed his famous "personal construct theory". Personal constructs are the dimensions that we use to conceptualise aspects of our day-to-day world. Kelly proposed a view of people actively engaged in making sense of and extending their experience of the world through these personal constructs. Cohen et al (2000) summarise the importance of Kelly's personal construct theory as follows:

> " Education, in Kelly's view, is necessarily experimental. Its ultimate goal is individual fulfilment and the maximising of individual potential. In emphasising the need of each individual to question and to explore, construct theory implies a view of education that capitalises upon the children's natural motivation to engage in spontaneous learning activities. It follows that the teacher's task is to facilitate children's ongoing exploration of the world rather than impose adult perspectives upon them"
>
> (Cohen et al, 2000 p. 337)

Working in the context of the school science curriculum, Driver and Bell (1985) identified a set of key points that they referred to as a constructivist view of learning. The key points that they identified were:

- Learning outcomes depend not only on the learning environment but also on the prior knowledge, attitudes and goals of the learner.
- Learning involves construction of knowledge through experience with the physical environment and through social interactions.
- Constructing links with prior knowledge is an active process involving the generation, checking and restructuring of ideas and hypotheses.
- Learning science is not simply a matter of adding to and extending existing concepts, but may involve their radical reorganisation.
- Meaning once constructed can be accepted or rejected. The construction of meaning does not always lead to belief.
- Learning is not passive. Individuals are purposive beings who set their own goals and control their own learning.
- Pupils frequently bring similar ideas about natural phenomena to the classroom. Some constructed meanings are shared by many pupils.

There has been considerable debate on the extent to which constructivist learning theory has become associated with a particular model of instruction.

A number of writers have proposed instructional strategies based on constructivist principles (Driver and Oldham, 1986; Hewson and Hewson, 1988; Nussbaum and Novick, 1982; Osborne and Freyberg, 1985). Some common elements emerge from these proposed instructional strategies:

- Provide opportunities for pupils to make their ideas explicit.
- Encourage the restructuring of pupils' conceptions through a range of strategies such as discussion, exchanging ideas, demonstration or experience with conflict situations.
- Allow pupils the opportunity to apply these new conceptions to experience their fruitfulness.

Some researchers in this area (White and Gunstone, 1989) emphasise the importance of pupils being encouraged to reflect on their understandings and to take greater responsibility for their own learning. They argue that unless pupils employ these strategies, it is unlikely that cognitive restructuring will occur.

However, from a survey of the literature in the area of the use of constructivist learning theory in science teaching, it is clear that several authors question the appropriateness of linking any particular teaching approach to constructivist learning theory. Matthews (1994) argues that many so-called constructivist teaching techniques are not unique to constructivism and he criticises the extrapolation of constructivist learning theory to curriculum and pedagogical issues. He argues that the basic tenet of constructivism (i.e. that pupils have prior ideas of their own and that these ideas may obstruct the learning of new ideas) is not a new idea and most teachers are aware of this. He also argues that the claim of advocates of constructivism that knowledge is constructed by the learner is misleading and based on a false view of scientific knowledge. He points out that most science learning involves being told by someone who already understands the scientific view and it is misleading to imply that pupils can construct scientific knowledge for themselves since learning involves induction into an agreed way of thinking about natural phenomena. Similar arguments are also made by Solomon (1994) and Ogborn (1997).

Millar (1989) has questioned the linking of constructivism with a particular model of instruction. He points out the difference between claiming constructivism as a model of learning and constructivism as a model for the design of teaching strategies. The fact that learning can be thought of as the assisted construction of more powerful explanatory ideas does not lead logically to any conclusions about how learners can be encouraged to do this mental construction or reconstruction. It does not follow from a constructivist view of learning that teaching has to be planned in a particular way in order to be effective. He points out that constructivism has an important role to play in mapping the general features of pathways that individuals follow in order to achieve more productive understandings. This may help to better inform the process of curriculum selection, sequencing and pacing. Millar also proposes that rather than attempting to identify a constructivist-based model of instruction, it may be more productive to focus on increasing the active involvement of pupils, as this is a requirement for reconstruction to take place. Garnett et. al (1995) support the view of Millar and agree that science teaching is not about developing personal theories about phenomena but about coming to share, at some level, in the consensually held theories of science.

Another criticism of constructivism concerns its lack of a theoretical framework. While it documents what children do and do not understand, it does not tell us why some ideas are difficult and others easier. This has resulted in some researchers in this area to go back to the Piagetian emphasis on domain-general thinking skills (Kuhn et al., 1988) and other researchers towards an emphasis on metacognition (the value of reflection by the learner on the actual process of learning) as a means of enhancing that learning (White and Gunstone, 1989).

An interesting example that may be used to show the conflict between everyday ways of talking about phenomena and the scientific description is that of atmospheric pressure (Leach and Scott, 2000). The action of drinking a liquid through a straw is described in everyday language as "sucking". Children learn this concept from a very early age. However, difficulties arise when this concept is encountered in science lessons. The teacher is faced with the challenge of introducing pupils to the scientific way of interpreting and explaining this phenomenon in terms of atmospheric pressure. Establishing a shared understanding between the pupil's everyday knowledge and the more formalised scientific knowledge is a source of great potential difficulty. Some of the sources of this difficulty are summarised in Table 2.1

Everyday knowledge	Scientific knowledge
1. Commonsense ways of talking and thinking	1. More formalised ways of talking and thinking.
2. Developed and reinforced by growing up in a culture	2. Developed and validated by scientific communities.
3. Learned and reinforced subconsciously through everyday communication	3. Learned through explicit teaching.

Table 2.1 Some characteristics of everyday knowledge and scientific knowledge

Thus, learning science involves the pupil in developing ways of thinking about phenomena about which we already talk in familiar ways. Not only does science offer a different way of thinking about and explaining these phenomena, but also the scientific view can appear to be counter-productive and challenging the common-sense ideas about these phenomena. Wolpert (1992) refers to this conflict as the "uncommonsense of science" and Leach and Scott (1995) discuss the problem in terms of a "learning demand". The learning demand can be thought of as a description of the differences between everyday and scientific ways of thinking about the world and the challenges that pupils face in coming to an understanding of scientific accounts of phenomena. This learning demand can be caused by various kinds of differences e.g. differences in the conceptual tools used, differences that relate to basic assumptions about the world (ontological assumptions) and differences that relate to the nature of the knowledge being used (epistemological assumptions). Thus, in the case of the air pressure explanation for drinking through a straw the learning demand involves:

- Using the concept of air pressure rather than the "sucking" description (conceptual demand).

- Accepting that air is a substantial material that can exert large pressures (ontological demand).
- Appreciating that the concept of air pressure is a general one and can be used to explain a whole range of different phenomena (epistemological demand)

Therefore, learning the scientific explanation involves the pupil in making major changes to his or her assumptions about the nature of the world. Posner et al. (1982) suggest that the pupil can often understand the explanation (i.e. the concept of air pressure is **intelligible**) but it does not make sense to the pupil (i.e. it is not **plausible** – "surely the air is not pushing the lemonade up through the straw").

The concept of learning demand provides a good starting point for identifying the nature of difficulties that the learner is likely to experience in coming to accept the scientific point of view.

In summary we can say that:

- Learning science involves being introduced to the ways of talking and thinking used in the scientific community and these are based on particular scientific concepts and modes of explaining.
- Pupils already have everyday ways of thinking about the phenomena. Detailed accounts of some of these phenomena are given in section 2.3.

- Pupils' own alternative conceptions are continually reinforced in their everyday lives and this can act as a barrier to science learning.
- Science teaching provides the conceptual tools for thinking about science.

2.3 Pupils' misunderstandings of ideas in chemistry

In research carried out on aspects of secondary school pupils' understanding of elementary ideas in chemistry (Briggs and Holding, 1986), an attempt was made to document the different kinds of ideas that 15 year-old secondary school pupils have about some fundamental chemical concepts. In addition, the researchers tried to analyse the extent to which pupils used taught ideas in a meaningful way and concentrated their research on four specific areas:

- What meanings do pupils attribute to the terms "element", "mixture" and "compound"?
- What meanings do pupils attribute to commonly used diagrammatic representation of elements, compounds and mixtures?
- What experimental observations do pupils regard as evidence for chemical change?
- What conceptions do pupils have about the relative masses of reacting substances?

The analysis of the responses of the pupils gave an insight into the ways in which pupils conceptualise various phenomena, the extent to which accepted school science ideas are used and the alternative ideas in pupils' responses. It was clear from a study of pupils' conceptual knowledge of chemistry that many pupils do not understand some of the fundamental ideas that form the basis of chemistry. From a study of the results of this report, it is clear that pupils, when engaging in chemical reasoning, must constantly shift between macroscopic and microscopic representational systems employing each at an appropriate time. The macroscopic system in which matter has bulk properties is in stark contrast to the microscopic system in which matter is regarded as being composed of moving atoms, molecules and ions. Because pupils use their prior knowledge to construct new understanding, pupils will first construct new understanding in the system in which they are already most comfortable, i.e. the macroscopic system.

On the macroscopic level, Osborne and Cosgrove (1983) in a study involving 43 children on the changes of state of water found that 50% of their sample of 17-year old chemistry pupils thought that the bubbles of boiling water were made of air. Further research in this area showed a basic problem among pupils in understanding the basic concepts of evaporation and condensation (Tytler, 2000). Similarly, when Shepherd and Renner (1982) examined pupils' perceptions of the states of matter on the microscopic level, they found that none of the high school pupils in their sample had a sound understanding of the particulate nature of gases, liquids and solids, and that only 43% had a partial understanding.

Driver et al. (1994) present a perspective on science learning as a process of enculturation rather than of discovery. They argue that empirical study of the natural world does not reveal scientific knowledge because scientific knowledge is discursive in nature. They show very clearly that learners of science have everyday representations of the phenomena that science explains and argue that although learning science involves social interactions, individuals have to make personal sense of newly introduced ways of viewing the world. They conclude that the relationship between views of learning and pedagogy is problematic and that no simple rules for pedagogical practice emerge from a constructivist view of learning.

In research carried out into how a context-based approach influences the understanding of key chemical ideas of pupils aged 16+ (Ramsden, 1997), it was found that under 25% of the pupils understood the following key ideas:

- Conservation of mass when precipitation reactions occur.
- Conservation of mass as a means of predicting reacting quantities.
- The Periodic Table as a means of predicting properties of compounds.
- The Periodic Table as a means of predicting formulas.

As an example of a misunderstanding in the conservation of mass, pupils considered that since a precipitate was a solid, it weighed more than a liquid:

> "A solid is formed and because particles in a solid are more closer together, it is more dense and so it is heavier."
>
> "A solid is formed which has a greater density than a liquid. So it will weigh a little more."
>
> "A precipitate is formed, which must weigh more than the liquids"
>
> (Ramsden, 1997 p. 707)

Thus, despite the context-based approach, difficult ideas in chemistry are still difficult!

Some of the main misunderstandings in chemistry that have been identified in the literature and that are relevant to this research project will now be discussed.

2.3.1 Misunderstandings on the particulate nature of matter

The lack of understanding of the particulate nature of matter has already been referred to in section 2.3. Among the earliest researchers in this field were Novick and Nussbaum (1978) who investigated the extent that 13 – 14 year old pupils who had learned about the particulate nature of matter had understood the basic aspects of the model related to gases. Using the interview method accompanied by presentation of concrete phenomena, they were able to ascertain that while some 70% of the pupils held the idea that a gas is composed of particles, a far smaller percentage accepted the idea of empty space between gas particles or viewed gas particles as being in constant motion. They found that the aspects of the particle model least assimilated by pupils were those most in conflict with their sensory perception of matter. These aspects are: empty space (vacuum concept), motion of particles and interaction between particles. They also found that a conflict between the continuous and particle pictures resulted in a distorted understanding of the particle model. For example, they found that many pupils could not conceive of "empty space" in ordinary matter, including gases. The pupils therefore reverted to a continuous interpretation and believed that the "empty" space was filled with more particles, dust, air, etc. They found that 30% of the pupils initially failed to correctly describe the expansion of a gas in an enclosed space and two thirds of these pupils persisted in their misunderstanding even when shown the correct picture. The researchers interpreted their findings to mean that aspects of the particle model that are most in conflict with immediate perception, present the greatest difficulty in understanding for the pupils.

These results were in keeping with the work of other researchers (Brook et al., 1984) who proposed that pupils in secondary education hold the view that matter is continuous (not made up from discrete particles) and accept the particle model (atoms molecules) in very limited contexts.

In further research, Novick and Nussbaum (1981) investigated whether pupil's ideas changed as they were exposed to additional information about the particulate nature of matter in higher grades. They looked at the following specific aspects of the particulate nature of matter:

- Gas particles are uniformly distributed in a closed system
- Gas particles are in constant motion
- Heating and cooling causes changes in particle motion.
- Liquefaction is viewed as a change in particle density.
- There is empty space between the particles in a gas.

They used a large sample over a wide age range (ages 11 – 17) using a paper and pencil instrument to try to penetrate the understanding of the pupils. They developed a test called TAP (Test About Particles in a gas). The test consisted of nine items, each involving a phenomenon, a simple experiment or a situation. Pupils were asked to (a) complete a drawing, (b) write an explanation or (c) choose among a number of given explanations or drawings. The researchers found that over 60% of the subjects beyond the junior level of high school did not picture empty space in a gaseous medium. This indicates that there is a persistent and widespread preconception of matter as essentially a continuous medium.

Novick and Nussbaum (1981) also found that pupils did not apply the idea of particle motion to arrive at a uniform distribution when an operation is performed on the gas. Close to 30% of the junior high school sample and 10% of the senior high school sample retained this misunderstanding. From similar cross-age comparisons, they found that cognitive difficulties raised by certain aspects of the particle theory are not overcome by older pupils. For example, difficulty in conceiving a vacuum persisted even into the senior high school level where only 37% of the pupils in this study responded correctly in terms of the particle model. In addition, further research (Johnson, 2002; Krnel et al., 2003) showed the existence of a general problem among pupils in developing an understanding of the concept of matter.

In a research study carried out by Mas et al. (1987) regarding misunderstandings about the nature of gases, they concluded that the material nature of gases is an important factor to be considered in the teaching of the principle of conservation of mass. They showed that three out of four pupils did not accept the principle of conservation of mass when reactants or products were in the gaseous state, after having been taught by methods that ignore the pupils' preconceptions. They concluded that the pupils' previous knowledge had a great influence on the process of learning and must be taken into account when studying chemistry.

2.3.2 Misunderstanding on atomic structure, atoms and molecules

Research was carried out by Harrison and Treagust (1996) into pupils' understanding of atoms and molecules. They examined the reasoning behind certain views of atoms and molecules held by pupils and investigated how pupils' mental models may assist or hamper further instruction in chemistry. The study also explored the variety of pupil models of atomic structure. Harrison and Treagust (1996) make the point that atomic theory depends more than any other topic in chemistry on a variety of models to explain particulate behaviour. Many pupils however, find the range of models used to represent specific concepts both challenging and confusing. This problem is particularly severe for young pupils and for those pupils whose abstract reasoning is weak.

In a study of 48 pupils in the 13 – 15 year age group, it was found that various pupils described atoms as being like a ball, a solar system, a plum and even as a structure that is able to divide and reproduce like a cell. Metaphors used by teachers such as "electron clouds" and "electron shells" appear to conjure in the minds of pupils, quite different models from those intended by the teacher. Some pupils held a view of an electron cloud as a matrix within which the electrons were embedded like the water droplets in a cloud. It appeared that many pupils did not interpret metaphors and analogies by teachers in the intended manner. Rather, they transferred attributes from the teacher's analogy to the target (atoms and molecules) in a literal and undifferentiated sense.

In one of the tests carried out by Harrison and Treagust (1996), pupils were shown a sheet containing six ways of representing some of the ways that atoms have been described. Pupils were asked to indicate, in order of preference, the diagrams that best fitted his or her mental model of an atom. The most popular model was the orbits model which was the first preference of 46% of the pupils. This diagram probably best represents the popular conception of an atom as used on television and in the print media. In addition, this model showed the subatomic particles as separate entities and clearly showed the electron paths as complete circles and ellipses. On the other hand, the model involving the electron cloud was chosen as first preference by only 17% of the pupils despite the fact that teachers had emphasised this model and almost 60% of those interviewed had heard of electron clouds.

Harrison and Treagust (1996) also found that language that is common to both biology and chemistry (e.g. nucleus and shells) was a major source of confusion for some pupils. For example, some pupils confused the nucleus of the atom with the nucleus of a cell and believed the nucleus to be the control centre of the atom. The biological influence was also evident when discussing shells, as some pupils saw shells as acting as a form of protection and, when asked for examples, listed items like sea shells, snail shells, clam shells, etc. In addition, terms like "electron cloud" appeared to conjure in the minds of pupils, quite different models from those intended by the teacher. Some pupils had an image of the electron cloud as being like a cloud in the sky and the electrons were like the droplets of water in the cloud. On discussing this with the pupils, the researchers found that these pupils saw the cloud as a separate entity, containing the electrons.

2.3.3 Misunderstandings on dissolving and solubility

Longden (1991) carried out research into children's interpretation of dissolving. Children of two different age groups (11 – 12 and 13 – 14) were tested in their understanding of what happens when a crystalline substance is added to water. Each pupil was given two sheets of paper. The first sheet contained two drawings. The first drawing showed a red crystal in a blue liquid (water). The second drawing was a particle representation of the experimental set-up in the first picture. Water "atoms" were shown in blue and crystal "atoms" were shown in red. Pupils were asked to draw a picture of what would be observed if the beaker of water was stirred until the crystal dissolved. On a second sheet, pupils were shown two blank outline drawings of a beaker of liquid. In the first drawing they were asked to draw what the solution would look like when it was stirred until the crystal dissolved. In the second drawing, they were asked to show the atoms after the crystal had dissolved.

One of the most striking findings of this research was that a greater percentage of pupils in both age groups (first year pupils = 49 %, third year pupils = 62%) gave an accurate particle interpretation compared to the percentage of pupils who gave a correct view of dissolving at the everyday level (first year pupils = 40 %, third year pupils = 42%). This was true despite the fact that the pupils in the lower age group had not been taught about the particle theory of matter. The researchers also noted the small difference between the percentage of first year pupils (40%) and third year pupils (42%) in their understanding of the everyday notion of dissolving. In contrast, there was a marked improvement in understanding of the particle theory of dissolving between the lower age group (49%) and the higher age group (62%). The particle theory had been taught to the older age group but not specifically in the context of dissolving.

Another interesting finding of the research was the fact that a significant percentage of third year pupils (8%) represented the particulate dissolving picture in terms of red and blue dots stuck together. The authors suggest that this may be as a result of the pupils believing that a compound was being formed. Thus, the knowledge they had acquired about compound formation is helping to reinforce their misunderstanding of the process of dissolving! A similar finding was made by Ebenezer and Erickson (1996) who found that some pupils had the notion that when sugar was added to water some type of chemical reaction or chemical combination was taking place to produce "sugar-water" in which the product is different from its constituents in physical appearance and also in taste.

In discussing the poor performance of pupils in explaining the everyday notion of dissolving, the authors point to the difficulty that pupils have of recognising some everyday instances of dissolving. For example, even the simple example of a solid dissolving in a liquid to give a perfect mixture may become problematic if taken beyond the point of saturation. Compare, for example, a half spoonful of sugar stirred into a cup of tea with three spoonfuls stirred into a cup of tea. In the latter instance there is dissolving with a residue. A child who has tea with only a little sugar may develop a different idea of dissolving from one who has a large amount. Although teachers might hope that pupils would always be looking for a clear solution implying perfect intermingling at the particle level, a child's observation of many everyday examples may not be consistent with this. For example, coffee granules dissolve in hot water but the resultant drink is far from a clear solution!

Another problem leading to misunderstanding in the area of dissolving is the use in daily speech of metaphors like "dissolving into thin air" and "dissolving into tears". It was discovered by Longden (1991) that significant numbers of pupils (first year = 13%, third year = 22%) showed the red crystal as simply disappearing completely to leave a blue solution. They attribute this in part to the use in daily speech of metaphors like the above which colour our thinking. The use of these metaphors may confuse the pupil whose own understanding of dissolving in its scientific sense is unclear.

Ebenezer and Gaskell (1995) also pointed to the problems created by the fact that solution chemistry has borrowed and uses many everyday words. For example, words such as particle and solution are used in everyday contexts as well as in the chemistry classroom. For some pupils, in everyday language the word "particle" refers to a very small, visible piece of solid substance, e.g. "particles" of sugar means "granules" of sugar. However, for the teacher, the term "particle" refers to "atoms", "molecules" or "ions". There is a discrepancy between language in the domain of everyday knowledge (Claxton 1983; Solomon 1983) with which pupils are familiar and the language in the domain of chemical knowledge which teachers are using in the classroom.

One of the conclusions drawn from this research is that science teaching would be more successful if teachers addressed the conflict between the use of terms like dissolving in everyday speech and their use in science lessons. Thus, it is necessary for the teacher to be aware of the match and mismatch between the everyday knowledge and the school knowledge which pupils hold in order to determine the best strategy for helping pupils to overcome their misunderstandings.

Prieto et al (1989) found that a very high percentage (80%) of pupils in their sample referred to outside action (stirring, mixing and, in some cases heating) when being asked about the meaning of the term dissolve. The necessity of stirring for a substance to become dissolved was emphasised by many pupils who used phrases like "Stirring makes the substance distribute itself through the water", "Stirring divides the solute" or "Stirring makes it dissolve better". This misunderstanding was also documented by Llorens (1987) who found that pupils in the 14 – 16 year age group believed that stirring was one of the accepted meanings of the process of dissolving. Similarly, Stavridou and Solomonidou (1989) reported that for certain pupils in the 11 – 14 age group, dissolving is seen as a result of human action on the system.

In research carried out by Cosgrove and Osborne (1981), they described an interpretation by 12 – 15 year old pupils of the role of hot water during dissolving. A common misunderstanding among the pupils was that it was the heat that caused the sugar to dissolve. Blanco and Prieto (1997) investigated how pupils in the 12 – 18 year age group viewed the effects of two external factors, stirring and increase in temperature, on the process of dissolving of a solid in a liquid. They also analysed the problem of the interaction between the ideas taught in school and those that have their origins in everyday experience. In keeping with other research findings, they found that a significant number of pupils believed that stirring and/or an increase in temperature were essential pre-requisites for the process of dissolving.

A further misunderstanding was highlighted by various research studies which reported that pupils frequently did not distinguish between the processes of melting and dissolving (Cogrove and Osborne, 1981; Renstrom, 1988; Ross and Law, 2003). These authors pointed out that this distinction is problematic because microscopically the initial stages of melting and dissolving are similar. Similarly, Ebenezer and Erickson (1996) reported that their research showed that pupils had the notion that the solute (sugar or salt) when added to water melts and becomes a liquid. Thus, their inclination was to focus on the seen and not on the unseen, i.e. the visible characteristics guide their reasoning (Driver, 1985; Paik et al., 2004; Piaget and Inhelder, 1974). For example, since the mixing of sugar and water yields sugar solution which appears to be in a liquid state, several of the pupils proposed the idea that solid sugar is converted into liquid sugar. This conversion was compared to the process of melting. Pupils were being influenced by their experience of seeing substances such as wax and ice melting in the presence of heat. They likened this to the hot water providing the heat to "melt" the sugar. Similarly, pupils described what happened when a sweet is sucked in terms of the sweet melting in the mouth. These findings are consistent with the study of Cosgrave and Osborne (1981) who found that over 25% of pupils used the word "melt" and "dissolve" synonymously.

Similar findings were reported by Ebenezer and Gaskell (1995) who showed that while some new conceptions and insights were gained by pupils from the instruction received, pupils also retained many of their initial conceptions such as the use of melting as a metaphor for dissolving. The data presented by these two authors suggest that rather than simply replacing the initial ideas and language, that new ideas and language are being gradually added to the pupils' repertoire as they learn to distinguish appropriate contexts.

From a study of the literature on this topic it is clear that school chemistry tries to teach pupils that a liquid solution should always be clear, that a solution implies a perfect mixture at the particle level, and that outside actions only influence the speed of the process of dissolving or the extent to which it takes place (solubility). In order to progress in this way, it is essential for pupils to know and to use a model of matter which includes the ideas of movement and interaction among particles. Without such a model, pupils lack any explanatory mechanism of why, for example, some materials dissolve and others do not (Haidar and Abraham, 1991). Nevertheless, one might anticipate pupils difficulty in assimilating a model that did not establish itself among chemists until the second part of the last century (Nicol, 1883), one which replaced other models and theory that had enjoyed acceptance for a long time. Some authors (Blanco and Prieto, 1997) indicate that pupils do not reason spontaneously in terms of particles even when asked directly using such terms. Neither do they refer to interactions between substances.

2.3.4 Misunderstandings on chemical formulas and equations

In addition to the misunderstandings on the macroscopic and microscopic levels discussed previously, it has also been found that there are considerable misunderstandings in the area of the symbols that chemists use to represent atoms and molecules. Eylon, Ben-Zvi and Silverstein (1982) found that when given a chemical formula for a relatively simple molecule, 35% of the high school chemistry pupils in their sample were unable to represent it correctly using circles to represent atoms.

Yarroch (1985) interviewed a group of 17 year old pupils in the USA who had been successful in balancing chemical equations. He found that success in this exercise did not necessarily mean that pupils had a sound, conceptual understanding of what an equation represents. About half the pupils who were successful in balancing equations were unable to draw a correct diagrammatic representation of the equation at a particulate or molecular level. Yarroch concluded that these pupils regarded coefficients and subscripts as numbers distinguished primarily by their location in the equation rather than in terms of their chemical significance. For example, when pupils were asked to draw diagrammatic representations of equations (e.g. $N_2 + 3H_2 \rightarrow 2NH_3$), they would commonly represent $3H_2$ as H_6 and $2NH_3$ as N_2H_6. This showed a lack of understanding of the different use of subscripts in formulas and coefficients in chemical equations. This is consistent with Johnstone's view (1991) that attention to the submicroscopic level is often inadequate. More recent research in this area (Boujaoude and Barakat, 2000; Fensham and Lui, 2001) have reinforced the findings of Yarroch (1985).

Difficulties that pupils have with using the Periodic Table to predict the formulas of simple compounds were documented by Ramsden (1997). From the research findings, it was obvious that a considerable amount of guesswork was involved, with one pupil even saying that her teacher "tells us to have a guess if you don't know". The fostering of this type of speculation has been advocated by other researchers (Reynolds and Brosnan, 2000).

2.3.5 Misunderstandings on acids and bases

In research carried out to study high school pupils' understanding of acids, bases and pH (Nakhleh and Krajcik, 1994), it was found that pupils had various misunderstandings in this area. The analysis of understanding was carried out with the assistance of concept maps. Among the misunderstanding relating to acids and bases that were documented with the aid of these concept maps were:

- The meaning of the term strong as applied to acids and bases. More hydrogen gas is displaced from a strong acid than a weak acid. This problem is also documented by Oversby (2000).
- The tendency to make acids and bases "opposite" to each other, i.e. if acids are harmful, bases are harmless; if acids have a bitter taste, bases would be expected to have a sweet taste; the formulas of acids contain hydrogen but the formulas of bases have no hydrogen.
- Confusion about the pH concept. pH is a measure of acidity but not basicity.
- Acids and bases when added together form a mixture rather than chemically react to form a salt and water.
- Misunderstanding of the role of an indicator in an acid-base titration e.g. "Acids destroy bases by causing phenolphthalein to change colour".

It was found that the pupils who carried out the experimental work with the aid of computer technology acquired a more detailed and a more integrated understanding than those pupils who carried out the laboratory work in the more traditional manner. Pupils using the computer technology were provided with the highest level of information. They could read the pH value after each addition of base and also observe the on-screen graph of pH vs the volume of base added as the titration progressed. Similar findings were reported by Linn, Layman and Nachmias (1987) who found that the pupils' level of understanding was increased by the fact that the computer functioned as an auxiliary memory device by maintaining the visual display as a constant reference for the pupil. In addition, Linn, Songer, Lewis and

Stern (1993) also asserted that "real-time data collection frees pupils to think about their experiments". They argued that the opportunity to reflect on the dynamic, changing data displayed on the screen contributes substantially to pupils' construction of knowledge about the experiment and leads to greater understanding.

2.3.6 Misunderstandings about chemical reactions

Research carried out into misunderstandings that pupils have with regard to chemical changes (Andersson, 1986; Cavallo et al., 2003; Johnson, 2000; Solsona et al., 2003) found that pupils used various ways to explain to the science teacher what a chemical reaction is. These may be summarised as follows:

1. "It is just like that". These pupils can offer no explanation for what has occurred. For example, when pupils are asked why a copper roof turns green, pupils in this category would not be concerned about what the green substance is and why it is formed. They just consider it as something that happens to copper.
2. Displacement. This means that the new substance has simply been displaced from another position, e.g. water droplets on a table that have come from a wet sponge. For example, when explaining the tarnishing of copper water pipes, many examples of the displacement concept were apparent in the replies of pupils.

> "Hot water makes steam, which forms a coating on the pipe."
>
> "Some substance has penetrated the hot pipe".
>
> "There is so much lime in the water that it must be noticeable on the pipes".

> "Heat attracts dirt".

3. Modification. This means that what appears to be a new substance is the same substance as before, although in a changed form. For example, when alcohol is observed burning, pupils explained their observation by saying that the alcohol changed into alcohol vapour (Pfundt 1982, Meheut et al. 1983).
4. Transmutation. This means that a given substance is transformed into a new one, e.g. iron into carbon. It was found by Andersson and Renstrom (1981) that pupils who observed steel wool burning, explained the formation of a back substance in terms of the steel wool turning into carbon.
5. Chemical interaction. This means that the original substances cease to exist and new substances are formed. When questioned about the tarnishing of the copper water pipe about 15% of pupils understood what was happening and gave replies like:

> "Copper and oxygen have reacted"
>
> "It is oxidation. Air = oxygen reacts with copper, copper oxide is formed, and that is the dark coating"
>
> "Oxygen reacts with copper and forms copper oxide".

In addition to the above, it has also been found that pupils have considerable difficulty understanding the relationship between chemical reactions, chemical equations and the conservation of matter (Ozmen and Ayas, 2003). Andersson and Renstrom (1983) point to the limitations of written questions and answers when testing pupils' understanding of this topic. For example, when 2800 pupils in the age group 12 – 15 were questioned on the reasons why a hot copper water pipe was more tarnished than the equivalent cold water pipe, they found that the answer “rust is formed” was commonly given. The authors refer to the ambiguity of the meaning of this term and point to the need for further questioning in an interview situation to test the pupils' understanding of the chemical reaction occurring.

Research has also been carried out into other areas of chemistry in which pupils experience difficulty, e.g. qualitative analysis (Tan et al., 2003), charges/chemical bonding (Coll and Treagust, 2003; Taber, 2002a; Tan and Treagust, 1999), isotopes and allotropes (Jurgen-Schmidt, 2003), molecular structures (Ferk et al., 2003), scientific models (Treagust et al., 2002), the mole concept (Furio et al., 2000), chemical nomenclature (Jurgen-Schmidt, 2000). Since these topics are not encountered to any significant detail in the Junior Certificate science course in Ireland, they will not be discussed further.

In the context of this research project, a difficult idea is taken as having the following characteristics: one where misunderstandings have been investigated and documented, where the misunderstandings relate to the ideas that pupils themselves bring to lessons (based on their everyday experience), where the ideas differ from the scientifically accepted explanation, and where they are resistant to change and commonly retained by the pupils despite teaching.

2.4 Implications for Teaching and Learning

The difficulties documented in the preceding sections have implications for teachers' subject knowledge, for teachers' pedagogic content knowledge and for the design of curriculum materials. In this section an attempt is made to draw together the main issues emerging from the studies reported in the previous section using a number of categories similar to those used by Driver in research carried out into children's ideas of science (Driver et al., 1986).

(i) Teaching Methodology

In a study investigating misunderstandings among pupils in the 12 – 18 year old age group, Mas et al (1987) postulated that these misunderstandings were associated with "the inefficiency of the way in which the sciences, and chemistry in particular, are usually taught; as if the pupil were a *tabula rasa* where information can be written. Consequently, it is not surprising that pupils' pre-existent conceptual framework remains unchanged, even after having seen the same material several times". Andersson (1986) suggests that it is easier for pupils to change from spontaneous everyday conceptions to those accepted by the scientifically-trained community if the pupil becomes aware of his/her own concepts and their limitations. However, Posner et al (1982) point out that the conditions for conceptual change must be considered by the teacher and that making the pupils aware of their conceptions and their limitations is a preparation for conceptual change. In many cases, pupils put forward their own explanation of chemical observations. These explanations are regarded as hypotheses to be discussed and tested. The above authors stress that if the atmosphere in the classroom is of a kind in which the pupils can express themselves without worrying too much about making mistakes, their hypotheses can be expected to illustrate their conceptions. They should then become aware of the limitations of their own concepts and inclined to exchange them for the teacher's alternatives.

The teacher should recognise that the majority of the pupils' answers may contain ideas that are both sensible and capable of development. It can be of great psychological significance if the teacher can point out that an idea put forward by a pupil, although it does not lead to anything just then, is productive in other connections. In this way, the pupils will not lose their inclination to join in fresh discussions.

(ii) Reinforcement of misunderstandings by textbooks

There appears to be considerable problems caused by the representation of certain key scientific ideas in textbooks. Harrison and Treagust (1996) studied the problems caused for pupils by representations used in textbooks. For example, they found that the majority of pupils in their sample had misunderstanding about the relative size of an atom's nucleus and electron cloud. The researchers represented the nucleus as being 5 cm in diameter and asked the pupils to indicate the position of the electron cloud. Only one pupil in the sample of 42 pupils provided a realistic estimate by saying that the electrons would start "several kilometres away" and would extend " to about three times that distance". This clearly indicates that the majority of pupils have an image of an atom that does not take into account spatial dimensions. These findings are not surprising and are consistent with textbook models that do not show the proper scale or fail to emphasise the relative scales.

Andersson (1986) points out that textbooks use different models of the atom e.g. Bohr atom, hard sphere model, etc. and these can give rise to misunderstandings of atoms among pupils. Similarly, Novick and Nussbaum (1981) suggested that writers should explicitly take into account the relative difficulties of various aspects of the particle model as identified by their own TAP (Test About Particles in a gas) model. They also suggested that instruments similar to TAP should be used by teachers for both diagnostic and evaluative purposes as these instruments probe the quality of understanding of a model in its various aspects and do not deal merely with information.

One of the main contributing factors to the misunderstandings regarding the particulate nature of matter among pupils may be due to the representations found in school textbooks (Andersson, 1992). Indeed it has been found that pupils' representations of the structure of matter are along the same lines as the way this topic is pictured by school (Kokkotas and Vlachos, 1998). School texts frequently represent matter as continuous and static and represent molecules as small particles that keep their macro properties such as hard, soft, etc.

(iii) Use of analogies when teaching science

The need for care when using analogies to avoid the transference of unshared attributes to the topic being taught has been highlighted by a number of researchers in this field (Harrison and Treagust. 1993; Harrison and Treagust, 1996; Glynn et al., 1991; Duit 1991). Harrison and Treagust (1996) highlighted the dilemma faced by the science teacher. They pointed out the stark contrast between the work of the theoretical scientist and the work of the science teacher. Scientists can disseminate many of their new ideas and discoveries through pathways that often involve complex mathematics. However, the science teacher, who is the second last link in the education chain, often has to employ imperfect models and analogies that many theoreticians would deplore. Research has shown that many modern science textbooks contain numerous analogies and models that are questionable (Thiele and Treagust, 1994a; Thiele and Treagust 1994b). The problem is particularly acute in the case of chemistry since when introducing non-observable entities like atoms and molecules to pupils, teachers and textbook writers are constrained to use analogies and models as well as introducing concepts like chemical formulas and chemical equations. Although these models are often easily represented on paper, pupils need time to develop the visualisation skills required to interpret these diagrams.

It appears from the literature that pupil understanding breaks down when models are used because pupils often do not recognise that the explanation or process they are using is a model and, consequently, they mistake the model for reality. Harrison and Treagust (1996) recommend that whenever any of these models are used during instruction, it is important that the model is a familiar one and that teachers explain that each diagram is only an analogical model and that models contain valid features along with many invalid features. If pupils develop an understanding of the role, status and limitations of scientific models, it is likely that they will be less inclined to see the variety of models used in textbooks and in the classroom as "reality". In fact, research has shown that when pupils appreciate the strengths and limitations of analogies and models, their understanding is enhanced (Gilbert, 1993; Treagust et al., 1996).

Harrison and Treagust (1996) recommend that some science instruction time should be devoted to the development of pupil modelling skills particularly when pupils are taught about non-observable phenomena like light, electricity, semi-permeable membranes, genetics, atomic structure, etc. This recommendation is in agreement with other research in the area by Grosslight et. al (1991) and supports their findings. Harrison and Treagust (1996) also recommend that teachers need to discuss with pupils their conceptions of scientific models, metaphors and analogies. Listening to pupils can enhance science teaching if teachers take the time to carefully consider the mental models that pupils either bring to instruction or construct during the process of instruction.

(iv) Language in science

Johnstone (1992) points out that everyday science and language are related to pupils' ideas and withstand formal teaching methods. In addition, Ebenezer and Gaskell (1995) suggest that it is important for the teacher to distinguish between the everyday context in which words like particle and solution are used and their use in the scientific field. This is important so that pupils come to appreciate them and recognise when it is appropriate to operate in each. The language of school chemistry takes time to develop and, as Linder (1993) argues, should not necessarily be seen to replace everyday knowledge. The goal of school chemistry is to enhance "pupils' capabilities to distinguish between conceptualisation in a manner appropriate to some specific context" (Linder, 1993, p. 298). Even within the school chemistry context, however, pupils must learn to appreciate conceptions appropriate to different chemical contexts. The chemistry classroom, then, is a context in which the emphasis for pupils is on learning to appreciate contexts where everyday conceptions of chemical phenomenon are appropriate and contexts where conceptions from the community of chemists are more appropriate. A person who says that "the chocolate is melting in my mouth", at a social event, is probably conveying sufficient meaning for his or her purposes at the time.

Within the domain of school chemistry, pupils must also learn to distinguish between related conceptions appropriate to different contexts. The chemistry classroom, then, becomes a place where pupils' everyday ideas are initially considered but, in addition, pupils are also encouraged to see chemists' ways of looking at the same phenomenon as a good alternative in particular contexts.

Harrison and Treagust (1996) point out that teachers need to be vigilant in differentiating between terms used in different contexts. They recommend that teachers should explicitly define the intended meaning of terms in the context in which these terms are being used. For example, the majority of pupils in their study who were confused between the concept of a nucleus in chemistry and in biology, were being taught by a specialist biology teacher who did not specify the meaning of the term nucleus in a chemistry context.

Furthermore, it has been argued (Black and Lucas, 1993) that pupils should understand why it is necessary to learn a distinctive language when studying a subject such as chemistry. Hopefully, they should then begin to understand how such a specialised language can eventually provide them with a mechanism for viewing their everyday world, as well as the world contained in the chemistry classroom.

Furthermore, teachers should be aware (Mercer, 1992) that the language and visual representations that they use, as well as those in instructional materials like textbooks, multimedia materials and so forth, are open to multiple interpretations by their pupils.

(v) Pupils' own understanding of scientific phenomena

The problem of the conflict between the pupils' own understanding of scientific ideas and the understanding held by the scientific community is very well documented in the literature. Ebenezer and Erickson (1996) point out that in school, pupils are often expected to abandon their perceptually-sensible models in favour of the more abstract models developed by scientists. For example, a particle model often contradicts one's sensory perceptions of matter and this contributes to many of the instructional difficulties (Novick and Nussbaum, 1978; Nussbaum, 1985).

Ebenezer and Erickson (1996) argue that an understanding of the typical conceptions used by pupils should form an integral component of chemistry teaching, both as points of origin for lesson planning and for the development of curricular materials. They pose the question: "Should teachers strive to change the pupils' everyday talk in their science classes?". If so, how successful will teachers be? In a similar fashion, Solomon (1983) distinguishes between the symbolic and life-world domains of knowledge and documents the difficulties that pupils have in relating to the two. Although pupils' imprecise use of language can be readily acknowledged, it may be neither realistic nor desirable to expect them to dissociate themselves from the language of everyday experience which is so much part of their lives when they come into a science classroom. Pupils should, however, be made aware of the differences in the meanings based upon their everyday talk and the meanings embedded in the chemist's language. For example, Andersson (1986) points out that when the teacher states that water consists of hydrogen and oxygen or that water is built up of hydrogen and oxygen, the pupils lacking adequate knowledge of atoms and molecules, are likely to interpret the teachers statement as indicating that water consists of a mixture of hydrogen gas and oxygen gas.

In attempting to summarise the problem, Nakhleh and Samarapungavan (1999) in discussing elementary school children's beliefs about matter, point out that teaching "must focus on helping children make the ontological transition from thinking about matter purely in terms of macroscopic properties which are intrinsic and self explanatory to thinking about matter as being composed of microscopic particles with properties and ways of behaving which are different from the macroscopic, observable properties and phenomena, but which can in turn explain these macroscopic properties and phenomena".

In conclusion, it is well to remember that theoretical advances and the accompanying conceptual change has been historically difficult for scientists and therefore is bound to be difficult for pupils as well (Chi et al 1994). Johnstone (1984) explains the problem in terms of activities like laboratory work leading to misunderstandings by overloading the "working memory" of the pupils who become so overwhelmed with the task in hand that they have no memory space left with which to think conceptually. In order to avoid this problem, Nakleh and Krajcik (1994) stress the need to understand pupils' thoughts during a laboratory activity, so that experiments may be designed that allow pupils time to reflect on how the principles learned in the classroom are related to phenomena observed in the laboratory. In addition, they point out the need for considerable amount of research to be done on effective methods of using computer technology in teaching. They emphasise the need to ensure that appropriate instruction is provided to complement the use of computer technology in order to integrate technology successfully into the teaching and learning situation.

> "However, we believe that this tendency to form inappropriate understanding places a serious obligation on teachers to ensure that their instruction provides opportunities for students to reflect on, defend, and integrate the understandings that they gain from interaction with these technologies in the laboratory and from studying concepts and principles in the classroom"
>
> (Nakleh and Krajcik, 1994 p.1095)

The authors proceed to suggest that careful analysis of the laboratory tasks, teacher-mediated instruction and class discussion are needed to counteract the formation of misunderstandings. They recommend extensive discussions prior to the laboratory session to:

- Focus the pupils' attention on what important clues to observe as the experiment progresses.
- State the objectives of the experiment
- Encourage the pupils to recall what they know about the topic and how that knowledge applies to the laboratory activity.

After the completion of the experiment, they recommend the need for discussions to:

- Uncover and confront any misunderstandings that may arise during the course of the experiment.
- Remind the pupils of the purpose of the experiment.
- Encourage them to relate what they found in the laboratory activity to the chemical principle discussed in the classroom and presented in the textbook.

When discussing laboratory work, Nakleh (1992) suggests that it should be a primary means of "building a bridge" to overcome misunderstandings between the macroscopic representation system of chemistry and the microscopic system. Pupils experience chemistry in the macroscopic system, but must interpret their work in the microscopic system. A similar finding was made by Anderson and Renstrom (1983) who reported that very few pupils in their sample, after instruction in chemistry, used the concepts of atom and molecule in their reasoning about chemical reactions. Of those who did, some treated the atomic world as an extrapolation of the macroscopic world. They believed that what applies in the macroscopic world, also applies in the atomic world. If, for example, wood burns up, then the wood molecules also burn up. The pupils do not seem to understand that the concept of the atoms is part of the model invented in order to explain and predict what takes place in the macroscopic world. The problem arises because pupils' prior knowledge is in the macroscopic system and comes from instruction and experience and hence pupils have difficulty understanding the microscopic system in chemistry. Therefore, connections between the macroscopic and microscopic modes of thinking must be encouraged by the teacher at all times. Teacher mediated instructions for laboratory work are essential because laboratory activity apparently does not automatically help pupils to form ideas about the microscopic model of science

Blanco and Prieto (1997) suggest that it becomes necessary from the very early years of pupils' science education to prevent some misconceptions regarding the process of dissolving by adapting the following strategies:

- Demonstration by experiment that some familiar substances such as sugar and salt dissolve in water if left for an adequate length of time while other substances do not dissolve if left for a prolonged time, even if stirred or even if the temperature is increased.
- Introduction and use of a particulate model of matter (developing ideas of movement and of interaction at the molecular level) in order to explain the process of dissolving.
- Analysis and clarification of the role of stirring and temperature in the dissolving process.

Mas et al (1987) suggest that an important implication for teaching is to overcome the notion among pupils that gases are substances "without weight" and hence to devise strategies to make the conceptual change necessary for a fundamental understanding of phenomena involving gases (Hewson 1981).

In research carried out to compare the effects of learning on context-based approaches to science teaching with more traditional approaches (Ramsden 1997), it was found that there was little difference in the level of understanding regardless of which approach was adopted. The context-based approach, with "drip feeding" of ideas, appears to be as effective as a more traditional approach in developing understanding. However, it was found that there were some key areas of chemistry which are poorly grasped whatever the approach.

> "The marks obtained on the questionnaire suggest that the understanding of key chemical ideas of pupils of age 16+ is independent of the approach adopted, i.e. pupils following a context-based or drip-feed approach are likely to develop the same level of understanding of ideas as pupils following courses with a more conventional approach to concept development. Where ideas were generally poorly understood, pupils appear to share the same difficulties irrespective of the course they had followed".
>
> (Ramsden, 1997 p. 705)

It may be that some of these ideas, such as using the Periodic Table to predict formulas, are difficulty concepts and present too great a challenge to most pupils. Other concepts, for example the conservation of mass in chemical reactions, or what happens when a chemical reaction takes place, appear simpler to grasp. The author suggests that it is likely that a more explicit treatment of these basic ideas, with explanations being reinforced as further examples are met, would enhance understanding. In addition, it is worth noting that a context-based approach is more successful in terms of stimulating pupils' interest in science and providing them with what they perceive to be a worthwhile experience in their science lessons. From the comments made by pupils who had been taught using the Salters approach, it was clear that the pupils had developed a greater appreciation of how science contributes to their lives and to the lives of others around the world, and this helped them to acquire a better understanding of the environment.

2.4.1 Evaluation of effectiveness of teaching approaches based on addressing specific learning demands.

Although there is a large amount of research evidence regarding pupils' misunderstandings, only a small number of experimental studies have been conducted to evaluate the effectiveness of teaching approaches based on addressing specific learning demands (Leach and Scott, 2002). One of these involves teaching about gravity and inertia (Brown and Clement, 1991). For many pupils, force is associated with movement. It is therefore very difficult for these pupils to accept that an object at rest, such as a mug on a table, is subject to a gravitational force and to an equal and opposite force from the table on the mug. Usually, pupils believe that there is no upward force acting when the mug is at rest. A teaching sequence was prepared to address this learning demand, using what Brown and Clement term "bridging analogies". These analogies are designed to encourage pupils to draw an analogy between an idea which is obvious to them and one which is difficult to accept. In this case, the researchers suggest placing a heavy object upon a pupil's upturned hand. Pupils readily accepted that their hand exerted an upward force on the object as they felt the weight of the object on their hand and they needed to exert an upward force to balance the downward gravitational force. Then, the same object was placed on a long ruler, supported at each end but not in the middle. As the pupils can see the ruler bend under the weight of the object, pupils were persuaded that that ruler was exerting an upward force on the object due to the presence of the springiness of the ruler. Finally, the pupils were asked to make a logical leap from the hand and ruler examples to the original situation of the object on a table. The idea of the upward force being exerted by the table on the mug was then introduced. A follow-up evaluation of this teaching strategy was carried out with a test group and a control group of pupils. The test group showed marked improvement in written tests and the long term retention of the test group was significantly higher than the control group.

Leach and Scott (2000) point out that a common criticism of teaching approaches based upon an analysis of learning demands is that they are unfeasible due to the fact that they tend to be very time consuming. However, in a study of upper high school pupils learning about electricity in physics, Viennot and Rainson (1999) present very strong evidence that such teaching sequences can be designed in such a way that they take no more time than conventional approaches and result in consistent improvements in pupil learning compared with traditional approaches. In this study, the same teacher taught control classes, using a conventional teaching sequence and experimental classes using the designed teaching sequence. This addressed, to some extent, the problem of comparing an enthusiastic teacher's use of experimental teaching approaches with a less enthusiastic teacher's use of conventional methods. In addition, the pupils in the control classes in the study would have been expected to have performed better than those in experimental classes, given their previous higher academic performance. The teaching approach used over four years, showed that mean pupil test scores in the experimental classes were typically in the order of 20 per cent better than those for pupils in the control classes. This suggests that improvement in pupil learning was due to the teaching approach used rather than the effect of the teacher.

Other smaller-scale studies have been conducted (Johnston and Driver, 1990; Mirzalar-Kabapinar, 1999; Mirzalar-Kabapinar et al., 2004) which tend to show significant but fairly small improvement in pupils' learning as a result of following teaching interventions designed to address specific learning demands.

In summary, there is some evidence to suggest that teaching approaches, based on an analysis of learning demands, are more effective at promoting learning than are conventional approaches. As discussed earlier, further research on the effectiveness of teaching approaches based on the analysis of learning demands, similar to those carried out by Adey and Shayer (1993) in the context of teaching for cognitive acceleration, would be valuable in determining the effectiveness of such approaches.

From the above discussion, it is clear that difficult ideas for pupils pose particular problems for teachers in terms of both subject knowledge and pedagogic content knowledge, i.e. how to teach these ideas. As the main focus of this thesis is on how student teachers teach selected difficult ideas, we now consider how teachers' thinking about their own teaching can be accessed.

2.5 Misunderstandings among student teachers

A survey of the relevant literature shows that little research has been carried out in the area of misunderstandings among student teachers of science. However, it is reasonable to assume that if pupils have difficulty with understanding certain key ideas in science, then student teachers also have difficulty understanding some of these topics.

Novick and Nussbaum (1978) recommend that student teachers should, as part of their teacher training course, be taught the techniques of interviewing pupils to establish an understanding of pupils' ideas about scientific phenomena. In addition, as part of their research on prospective elementary teachers views of the particulate nature of matter, Gabel et al. (1987) found that the following misunderstandings commonly occurred among these student teachers:

- The enlargement of atoms as they changed from liquid to gases rather than becoming farther apart.
- The addition of lines to show levels of liquids rather than letting the top of the particles indicate the surface boundaries.

- Representing gases in an orderly rather than a disorderly fashion.
- Showing particles in intact groups rather than in smaller groups after a molecule has decomposed.

Similar problems were identified by Kokkotas et al. (1998) who investigated student teachers' understanding of the particulate nature of matter. Their results showed that prospective teachers shared a number of misunderstandings with pupils. They point out that teachers lacking scientific knowledge about the particulate nature of matter could reinforce pupils' misconceptions or reject their pupils' efforts. In addition, such teachers lacked a theoretical framework within which they could analyse pupils' difficulties and search for teaching strategies to overcome these misunderstandings.

Lenton and Turner (1999) found that subject knowledge was a particular problem among science student teachers due to their specialisation in a narrow area of science. By assessing the subject knowledge of these student teachers in certain concepts in biology at the beginning and end of their teacher training course, little improvement was found in this subject knowledge at the end of the course. They recommend subject knowledge audits and independent study in an effort to tackle the problem.

A research study carried out to investigate the ability of final year student teachers to relate their theoretical learning of redox concepts to everyday life (Soudani et al., 2000) found that the student teachers had very significant problems in this area. Similar problems are reported in a research study

(Pozo, 2001) into the ideas held by student teachers about the composition of matter. Likewise, Goodwin (2003) found a worrying lack of understanding among student teachers of the concepts of evaporation and boiling and Kikas (2004) reports that student teachers had basic problems explaining chemical reactions.

The general problem of misunderstandings among student teachers has been discussed by Ireson and Twidle (2004) who recommend the enhancement of the subject knowledge of student teachers during and prior to their formal training period.

2.6 Student teachers' planning and teaching of lessons on difficult ideas in science

Since pupils have difficulty understanding certain key ideas in science, it is true to say that student teachers also have difficulty in teaching these ideas. However, there is very little research reported in the literature about how student teachers plan and teach lessons on difficult ideas in science. One of the few pieces of research (Fischler, 1999) was carried out to investigate the impact of teaching experiences on conceptions of teaching and learning by student teachers of physics. The focus of this research was on identifying the teachers' conceptions prior to, and after, the teaching phase of a teaching unit. The researcher was guided by a number of assertions in his approach to carrying out the research:

- During teaching practice, some student teachers changed towards a teacher-centred approach to teaching based on the principle that a well-arranged methodical presentation of a topic is the main task of the teacher. For these student teachers, their existing conceptions about teaching and learning are either suppressed during the time of the teaching practice or are replaced by the conceptions developed whilst teaching.

- Some student teachers have teacher-centred conceptions of teaching and learning which are reinforced during teaching practice.

A total of 36 student teachers were interviewed and observed during the project. The project involved three stages:

1. Prior to the teaching practice, the conceptions of the student teachers about teaching and learning were identified.
2. During the teaching phase, two lessons per student teacher were video recorded in the presence of the mentor of the student teacher and the supervisor.
3. Immediately after the completion of the teaching, the student teachers were questioned in order to identify their conceptions and address these in relation to the student teacher's "instructional behaviour" (Fischler, 1999).

Having carried out structured interviews with these student teachers, Fischler (1999) used repertory grids as a means of accessing information about the thought processes of these teachers, i.e. the factors that inform decisions they make about their teaching. He looked on repertory grids as models of how we represent and make sense of our experiences (our personal constructs). Fischler developed some repertory grids from first principles using a variation of standard procedures for grid construction. (Cohen et al., 2000). Using a mixture of conversations and interviews with student teachers about video clips or written descriptions of problem situations, Fischler generated a list of "teaching principles". These teaching principles formed the elements of the grid. The ten principles that formed the elements of the grid are shown in Table 2.2.

1. My teaching
2. Good teaching
3. Ideal teaching
4. Concrete presentations (including experiments)
5. Formulation of central results
6. Everyday orientation of presentations
7. Taking seriously students' everyday lives
8. Laboratory work
9. Written summary of important findings
10. Friendly classroom climate

Table 2.2 The teaching principles of Fischler's repertory grid.

These elements were written on cards and the student teachers were asked to select any three cards at random. The student teachers were then asked to state one way in which one of the elements differed from the other two. For example, they might select 1, 2 and 10 above and could possibly say that his/her teaching differs from good teaching and a friendly classroom climate because the pupils in the class were not very positive towards science. This response allowed a bi-polar construct to be identified, e.g. a positive/negative attitude to science. The process of card selection was then repeated until the student teacher could identify no more differences to generate the bipolar constructs. The repertory grid was then generated by mapping the elements (the teaching principles) against the constructs (effect on students). The grid was completed by asking the student teachers to rate each element against each construct on a seven-point scale. The grids were completed before and after the teaching placements of the student teachers and the ratings were compared.

The generation of repertory grids by Fischler did not follow standard repertory grid procedures as the latter procedure involves eliciting the "teaching principles" directly from the student teachers. However, Fischler used his own list of teaching principles and it is very difficult to understand from the research paper how he interpreted the repertory grids. It appears that Fischler's views of teaching have influenced his interpretation of his work as some of the elements are based on what he thinks is important rather than what the student teachers think is important.

Among his conclusions were:

- Effective teacher performance is influenced by lesson content, methodology (i.e. the approach to teaching the content) and learning goals.
- There is a gap between what teachers plan to happen in a lesson, and what actually does happen, and this gap is greatest for student teachers.
- Because of the above gap, research into how teachers teach should involve talking to teachers, observing them in action and trying to access their thought processes.

Although repertory grids may be a useful psychological tool for gathering data on personal constructs, there is considerable debate over how the grids should be completed (Bannister and Mair 1968, Cohen and Manion 1997; Cohen et al. 2000). Cohen et al (2000) summarise the problem well:

> "Fransella and Bannister (1977) point to a number of difficulties in the development and use of grid technique, the most important of which is, perhaps, the widening gulf between technical advances in grid forms and analyses and the theoretical basis from which these are derived. There is, it seems, a rapidly expanding grid industry. Small wonder, then, as Fransella and Bannister wryly observe, that studies such as a one-off analysis of the attitudes of a group of people to asparagus, which bears little or no relation to personal construct theory, are on the increase."
>
> (Cohen et al, 2000 p. 345)

Thus, the increasing sophistication of ways in which the grids might be completed has had the effect of generating quantitative data, which is at odds with the information such grids were originally intended to collect.

2.7 Researching Teaching

One of the most detailed research projects carried out to explore the professional knowledge and thought that teachers use in their day-to-day classroom teaching was that of Brown and McIntyre (1993). The professional knowledge of teachers is not generally made explicit by teachers and teachers are not always conscious of using this knowledge. Brown and McIntyre (1993) refer to this as the **professional craft knowledge** of teachers. They define professional craft knowledge as follows:

> ".... that part of their professional knowledge which teachers acquire primarily through their practical experience in the classroom rather than their formal training, which guides their day-to-day actions in classrooms, which is for the most part not articulated in words and which is brought to bear spontaneously,

> routinely and sometimes unconsciously on their teaching."
> (Brown and McIntyre,1993 p. 17)

The research work involved studying teachers at work and attempting to understand how teachers themselves make sense of the knowledge and thought that they use in their everyday classroom practice. Brown and McIntyre outlined three important reasons for studying teachers' professional craft knowledge:

1. The importance in teacher education of enabling student teachers to gain access to such knowledge and of enabling experienced teachers to share this knowledge with one another.
2. The importance for curricular innovation of understanding the practical knowledge on which teachers depend and which they may be unwilling to abandon.
3. The importance for teacher appraisal of knowing how teachers themselves conceptualise and evaluate their teaching, so that any system of appraisal can take full account of this.

One of the problems of identifying "good teaching" is the question of who is to decide what counts as good teaching and on what basis is that decision made. There are many categories of people who make judgements on teaching and teachers:

- Teacher educators in third level institutions who decide whether student teachers are fit to becoming practising teachers.
- Members of the inspectorate who report on what they observe in classrooms

- School principals who recommend teachers for promotion or write references for teachers who transfer to other schools.
- Teachers themselves often evaluate their own teaching and may comment about the capabilities of their colleagues.
- Parents discuss among themselves the relative teaching abilities of different teachers.
- Educational researchers who assess the teaching skills of teachers according to some theoretical model.
- Pupils continually assess their teachers according to various criteria.

There is obviously quite a variation among the above groups in the extent of their first-hand knowledge about what goes on in the classroom. In the final analysis, it is only the teachers themselves and their pupils who have this comprehensive first-hand knowledge.

There are different criteria used by different groups in order to make their judgements about teachers. Among these criteria are:

- How well teachers carry out their responsibilities that have direct impact on the rest of the school e.g. co-operation with colleagues and school management, completion of administrative duties, organisational competence, etc.
- Is the teacher able to keep sufficient control of the class so that other teachers are not disturbed?
- Has he or she managed to complete the course in the time allowed?
- How do the pupils of the teacher perform in examinations?

- Does the teacher have the type of personality suited to teaching?

While many of the above points are often used to judge the quality of teaching and teachers, they do not help us in our efforts to **understand** teaching. Therefore, Brown and McIntyre did not select "good teachers" for their research study using pre-defined criteria like the above. Their decision as to what was to count as good teaching depended on judgements made by teachers themselves and their pupils. The main criteria used by the researchers in selecting teachers for the study were based on asking pupils in the 12 – 13 year age group to describe the strengths of some of their teachers. They then looked for consensus among pupils both in their nominations of a particular teacher and about the strengths that were identified for that teacher. These strengths were identified by means of the following four questions:

1. "Please tell us something about the three teachers whose teaching you thought was best. Probably there were different things you liked about each of these teachers. Please say what each teacher did in his or her teaching that you thought was good.
2. What do your teachers do well? Tell us which teacher you are talking about and what it is that he or she does well.
3. What do you think makes a good teacher? Which of your teachers do these things? In each case, tell us what he or she does.

> 4. Please tell us about anything you think that any of your teachers do especially well. For each teacher say what it is that he or she does well when teaching."
>
> (Brown and McIntyre, 1993 p. 25).

From the responses received, the researchers identified sixteen teachers to participate in the study. Each of these teachers was given a summary of the statements made about him or her by the pupils. This provided positive reinforcement for the teachers as teachers seldom have the opportunity to read such encouraging feedback about their own performances.

The teachers agreed to teach a unit of work (two – six hours of teaching) while being directly observed by the researcher and being recorded on audio-tape. At the end of each lesson the teachers were asked to discuss with the researchers those aspects of their teaching that particularly pleased them. These accounts by the teachers provided the core of the research data and gave them a means of identifying the criteria that teachers use to evaluate their own "good teaching", and of understanding how teachers view their classroom practice.

A similar study was carried out with pupils in the 14 – 15 age group in Australia (Batten, 1990) using the model developed by Brown and McIntyre (1993). The interviews of the teachers were relatively unstructured. The teachers were encouraged to reflect on and talk about the positive aspects of the lesson, i.e. the application of their craft knowledge in the classroom. It was seen as important for the study that the basis of the discussion about the teacher's craft knowledge should be established by the teachers themselves and not imposed by the researcher. In other words, the researchers had to avoid circumstances which would encourage the teachers to fit responses to the questions into frameworks offered by the researchers. McNamara (1980) refers to this as the "Outsider's Arrogance" and Spradley (1979) gave the same advice:

> "Before you impose your theories on the people you study, find out how these people define the world"
>
> (Spradley, 1979 p.11)

The researchers recognised that the teachers' comments did not convey the complete craft knowledge repertoire of the teacher, but rather a "slice" of it. From these "slices" it was planned to construct a pedagogical profile for each teacher. While this pedagogical profile would reflect only a part of the teacher's craft knowledge, and might not even represent fully all the things a teacher was thinking and doing in those particular lessons, it was felt that it would give some indication of how and why the teachers operated as they did in the classroom.

How valid is the research strategy used by Brown and McIntyre? In attempting to answer this question, a number of factors led the researchers to believe that they had successfully gained access to the professional craft knowledge of the teachers:

1. There was great consistency in the teachers' accounts of their teaching, i.e. what they said when commenting on tape-recorded extracts from units was not significantly different in form or substance from what they had said after particular lessons.

2. When teachers were presented at later stages with the researchers' accounts of the interviews, they enthusiastically endorsed these as valid representations of the thinking underlying their teaching.
3. Virtually everything that all the teachers said on all occasions could be represented in terms of the models that the researchers abstracted.

The confidence of the researchers is well stated as follows:

> "Our confidence is based mainly, however, on the belief that conditions were created in which the teachers were both able and willing to recall the thinking which underlay their actions. Because of our strong emphasis on what had been successful in their teaching, they had no reason to be defensive and instead gave every appearance of trying hard to articulate their perceptions of their successes and what had been involved in their achievement. Because the researcher had always observed the particular events under discussion, there was both an opportunity to concentrate on these particular occasions and an obligation to give accounts consonant with what had happened on these occasions; and this the teachers consistently did. Because the researcher did not introduce any ideas which might be used in describing or explaining what had happened, the teachers were entirely dependent on their individual ways of construing the events of the observed lessons. Because the main interviews were conducted very soon after the observed lessons, it was probable that the teachers would be able to recall their thinking during the lessons, and they themselves claimed to be able to do so".
> (Brown and McIntyre,1993 p. 108-109)

Thus, there is good reason to be confident that the research designed by Brown and McIntyre gives a valid description of teachers' articulation of their professional craft knowledge. Hence, in this research study the research techniques of Brown and McIntyre are favoured over those that use repertory grids as data collection tools.

2.8 Summary

There is a large volume of evidence in the literature that documents misunderstandings in key science ideas among pupils. One of the main barriers to learning science appears to be the fact that pupils have everyday ways of thinking about these phenomena. The pupils' own ideas are continually reinforced in their everyday lives and this can act as a barrier to learning. The essential problem is summarised very well by Harrison and Treagust (1996):

> "Indeed, it is well recognised that students are adept at tolerating the teacher's concept for the duration of the instruction while conserving their personal conception".
> (Harrison and Treagust, 1996 p. 529).

In addition to the pupils' own understanding of scientific phenomena, additional problems are caused by factors like teaching methodology, representations in textbooks, use of analogies and the language of science. Although there is a large amount of research evidence regarding pupils' misunderstandings in science, only a small number of experimental studies have been conducted to evaluate the effectiveness of teaching approaches based on addressing specific learning demands. However, the small amount of evidence that exists does suggest that teaching approaches based on an analysis of learning demands are more effective at promoting learning than are conventional approaches.

There is even less research evidence on how student teachers plan and teach lessons on difficult ideas in science. There are difficulties in interpreting the work of Fischler in this area involving the user of repertory grids due to issues related to repertory grids themselves and the methodology of the research. The research techniques used by Brown and McIntyre appear to be far more satisfactory. The methodology to be adopted in this research project is described in detail in Chapter 4. Before discussing this methodology, we first consider the research question and the theoretical framework for data analysis used in this study.

CHAPTER 3

THE RESEARCH QUESTION. DEVELOPING THE THEORETICAL FRAMEWORK FOR DATA ANALYSIS

3.1 Introduction

This chapter begins with a brief review of the background to the research question and then continues with a description of the mechanism by which a theoretical framework was developed to assist in the analysis of the data collected. The reason for developing this framework is to provide a detailed map of various factors relating to the way student teachers teach, particularly in relation to their teaching of difficult ideas. The framework map serves as a useful frame of reference for identifying changes in practice as a result of the Intervention Package, i.e. the data can be mapped against this framework in order to help identify those aspects of the Intervention Package that lead to positive outcomes in terms of the classroom practice of the student teachers. The development of the theoretical framework was carried out by firstly surveying the literature for other related theoretical frameworks. Common features were then extracted from these related theoretical frameworks to assist in the development of the framework for analysing both the baseline data and the post-intervention data. Thus, it is hoped that the framework developed will assist in evaluating the effects (if any) of the Intervention Package.

3.2 The research question

As already discussed in chapters 1 and 2, there is an extensive body of literature documenting pupils' misunderstandings of key ideas in chemistry at secondary level. It is clear from the research literature in this area that these misunderstandings are widespread among pupils and are quite resistant to change. It is also clear from a study of the research literature in this area that there is a great dearth of research into how teachers teach ideas in those areas of science where these misunderstandings arise.

In Chapter 2 we learned that some research evidence indicates that a contributory factor to the persistence of misunderstandings is the way in which such ideas are taught. Science teachers may not always teach in ways that challenge or acknowledge misunderstandings. Therefore, pupils' grounding in some of the key ideas that underpin science may be poor and contribute to the idea that science is "difficult".

It is clear from a study of the research literature in this area that a great deal of the research into pupils' misunderstandings of ideas in science relies on a constructivist approach based on theories about how children learn rather than how teachers teach. In addition, much of the research appears to adopt a "once off" approach working on misunderstandings in specific areas with specific age groups of pupils with little follow-up in terms of development of teaching strategies or intervention packages for implementation in schools. As described in chapter 1, the following research question is being studied:

How do student teachers draw on the guidance they are given in their training course about dealing with pupils' misunderstandings in chemistry?

The research question puts the emphasis on the teaching strategies employed by student teachers in their teaching of difficult ideas in chemistry. Details of the methodology employed to answer the research question are given in Chapter 4. In broad terms, the methodology involves the analysis of current practice by student teachers when teaching difficult ideas in chemistry, the development of an Intervention Package to assist student teachers in their approach to teaching these difficult ideas in chemistry and the development of a theoretical framework to assist in the analysis of the data collected. The development of this theoretical framework will now be discussed.

3.3 Framework for analysing the data

A survey of the literature was carried out to identify frameworks that have been used when discussing factors that influence decisions made in science lessons. A total of seven frameworks was selected on the basis of their prominence in the literature (as exemplified by their frequency of citation by other researchers) and also on the basis of their applicability to this study (i.e. the frameworks emerged from research areas broadly similar to the research carried out in this study). These frameworks are summarised in Table 3.1.

In the following sections, a brief description of each framework is given, followed by an indication of how the particular framework is relevant to the present study. The frameworks are presented in chronological order.

AUTHOR(S)	TYPE OF ARTICLE	TITLE OF ARTICLE OR BOOK	FOCUS OF WORK	THEORETICAL FRAMEWORK FOR FACTORS THAT INFLUENCE DECISIONS MADE IN SCIENCE LESSONS
Dreyfus and Dreyfus (1986)	Book in which model developed to show the various stages in the acquisition of expertise. (Cf, Chapter 3, Developing Teachers - C. Day)	Mind over Machine: The Power of Human Intuition and Expertise in the Era of the Computer	• Model based upon learning from experience. • Recognises importance of perception, understanding and intuition • Recognised that "perception and understanding are based in our capacity for picking up not rules, but flexible styles of behaviour". • Criticism by Day: useful model for conceptualising growth but implies over-reliance upon learning from direct experience.	Identified five stages in Model of Skills Acquisition 1. Novice – rigid adherance, no discretionary judgement. 2. Advanced beginner – limited situational perspective, guideline for action based on global characteristics of situation. 3. Competent – conscious deliberate planning, sees actions in terms of longer term goals. 4. Proficient – decision making less laboured, sees what is most important in a situation. 5. Expert – intuitive grasp of situation based on deep understanding, vision of what is possible.
Wilson, Shulman and Richert (1987)	Paper in book, based on research (Exploring teacher thinking – J.Calder-head)	150 different ways of knowing: Representat-ions of knowledge in teaching	Followed a group of student teachers through their professional training and into their first year of teaching. • Focussed on how subject knowledge translated into classroom practice	Based on research, developed two frameworks: 1. Components of professional knowledge base for teaching. Introduced concept of pedagogical content knowledge. 2. Drew up a six stage model of pedagogical reasoning.

Table 3.1 Summary of theoretical frameworks developed to discuss factors that influence decisions made in science lessons.

Borko, Bellamy and Sanders (1992)	Article based on research project and published in book (Teachers and Teaching Eds. Tom Russell and Hugh Munby)	A Cognitive Analysis of Patterns in Science Instruction by Expert and Novice Teachers	Student science teachers and expert science teachers. • Used the theoretical framework to interpret differences between the two groups. • Looked at planning, teaching and post lesson reflections. • In contrast to expert teachers, found that student teachers had limited schemata for pedagogical content knowledge and did not have well developed pedagogical reasoning skills.	• Conceptual framework that characterises teaching as a complex cognitive skill. • Three central concepts: schemata, pedagogical reasoning and pedagogical content knowledge.
Brown and McIntyre (1993) Note: Model also used by Batten (1993) in Australia with similar results.	Book based on research project	Making Sense of Teaching.	Experienced and successful teachers. • Professional craft knowledge of teachers. • Identified 10 items that teachers do well (minority view of relaxed atmosphere and workload on pupils) • Research (i) Identified the criteria which teachers use to evaluate their own "good teaching", (ii) Helped to understand how teachers view their own classroom practice • What the teachers valued in their teaching: 1. How they maintained the interest and enthusiasm of their pupils. 2. How they maintained discipline 3. How they planned and managed lesson	• Built up theoretical framework around the following areas: 1.Normal desirable state of pupil activity (NDS) 2. Progress 3. Teachers' Actions. 4. Conditions which influence teaching • Experience gave rise to "repertoire of actions".

Table 3.1 (continued) Summary of theoretical frameworks developed to discuss factors that influence decisions made in science lessons.

Peterson and Treagust (1995)	Paper in Journal	Developing Pre-service Teachers' Pedagogical Reasoning Ability	Student teachers (second year pre-service primary teachers) • Focussed on development of pedagogical reasoning ability. • Student teachers only concerned with some stages: teacher-centred approach	• Used the six stages of Shulman's model: comprehension, transformation, instruction, evaluation, reflection and new comprehension. • Influenced by Reynold's (1992) four criteria for pre-service teacher education programmes: knowledge of subject matter, knowledge of strategies, knowledge of pedagogy and reflection.
Eraut M. E. (1996)	Textbook and published articles.	Professional Knowledge in Teacher Education	• Examined area of professional knowledge. • Teachers' ability to understand and interpret events in their classroom requires situational knowledge, i.e. knowledge based upon experiences in similar situations. • Societal knowledge relates to responsibility of teacher to relate what the student is learning to the broader context. • Outlined four kinds of process knowledge that play a critical role in work of classroom teacher.	Domains of teachers' professional knowledge can be mapped along two dimensions: • Vertical dimension describes the different contexts in which knowledge is used, i.e. classroom knowledge, classroom-related knowledge, management knowledge and other professional roles. • Horizontal dimension indicates the different kinds of knowledge, i.e. subject matter knowledge, education knowledge, situational knowledge and societal knowledge. • Need to have repertoire of teaching approaches from which to make selection.

Table 3.1 (continued) Summary of theoretical frameworks developed to discuss factors that influence decisions made in science lessons.

Fischler H (1999)	Paper in book, based on research. (Researching Teaching Ed. John Loughran)	The Impact of Teaching Experiences on Student teachers' and Beginning Teachers' Conceptions of Teaching and Learning Science.	Student teachers and beginning teachers. • Investigated the impact of teaching experiences on concepts of teaching and learning by student teachers in physics. • Important areas for pupils: (i) physics knowledge, (ii) ability to connect physics and everyday life, (iii) general intellectual abilities, (iv) interest, motivation, attention, active involvement, (v) experimental skills, (vi) positive attitude, (vii) social skills for group work. • Found that student teachers' teaching experiences only meet their expectations to a small extent.	From analysis of data, drew up five categories: 1. Content related principles – applications of content in everyday life, etc. 2. Principles related to nature of presentation – illustrating topics, using correct terminology, etc. 3. Principles aimed to activate pupils – exciting experiments, problem solving, etc. 4. Action oriented principles (for pupils) – pupils carry out experiments themselves, handle equipment, etc. 5. Principles re classroom climate – being fair and just, informality, etc.

Table 3.1 (continued) Summary of theoretical frameworks developed to discuss factors that influence decisions made in science lessons.

3.3.1 Framework developed by Dreyfus and Dreyfus

As already discussed, there are various theories of expertise which describe and explain differences between teachers. One commonly accepted view is that teachers learn to teach by experience and one of the most influential models for the development of expertise is that of Dreyfus and Dreyfus (1986). In this framework they identify a number of levels of skill development as the professional moves from being a "novice" through to "advanced beginner", "competent", "proficient" and "expert". The main features of this model are summarised in Table 3.2, page 91 (Dreyfus and Dreyfus, 1986). The Dreyfus and Dreyfus model recognises that "perception and understanding are based on our capacity for picking up not rules but flexible styles of behaviour" (1986, p. 5) within a given situation.

Dreyfus emphasise the development of intuition or "know-how" in the above model, i.e. "the understanding that effortlessly occurs upon seeing similarities with previous experiences". (Dreyfus and Dreyfus 1986 p.28). They describe some examples to illustrate their concept of intuition:

> "Intuition or know-how, as we understand it, is neither wild guessing nor supernatural inspirations, but the sort of ability we all use all the time as we go about our everyday tasks..... The proficient chess player can recognise a very large repertoire of types of positions. Grasping almost immediately, and without conscious effort, the sense of a position, he sets about calculating a move that best achieves his intuitive plan".
>
> (Dreyfus and Dreyfus, 1986 p. 29)

Level 1 Novice

- Rigid adherence to taught rules or plans
- Little situational perception
- No discretionary judgement

Level 2 Advanced Beginner

- Guidelines for action based on attributes or aspects (aspects are global characteristics of situations recognisable only after some prior experience)
- Situational perception still limited
- All attributes and aspects are treated separately and given equal importance

Level 3 Competent

- Coping with crowdedness
- Now sees actions at least partially in terms of longer term goals
- Conscious deliberate planning
- Standardised and routinised procedures.

Level 4 Proficient

- See situations holistically rather than in terms of aspects
- See what is most important in a situation
- Perceives deviations from the normal pattern
- Decision-making less laboured
- Uses maxims for guidance, whose meaning varies according to the situation

Level 5 Expert

- No longer relies on rules, guidelines or maxims
- Intuitive grasp of situations based on deep tacit understanding
- Analytic approaches used only in novel situation or when problems occur
- Vision of what is possible

Table 3.2 Summary of Dreyfus' Model of Skills Acquisition (Eraut 1994, p. 124)

Despite its emphasis on perception, understanding and intuition, the model does appear to have a logical progression that is based upon learning from experience. In another paper (Dreyfus and Dreyfus, 1977) the authors describe the transition that may occur towards becoming an expert performer as follows:

> “The performer is no longer aware of features and rules, and his/her performance becomes fluid and flexible and highly proficient. The chess player develops a feel for the game; the language learner becomes more fluent; the pilot stops feeling he he/she is flying the plane and simply feels the he/she is flying.”
>
> (Dreyfus and Dreyfus, 1977 p. 12)

The five steps from novice to expert developed by Dreyfus and Dreyfus are relevant to this study in that the framework provides a series of benchmarks to help analyse the progress of student teachers in the classroom. In addition, the framework may be used to help understand the views of the student teachers themselves about their science teaching, how they teach particular topics, their personal reflections, etc. The framework developed by Dreyfus and Dreyfus is one of the frameworks most often cited by other researchers as it has wide applicability, not only in the field of education, but in many other areas as well.

3.3.2 Framework developed by Wilson, Shulman and Richert

Wilson et al. (1987) carried out research which involved following a group of beginning teachers through their professional training and into their first year of teaching, to examine how their subject matter knowledge was translated into classroom practice. As part of their research they proposed two frameworks for data analysis. Firstly, they proposed that teachers draw upon many types of knowledge when they are making decisions about the content of their courses. These types of knowledge are summarised in Figure 3.1 (Wilson et al., 1987 p.113).

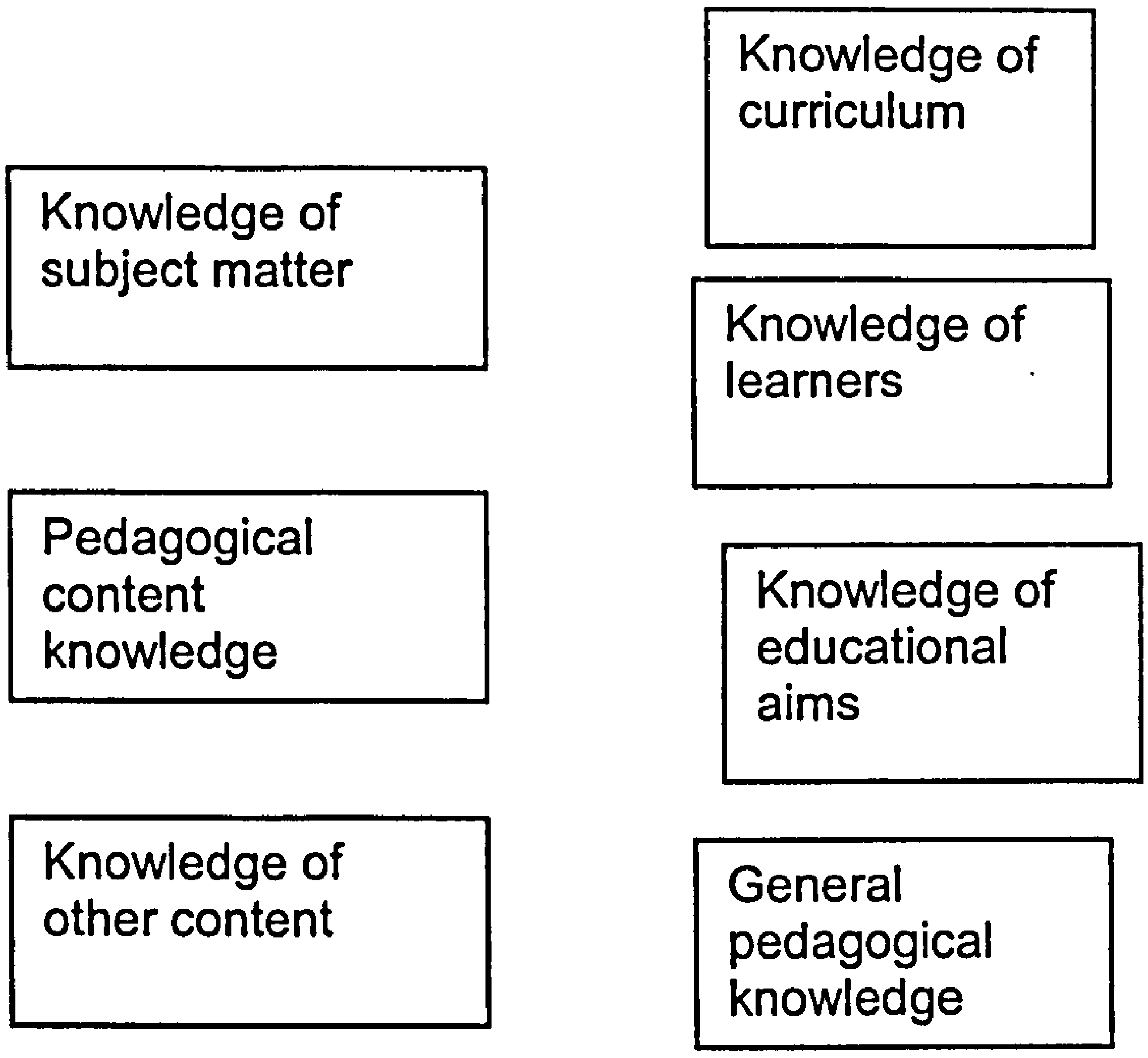


Figure 3.1 Components of the professional knowledge base of teaching.

This first model is described by Wilson et al. (1987 p.118) as "a logical model of the components of the professional knowledge base for teaching" and is described by the authors as follows:

> "We are developing this model from the perspective that teachers require a body of professional knowledge that encompasses both pedagogy and subject matter. General pedagogical knowledge includes knowledge of theories and principles of teaching and learning, knowledge of learners, and knowledge of principles of teaching and learning, knowledge of learners and knowledge of principles and techniques of classroom behaviour and management. Subject matter knowledge includes both the substantive and syntactic structures of the discipline. The substantive structures include the ideas, facts, and concepts of the field, as well as the relationships among those ideas, facts and concepts. The syntactic structures involve knowledge of the ways in which the discipline creates and evaluates new knowledge"
>
> (Wilson et al.,1987 p. 118)

Thus, in their everyday teaching, teachers use their content knowledge (i.e. their understanding of the facts or concepts within a domain) as well as their grasp of the structures of the subject matter. Teachers also use general pedagogic knowledge, i.e. knowledge of pedagogical principles and techniques that is not bound by topic or subject matter. Teachers also have knowledge of learners, including knowledge of pupil characteristics and cognition as well as knowledge of motivational and developmental aspects of how pupils learn. Finally, teachers frequently draw upon their curricular knowledge, i.e. their understanding of the programmes and materials designed for the teaching of particular topics and subjects at a given level. The authors do not attempt to show how these types of knowledge are inter-related. They admit that "how these kinds of knowledge relate to one another remains a mystery to us.....they are just boxes floating on a page" (Wilson et al., 1987 p. 118).

The second model that they drew up portrayed the process of pedagogical reasoning and action through six common aspects of teaching: comprehension, transformation, instruction, evaluation, reflection and new comprehension, Figure 3.2. An outline of this model is given in section 3.2.5 when discussing the work of Peterson and Treagust (1995).

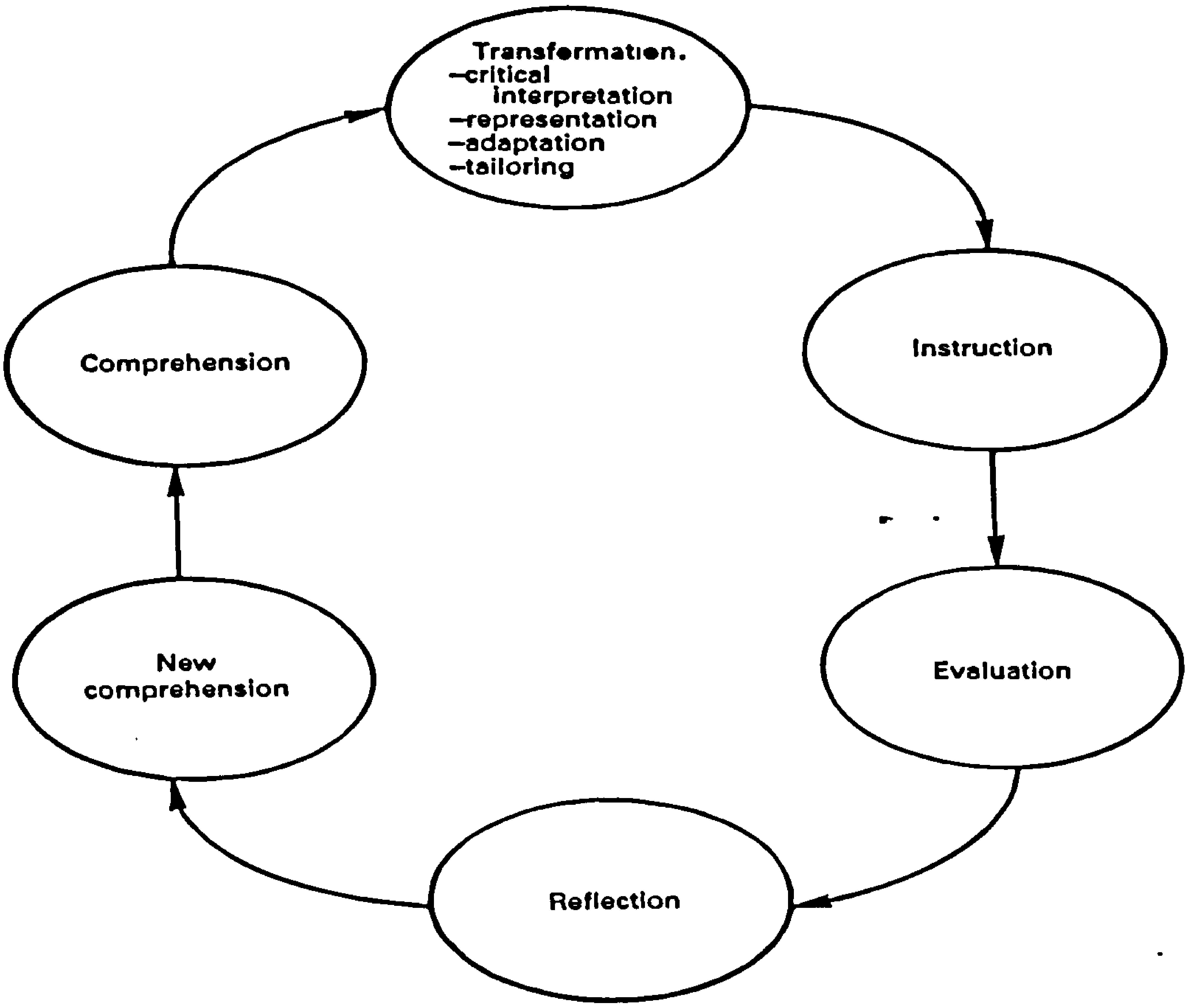


Figure 3.2 Diagram representing a model of pedagogical reasoning (Wilson et al., 1987 p.119)

Since the framework developed by Wilson et al. (1987) was developed using beginning teachers, it is highly relevant to the project under discussion. The reference to "knowledge of subject matter" is almost identical to that found in the frameworks developed by Borko et al. (section 3.3.3) and Peterson and Treagust (section 3.3.5). In addition, both sets of researchers also use the identical term "pedagogical content knowledge" when describing their respective frameworks. The concept of pedagogical content knowledge was introduced by Shulman (1986) and will be described in more detail in section 3.4.

3.3.3 Framework developed by Borko, Bellamy and Saunders

This conceptual framework (Borko et al., 1992) considered teaching as a complex, cognitive skill. The research project examined the thinking and actions of some expert and novice science teachers. The researchers used this conceptual framework that characterises teaching as a complex cognitive skill - determined in part by the nature of a teacher's knowledge system - to explain patterns in the teachers' planning, teaching and post lesson reflections. In devising a framework for interpreting differences between expert and novice teachers, they considered that teaching as a complex cognitive skill was characterised by three central concepts: **schemata, pedagogical reasoning** and **pedagogical content knowledge.**

- **Schemata** are the abstract knowledge structures that summarise information about particular cases in teaching and the relationships among them

(Anderson, 1984). People store knowledge about objects and events in their experiences in schemata or knowledge structures representing these experiences.

- **Pedagogical reasoning** is the "process of transforming subject matter knowledge forms into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the pupils" (Shulman, 1987b). According to Borko et al. pedagogical reasoning includes the identification and selection of strategies for representing key ideas in a lesson and the adaptation of these strategies to the characteristics of learners. This form of thinking is unique to the profession of teaching and is relatively undeveloped in student teachers (Feiman-Nemser and Buchman, 1986, 1987).

Pedagogical content knowledge is described by Borko et al. (1992) as "knowledge of subject matter for teaching..... This domain of subject knowledge consists of an understanding of how to represent specific subject matter topics and issues in ways that are appropriate to the diverse abilities and interests of learners" (Borko et al., 1992 p. 50). Borko et al. (1992) argue that developing knowledge structures and learning pedagogical reasoning skills are major components of learning to teach and support their argument with reference to research in this area (Feiman-Nemser and Buchmann, 1986, 1987; Wilson et al., 1987).

The framework of teaching as a complex cognitive skill was also used by Borko and Livingston (1989) in an investigation of the thinking and actions of expert and student teachers of mathematics. The researchers analysed the planning, teaching and post-lesson reflections of two groups of teachers using this conceptual framework of teaching as a complex cognitive skill. They found that, when compared to experts, the student teachers showed more time-consuming and less efficient planning, they encountered problems when attempts to be responsive to pupils led them away from scripted lesson plans, and they reported more varied, less selective post-lesson reflections. The researchers accounted for these differences by the assumptions that the cognitive schemata of the student teachers, particularly their schemata for pedagogical content knowledge, are less elaborate, less interconnected and less easily accessible than those of experts and that their pedagogical reasoning skills are less well-developed.

When analysing the results of their research in terms of the conceptual framework of teaching as a cognitive skill, Borko et al. interpreted the planning of the expert teachers in terms of a process of combining information from existing schemata to fit the particulars of a given lesson. They argued that, since experts have well-developed and easily accessible schemata for such aspects of teaching as content, pupils and instructional activities, they are able to plan quickly and efficiently. Also, once they select the desired activities, they need only pull the appropriate materials from their extensive activity files. They also noted that the benefits of well-developed knowledge systems were evident in the expert teachers' introductions to laboratory activities as well. These teachers drew upon their pedagogical content knowledge (which includes knowledge of pupils and content) to anticipate difficulties the pupils were likely to encounter and to devise introductory explanations and demonstrations to minimise the difficulties.

The researchers noted that the success of the experts' explanations and demonstrations seemed to depend upon their ability to assess pupil understanding and to quickly provide examples when pupils were uncertain or confused. This ability of the teacher to be responsive to pupils when providing explanations and demonstrations was interpreted within the conceptual framework in terms of the teachers having an extensive network of interconnected, easily accessible schemata and being able to select information from these schemata during actual teaching and learning interactions based on specific classroom events. The following quotation is taken from an interview with one of the expert science teachers:

> "I'll see their confusion and I'll realise I need another way to say the same thing, or make it visible to them, so they can see it happen"
> (Borko and Livingston,1989, p. 61)

Quotations like the above were used as evidence for the correct interpretation of the conceptual framework by the researchers.

The researchers comment that the student teachers, in contrast to the expert teachers, often have to develop or at least modify and elaborate their schemata as they plan. In addition, the schemata for pedagogical content knowledge of the student teachers was particularly limited. The researchers found that while the expert teachers' knowledge structure included "stores of powerful explanations, demonstrations and examples for representing subject matter to students" (Borko et al., 1992 p. 67), the student teachers had to develop these representations as part of the planning process for each lesson. Borko et al argue that since the pedagogical reasoning skills of the student teachers are less well-developed than those of the expert teachers, planning is often a very time-consuming activity for them and once they have planned the content of their lessons, they must then prepare the materials to carry out the plan.

The researchers explained the difficulties that the student teachers encounter when they do not make or follow detailed lesson plans in terms of the limitations in the knowledge systems of these student teachers. In contrast to the expert teachers, student teachers do not have as many "appropriate schemata for instructional strategies to draw upon in a given classroom situation" (Borko et al., 1992). In addition, student teachers do not have sufficiently well-developed schemata for pedagogical content knowledge to enable the construction of explanations on the spot. Since their schemata for content knowledge are not easily accessible, they are sometimes unable to answer questions asked by the pupils. The value of viewing teaching as a complex cognitive skill is underlined by Russell and Munby (1992) when commenting on the above research project.

> "The contrast between beginning and experienced teachers is particularly effective in illustrating the value of a cognitive skill perspective, as the experienced teachers revealed more appropriate and more developed schemata for interpreting and thus responding to the events of teaching. These schemata help to explain the experts' greater ability to interpret and respond to students' signals about how well they were understanding their lessons".
>
> (Russell and Munby, 1992 p. 5)

The framework developed by Borko et al. (1992) is of relevance to the present research study in that it emphasises the part played by cognitive reasoning skills and schemata in learning to teach. This framework takes into account the views of student teachers on how to plan and teach particular science topics and points out the limited store of teaching strategies possessed by student teachers. In addition, by emphasising the concept of pedagogical content knowledge, it focuses on an area recognised by student teachers as important, i.e. knowledge of subject matter for teaching and "the ways of representing the subject that makes it comprehensible to others" (Shulman, 1987). The framework is also useful in that it is used to compare the planning, teaching and degree of reflection possessed by experienced teachers and student teachers.

3.3.4 Framework developed by Brown and McIntyre

An outline of the research work carried out by Brown and McIntyre has already been given in section 2.7. The theoretical framework developed by Brown and McIntyre to assist in the analysis of the data collected from the sixteen teachers in their study is now considered. The researchers (Brown and McIntyre, 1993) built up this theoretical framework around four areas:

1. **Normal desirable state of pupil activity.** Brown and McIntyre found that one of the most common features of the various teachers' accounts of their teaching was that the teachers almost always talked about what their pupils were doing. The teachers placed great emphasis on what the researchers call a "Normal Desirable State of Pupil Activity" (NDS) in the classroom. This term refers to what the teachers saw as the normal and desirable patterns of classroom activity - lessons were seen as satisfactory so long as pupils continued to act in those ways which were seen by the teacher as routinely desirable.

   For the secondary school teachers involved in the research project, the NDS fell into two categories: (i) those that characterised activities where the teacher was interacting with the whole class and (ii) those where pupils were working independently on tasks of various kinds. The teachers were efficient at dovetailing the whole class teaching and independent working of each of the groups. Brown and McIntyre commented on the fact that "whatever way the teacher manages things, there appears to be 'rules' which develop over time and characterise the pattern of classroom activity." (Brown and McIntyre, 1993 p. 60).

2. **Progress.** A second set of goals identified by the researchers from the teachers' accounts of their teaching was simply called "Progress". All of the teachers evaluated their lessons not only in terms of maintaining particular

Normal Desirable States but also in relation to promoting specific kinds of Progress, The researchers identified three broad categories for these Progress goals: (a) Progress in terms of the development of pupils' knowledge, understanding, skills, confidence or other attributes, (b) Progress in the sense of generating a product, a performance, artefact or completed exercise, (c) Progress in terms of accomplishing a sequence of planned activities or getting through a course.

The concept of **Progress** introduced a development aspect in contrast with the steady situation of Normal Desirable State. When speaking about Progress goals, teachers emphasised pupils' cognitive learning, acquisition of concepts, picking up ideas and developing skills. There were also numerous examples of pupils' affective growth (e.g. confidence) among teachers priorities and of concern for such things as pupils becoming capable of thinking through problems for themselves and applying their theoretical knowledge to practice. A common type of goal was getting some kind of task, exercise or worksheet completed.

3. **Teachers' Actions.** Although when asked about their teaching, the teachers invariably responded by talking about their pupils and ultimately the teachers talked about what they themselves did in the classroom. Brown and McIntyre used this as their third generalisable concept which they called "Teachers' Actions". The researchers found that when teachers spoke about their own

> actions, they always appeared to evaluate them in terms of the extent to which they were effective in maintaining particular Normal Desirable States or promoting specific kinds of progress.

The above three inter-related generalisable concepts were used by Brown and McIntyre to build a theoretical framework that reflected how the teachers construed their teaching. This theoretical framework is illustrated in Figure 3.3.

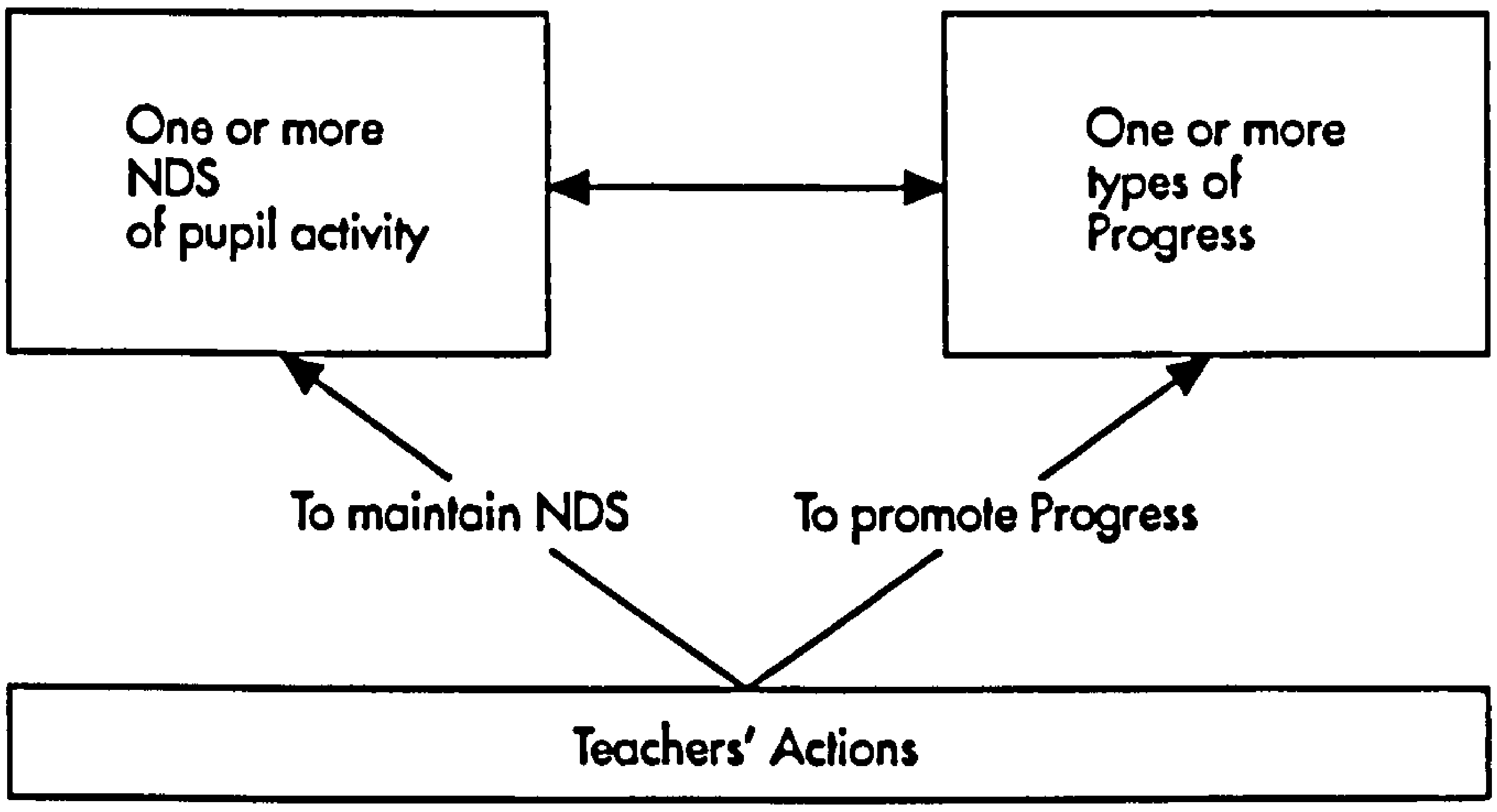


Figure 3.3 The three inter-related generalisable concepts used by Brown and McIntyre in developing a framework to describe how teachers evaluated their own teaching (Brown and McIntyre, 1993 p. 64).

In the above discussion, no mention has been made of the demands, pressures and influences that are important factors in the process of teaching. To take these into account, Brown and McIntyre included a fourth generalisable concept which they referred to as the "Conditions" which impinge on the teaching.

4. **Conditions which influence teaching.** Brown and McIntyre found that the teachers were very conscious of the circumstances in which they were working and of the impact of those circumstances on their teaching. In interviews with the teachers, it was found that the Conditions had a profound effect on the standards which the teacher felt they could apply in maintaining their preferred Normal Desirable State or promoting Progress. In some cases standards were lowered and in other cases standards were enhanced.

   The four conditions are summarised in Figure 3.4.

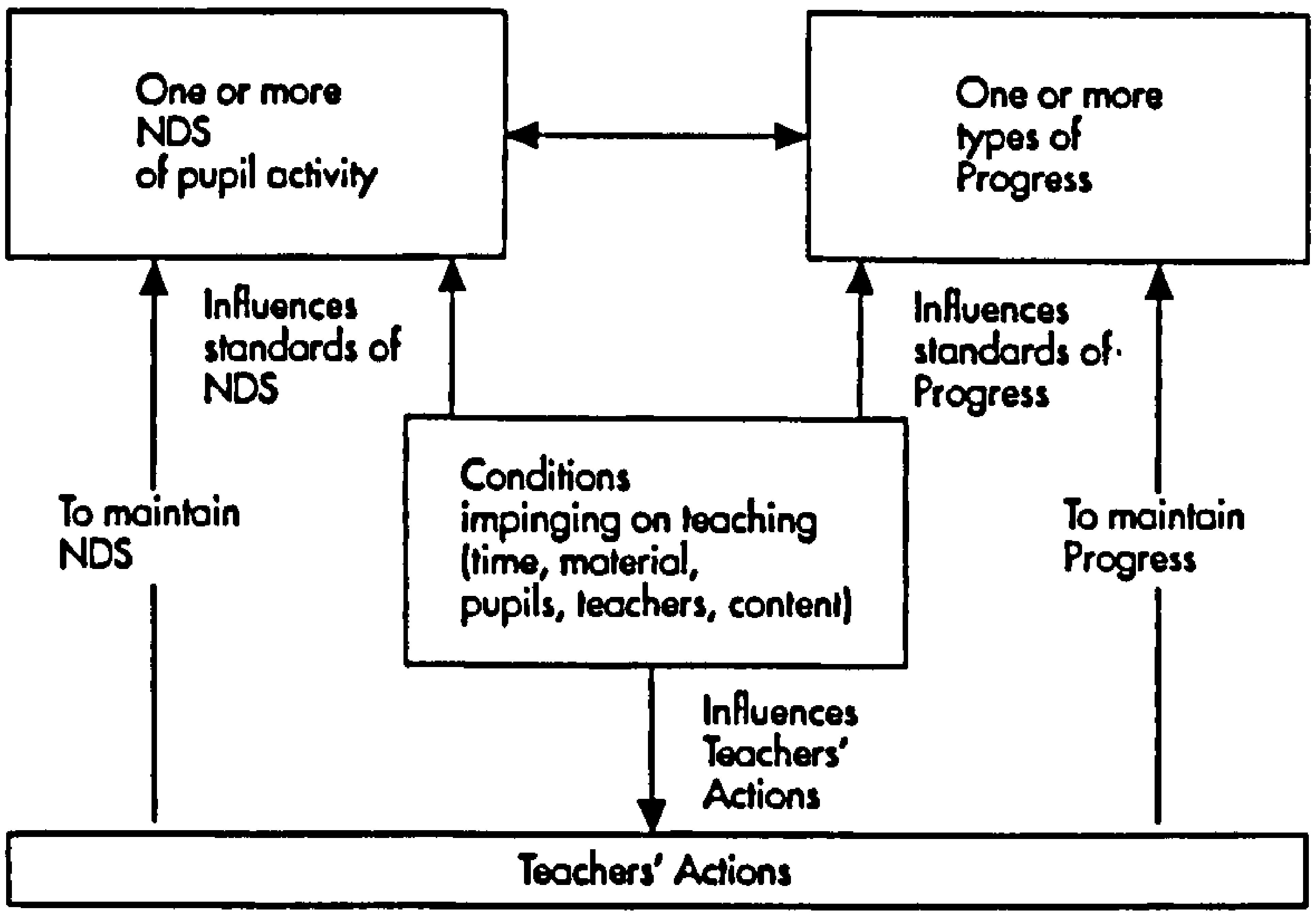


Figure 3.4 The framework developed by Brown and McIntyre showing the four generalisable and inter-related concepts which teachers use in evaluating their own teaching (Brown and McIntyre, 1993 p. 70).

The teachers' descriptions of the Conditions impinging on their teaching fell into five categories: pupils, time, content, material and teachers themselves.

(a) **Pupil Conditions**. Brown and McIntyre identified two types of Pupil Conditions. The first arose from the behaviours or characteristics which pupils displayed on a particular occasion, e.g. bored, noisy, "high", excited, subdued, fidgety, etc. These behaviours tended to reduce the standards of NDS or Progress which the teachers expected to maintain or to cause the teacher to change direction and try to establish a new NDS or Progress goal. Occasionally teachers mentioned that pupils performed better, grasped ideas, worked more quickly or generally managed their tasks more effectively than had been anticipated. In these circumstances, the standards expected of the NDS or Progress were raised. The second type of Pupil Conditions described by Brown and McIntyre refer to more enduring characteristics of pupils, e.g. ability, attention-seeking, attentiveness, gender, maturity, attitudes, shyness, etc. Some teachers placed more emphasis on these "permanent" characteristics of their pupils whilst other teachers placed emphasis on attending to pupils' behaviour on the day.

(b) **Time conditions.** Teachers involved in Brown and McIntyre's research identified time as being an important influence on their teaching. The standard of NDS or Progress which could be established during the first lesson of the day could not be accomplished in a lesson given towards the end of the day. In addition, having a class immediately after the mid-morning break or following lessons with a particular colleague affected their chances of being able to maintain their preferred NDS or to promote Progress.

(c) **Content conditions.** The content being covered in a lesson was seen as a Condition which influenced the nature and standards of NDS and Progress being made. For example, active learning with pupils cutting out shapes of triangles on cardboard could be used in a lesson on geometry whilst other areas of mathematics involved pupils taking on a more passive role.

(d) **Material conditions.** The actual resources available to teachers imposed major Conditions on their teaching. For example, teachers with large class sizes had problems squeezing extra desks into the room, resulting in overcrowding being a disruptive influence on the class. Likewise, excessive numbers in the laboratory was a constraining factor on the Progress made.

(e) **Teacher conditions.** The teachers in the research project referred to the fact that they themselves frequently had an effect on the standards of the Normal Desirable States and Progress. In most cases the effect was a detrimental one, e.g. pace too slow, forgetting the time, being tired and exhausted, failing to provide adequate guidance, etc.

The work of Brown and McIntyre presents a very powerful framework that is directly applicable to the present research study. The Normal Desirable State (NDS) presents a particularly striking view of teaching in terms of the type of classroom climate viewed as satisfactory by the teacher. The attainment of this type of classroom climate is also seen by student teachers as one of the key goals to be attained in their early days of teaching (Fischler, 1999; Bianchini et al., 2003). In addition, the concept of Progress developed by Brown and McIntyre enables us to examine data from the student teachers in terms of how they evaluate the success or otherwise of their lessons. Finally, the concept of Conditions discussed by Brown and McIntyre has implications for this study in that it allows us to investigate how the local conditions affected the teaching of the student teachers and the decisions they made in science lessons.

3.3.5 Framework developed by Peterson and Treagust

This research project (Peterson and Treagust, 1995) focussed on the development of the pedagogical reasoning ability of pre-service teachers in an attempt to improve their ability to teach primary science. The researchers reasoned that teachers not only need to develop a knowledge base for teaching science, but also need to use their understanding of science content, curriculum and the learner, when making decisions regarding their classroom teaching. This decision making process has been described as "pedagogical reasoning" by Shulman (1987b). Peterson and Treagust recommend that pedagogical reasoning be given a higher priority in teacher education programmes and that these programmes should encourage pre-service teachers to develop their reasoning ability and apply this to teaching situations. The six stages in Shulman's model, shown in Figure 3.5 page 109, were used by Peterson and Treagust.

In this study, the pedagogical reasoning ability of second year pre-service teachers was established at the beginning of, and during, a science education unit designed to encourage the development of all six stages of the pedagogical reasoning process.

1. **Comprehension.** Teacher understanding of the ideas to be taught and the educational purposes of the topic/subject
2. **Transformation.** Comprehended ideas are transformed by the teacher for use in a particular classroom setting. This includes critical interpretation of text materials, identifying ways of representing ideas, selecting appropriate teaching methods, adapting and tailoring ideas to the particular class group.
3. **Instruction.** The act of teaching. This includes organising and managing the class and students, presenting clear explanations, interacting with students, questioning and evaluating.
4. **Evaluation.** This includes both the evaluation of student learning and the teacher's own teaching performance, materials employed, etc.
5. **Reflection.** The review of the events and accomplishments that occurred during the lesson.
6. **New Comprehension.** New understanding of subjects, learners, purposes and pedagogy through the process of teaching.

Figure 3.5. Six stages of a model of pedagogical reasoning (Wilson et al., 1987)

The model used by Peterson and Treagust was also influenced by the work of Reynolds (1992) who, from a synthesis of the literature in this area, among other abilities proposed that beginning teachers should enter the first year of teaching with the following having been developed:

- Knowledge of the subject matter they will teach.

- Knowledge of strategies, techniques and tools for creating and sustaining a learning community, and the skills and abilities to employ these strategies, techniques and tools.
- Knowledge of pedagogy appropriate for the content area they will teach.
- The disposition to reflect on their own actions and pupils' responses in order to improve their teaching and the strategies and tools for doing so.

Reynolds (1992) also pointed out that by the end of their training, beginning teachers should be able to:

- Plan lessons that enable pupils to relate new learning to prior understanding and experience.
- Develop rapport and personal interaction with pupils.
- Establish and maintain rules and routines that are fair and appropriate to pupils.
- Arrange the physical and social conditions in the classroom in ways that are conducive to learning and that fit the academic task.
- Represent and present subject matter in ways that enable pupils to relate new learning to prior understanding and that help pupils develop metacognitive strategies.
- Assess pupil learning using a variety of measurement tools and adapt instruction according to the results.
- Reflect on their own actions and pupils' responses in order to improve their teaching.

The framework proposed by Peterson and Treagust is of direct relevance to our study and has many similarities to some of the other frameworks discussed. The first stage of Peterson and Treagust's framework (Comprehension) is very similar to the description of pedagogical content knowledge found in the Borko et al. framework (1992). Also, the second stage (Transformation) is almost identical to the description of teaching strategies and "routines" found in the frameworks of Dreyfus and Dreyfus (1986), Brown and McIntyre (1993) and Eraut (1996). The third stage (Instruction) has many points in common with the "schemata" found in the framework of Borko et al (1992) and that of "principles related to nature of presentation" described by Fischler (1999). The fourth and fifth stages (Evaluation and Reflection) are very similar to the concept of the "teacher as a reflective practitioner" discussed in Eraut's framework (1996). The sixth stage (New Comprehension) is very close to the "Progress" component of the framework proposed by Brown and McIntyre.

3.3.6 Framework developed by Eraut

Teachers' professional knowledge has been defined (Eraut, 1996) as "the knowledge possessed by professionals which enables them to perform professional tasks, roles and duties with quality". Eraut argues that the domains of teachers' professional knowledge can be mapped along two dimensions as shown in Figure 3.6.

Context of use	**Area of knowledge**			
	Subject Matter Knowledge	Education Knowledge	Situated Knowledge	Societal Knowledge
Classroom Knowledge				
Classroom-related knowledge				
Management Knowledge				
Other Professional Roles				

Figure 3.6. The domains of teachers' professional knowledge (Eraut, 1996 p. 25).

The vertical dimension describes the different contexts in which knowledge is used, i.e. classroom knowledge, classroom-related knowledge, management knowledge and other professional roles. The horizontal dimension indicates the different kinds of knowledge, i.e. subject matter knowledge, education knowledge, situational knowledge and societal knowledge. Teachers' ability to understand and interpret events in their classroom requires **situational knowledge** which itself will be based upon experience in similar situations. **Societal knowledge** relates to the responsibility of teachers to "look beyond the specific to the more general purposes of education". This kind of knowledge is vital in order to relate what the pupil is learning to the broader context which gives it meaning.

Eraut (1995) also points out in his framework the need for the teacher to have a repertoire of teaching approaches and activities from which to make an appropriate selection:

> ".. the choice from this repertoire can only be appropriate if there is a good understanding of the students' needs and an adequate conceptualisation of the decision-making process – for example of matching learning activities to students' capabilities.... Time for professional thinking is limited when routine duties are very demanding."
>
> (Eraut, 1995 p. 229)

Eraut points out that there are at least four kinds of process knowledge that play a critical part in the work of the classroom teacher:

1. **Process for acquiring information, especially information about students.** These range from deliberate searches to the almost intuitive "reading of an emergency situation."
2. **Routinised actions and skilled behaviour.** Much classroom teaching falls into this category, intuitive yet following discernible patters and still under some overall cognitive control.
3. **Deliberate processes such as planning, decision-making and problem solving.** These involve analysing the context, devising options, thinking about them and eventually choosing a course of action.
4. **Meta-processes such as assessing, evaluating and controlling.** These processes involve teachers assessing the impact of their actions and evaluating their personal practice. The processes also involve the teachers making use of this information to modify or rethink their decisions and work patterns.

Eraut's framework also includes reference to the moral dimension of teaching and the need for personal reflection (Eraut, 1995). He argues that "it is the moral and professional accountability of teachers which should provide the main motivation for their continuing professional development and suggests that being a professional practitioner implies:

> 1. A moral commitment to serve the interests of students by reflecting on their well-being and their progress and deciding how best it can be fostered or promoted.
> 2. A professional obligation to review periodically the nature and effectiveness of one's practice in order to improve the quality of ones's management, pedagogy and decision making.
> 3. A professional obligation to continue to develop one's own practical knowledge both by personal reflection and through interaction with others.
>
> (Eraut, 1995, p. 232).

The concept of the teacher as a reflective practitioner is discussed at some length by the author (Eraut, 1995) who points out that teachers continue to learn by reflecting on their own experience and assessing the effects of their behaviour and their decisions.

Eraut's framework (1995, 1996) is relevant to this study as it has a number of similarities to those of Brown and McIntyre (1993) and Dreyfus and Dreyfus (1996) in its emphasis on repertoire of actions and intuitive behaviour. As well as these components, Eraut emphasises the need for processes like planning, decision making, problem solving and reflection – these processes are of direct relevance to the procedures carried out by student teachers as part of their training. Eraut's model of teaching is summarised in Figure 3. 7

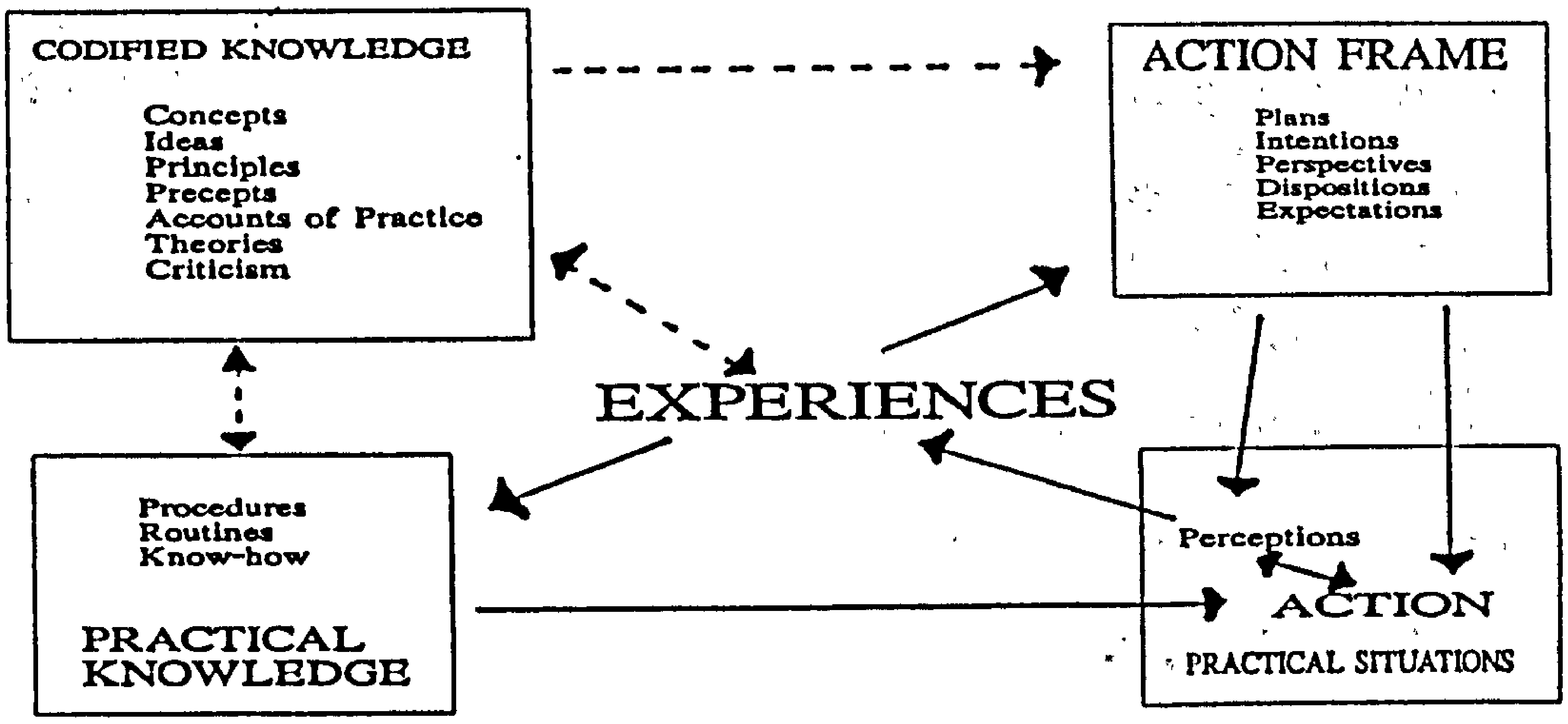


Figure 3.7 Model of teaching proposed by Eraut (Eraut, 1996 p. 26)

3.3.7 Framework developed by Fischler

In chapter 2, an outline of research carried out by Fischler (Fischler, 1999) was given. In this research, he carried out structured interviews with beginning teachers and tried to access information about the thought processes of these teachers, i.e. the factors that inform decisions they made about their teaching. In order to assist with the analysis of the data that he collected, Fischler drew up a framework consisting of five categories to which he assigned various "principles" as follows:

1. **Content-related principles.** The student teachers regarded the selection of content which has applications in everyday life as a means of giving pupils an understanding of the various applications of physics. In this way, the pupils would be more interested in understanding the physics behind these

applications. Examples given of this principle were relating the physics in the classroom to applications in the outside world, taking examples of topics from everyday life, showing the relevance of physics to our lives, etc.

2. **Principles related to presentation of material.** The student teachers felt that for successful learning to occur, it was necessary to have clear presentations which could be understood by the pupils. If possible, each presentation should be accompanied by a demonstration experiment. Examples given of this principle were using the correct physics terminology during presentations, illustrating topics that pupils have difficulty in understanding, etc.

3. **Principles aimed at stimulating pupils.** The student teachers tried to create opportunities in the classroom for pupils to be stimulated and actively participate in the lesson. Examples given of this principle were demonstrating exciting experiments to motivate the pupils, involving pupils in problem solving, etc.

4. **Action-oriented principles.** The student teachers felt that if the pupils were working independently on their own, then this increased their motivation to learn. Examples given of this principle were allowing pupils to carry out experiments that they have planned themselves, giving pupils the opportunity to handle physics equipment, etc.

5. Principles referring to classroom climate. The student teachers strongly felt that a positive classroom climate contributed to successful teaching and learning. They felt that the teacher's behaviour in the classroom has a crucial role in creating this positive classroom climate. Examples given of this principle were being fair and just in dealing with the pupils, dealing with pupils in an informal way, creating a friendly climate in the classroom, etc.

The framework developed by Fischler is of direct relevance to the study under discussion in this thesis as the five "principles" in the framework reflect the views of the student teachers involved in his study. In addition, there is some overlap with parts of other frameworks discussed, e.g. "principles relating to classroom climate" as discussed by Fischler (1999) bears a close similarity to the Normal Desirable State described by Brown and McIntyre (1993). Similarly, the "principles related to presentation of material" (Fischler, 1999) bear close resemblance to the "schemata" described by Borko et al (1992). The emphasis emerging from Fischler's framework is very close to the material presented in many teacher training courses, i.e. importance of clear presentation, variety in teaching, use of everyday example, keeping the pupils interested, use of practical work, etc.

3.4 Developing the categories for analysis of data

There is clearly a great richness of reflection in the theoretical frameworks discussed in section 3.3. It is also clear that there is considerable overlap in what the different authors and researchers describe when they discuss the various factors that influence the decisions that teachers make in the classroom. For example, the "repertoire of routines" discussed by Brown and McIntyre (1993) is similar to the "schemata" proposed by Borko et al. (1992) and is also similar to the "repertoire of teaching approaches" discussed by Eraut (1996); the "pedagogical content knowledge" of Wilson et al. (1987) closely resembles the "professional craft knowledge" discussed by Brown and McIntyre (1993); the "situational" knowledge described by Dreyfus and Dreyfus (1986) is similar to the "conditions" discussed by Brown and McIntyre (1993) and to the "situational knowledge" discussed by Eraut (1996); the "reflection-in-action" and "knowing in action" model proposed by Brown and McIntyre closely resembles the model of reflection of the professional practitioner described by Eraut (1996). In this section we attempt to draw together the different forms of terminology into common features to describe these factors as simply as possibly.

From a study of the various theoretical frameworks, seven common themes emerged from the frameworks to help understand the factors that influence the decisions that teachers make in the classroom. These seven common features are summarised in Table 3.3. and discussed in detail in the following sections.

Common feature to summarise concept	Dreyfus and Dreyfus (1986)	Wilson, Shulman and Richert (1987)	Borko, Bellamy and Sanders (1992)	Brown and McIntyre (1993)	Peterson and Treagust (1995)	Eraut M. E. (1995, 1996)	Fischler H (1999)
1. View of science	Set of facts to be mastered in various stages.	Subject matter - understanding of this must be fostered in pupils.	Subject matter – "stores of powerful explanations"	Subject matter covered by lots of activities.	Subject matter – "science content knowledge"	Subject matter knowledge - formally taught to pupils.	Basic principles of subject – "physics knowledge". Science as method of enquiry.
2. View of learning	Acquisition of skills. Accumulation of experience	Understanding of subject matter	Understanding of subject matter	Normal desirable state of pupil activity – emphasis on understanding of concepts, new ideas, etc.	Understanding of subject matter	Needs of clients being served by expert professional	Control and choice offered to pupils
3. View of teaching	Instruction to help acquisition of new skills. Intuitive grasp of situations.	Pedagogical content knowledge – ways to represent subject to make it comprehensible to others	Complex cognitive skill made up of schemata, pedagogical reasoning and pedagogical content knowledge.	Repertoire of routines – actions to maintain particular desired state of pupil activity or promote progress.	Pedagogical reasoning ability – knowledge base and understanding of science content, curriculum and learner.	Emphasis on repertoire of teaching approaches and process knowledge (four types).	Nature of presentation Links to everyday life. Classroom climate

Table 3.3 Summary showing the extraction of certain features or concepts from the theoretical frameworks (continued on next page)

4. View of science teaching. View of how to teach particular science topics	Similar to mastering skills in other areas. No view of how to teach particular science topics.	Present subject matter in a variety of ways – use of pedagogical content knowledge. Take prior learning of pupils into account (misconceptions).	Pedagogical content knowledge. Links to everyday life. Spend time explaining concepts, interacting with class – make use of schemata	Professional craft knowledge. "Progress goal" – sequence of planned activities.	Explaining science concepts. Discovery approach or theory followed by practical	Need to enhance teachers' knowledge of subject matter – everyday examples and practical work. Make subject matter comprehensible, capture interest of pupils.	Actively involve pupils. Practical work - exciting experiments.
5. Subject knowledge	Subject knowledge essential for competence.	Knowledge of subject matter one of cornerstones of theoretical framework	Pedagogical content knowledge defined in terms of subject knowledge.	"Progress goal" – development of knowledge of subject	Subject knowledge integral part of framework	Subject matter knowledge and education knowledge cornerstones of teacher education.	Physics knowledge. Ability to solve problems
6. Local conditions	"Situational" knowledge.	"Transformation" stage of pedagogical reasoning model.	Make use of pedagogical reasoning and pedagogical content knowledge. Select appropriate activity from schemata	Five categories of conditions: pupils, time, content, material environment and teachers themselves.	Take into account the prior knowledge of pupils.	Situational knowledge – child specific and situation specific.	Restrictions due to mentors and syllabus.
7. Personal reflection and other feedback	Expert has fluid performance and relies on own intuition.	Pedagogical reasoning model (incorporating reflection and new comprehension)	Compares degree of reflection of experienced and novice teachers.	Makes use of concepts of "reflection-in-action" and "knowing-in-action".	Reflection important for improving teaching.	Reflection woven into model of professional practitioner.	Realisation among student teachers of own shortcomings

Table 3.3 Summary showing the extraction of certain features or concepts from the theoretical frameworks

The emergence of these seven common features from the various theoretical frameworks may be explained as follows:

1. View of science

All of the frameworks included dimensions which could be characterised as relating to the **view of science** held by teachers. This view of science encompasses aspects such as a set of facts to be mastered in various stages, as subject matter to be formally taught to pupils, as subject matter in which understanding must be fostered in pupils, as a method of enquiry, etc. For example, in the theoretical framework developed by Brown and McIntyre (1993), the teachers involved in the study clearly viewed the subject they were teaching in terms of subject matter to be covered by various means, e.g. completing exercises, activities, worksheets, etc. for "the development of pupils' knowledge, understanding, skills, confidence or other attributes" (Brown and McIntyre, 1993, p. 61). There is a clear picture drawn of the expert teachers getting through a great deal of material:

> " ....went over the work of the previous week, introduced new activities, used his tone of voice to accentuate key points, had a quick turnover of activities, circulated the pupil groups to keep them at the activities.."
>
> (Brown and McIntyre, 1993 p. 99).

The emphasis on subject matter by the teachers is also made clear by Brown and McIntyre (1993) when they describe how one of the "progress goals" described by teachers had "emphasis on pupils' cognitive learning, acquisition of concepts, picking up ideas and developing skills". (Brown and McIntyre, 1993 p. 62).

Eraut (1996) expresses a similar view of science. In his discussion about knowledge, He divides it into a number of categories – one of which is "subject matter knowledge" (Eraut,1996 p. 25). He defines "subject matter knowledge" as that "found in school syllabuses and formally taught to pupils" (Eraut, 1995 p. 234). He sums up his view of teacher education in terms of an emphasis on subject matter and on pedagogy and questions the balance that should be given to both of these:

> "Teacher education has traditionally distinguished between courses designed to enhance the subject matter knowledge and education knowledge of intending teachers, but the aims and content of these courses have been much disputed......How much attention should be given to teaching subject-matter and how much to subject pedagogy, comprising not just teaching methods but the transformation of subject matter into forms which are comprehensible to pupils and capture their interest?"
>
> (Eraut ,1996 p. 3)

Wilson et al. (1987) express a view of science in which they emphasise the need for the teacher to have a specialised understanding of the subject matter that they teach:

> "In studying novice teachers, it is clear to us that teachers need more than a personal understanding of the subject matter they are expected to teach. They must also possess a specialised understanding of the subject matter, one that permits them to foster understanding in most of their students".
>
> (Wilson et al., 1987 p.104)

At a later stage in their article, Wilson et al. (1987) re-emphasise the importance of subject matter when they state that "one of the goals of education is the communication and development of subject matter knowledge" (Wilson et al., 1987 p. 107).

There is very clear evidence in the work of Borko et al. (1992) that the authors view science (and all other subjects) in terms of a body of subject matter. When discussing the differences between the expert teachers and the novice teachers, they refer to the fact that the expert teachers had "stores of powerful explanations, demonstrations and examples for representing subject matter to students" (Borko et al., 1992 p. 67). Their interpretation of pedagogical content knowledge appears to be narrower than that put forward originally by Shulman and focuses specifically on subject matter:

> "Pedagogical content knowledge or knowledge of subject matter for teaching, is also specific to the teaching profession. This domain of knowledge consists of an understanding of how to represent specific subject matter topics and issues in ways that are appropriate to the diverse abilities and interests of learners".
> (Borko et al. 1992, p. 50)

Peterson and Treagust's model (1995) based on "pedagogical reasoning ability" also emphasises the importance of subject knowledge. They clearly state that the first ability which beginning teachers should have developed is "knowledge of the subject matter they will teach" (Peter and Treagust, 1995, p. 292). Throughout their article, the view of science that is portrayed is that of a body of knowledge. In fact, analysis of the interviews with the student teachers was divided into two categories, one of which was "science content knowledge":

> "They [the student teachers] considered that an understanding of science content knowledge was necessary to ensure that primary students obtained the correct scientific information........The ability to answer primary students' questions during a lesson was considered important as these pre-service teachers believed they should provide the correct science content information to students".
> (Peterson and Treagust, 1995 p. 295)

Dreyfus and Dreyfus (1986) view science in a very clinical manner. When discussing their view that teachers learn to teach by experience, they view the material to be mastered simply in terms of a set of facts:

> "In general, a competent performer with a goal in mind sees a situation as a set of facts. The importance of the facts may depend on the presence of other facts. He has learned that when a situation has a particular constellation of these elements, a certain conclusion should be drawn, decision made or expectation investigated".
>
> (Dreyfus and Dreyfus, 1986 p. 28)

Fischler's model (1999) also views science in terms of subject knowledge, and emphasises the need for "physics knowledge" (p.185) among pupils so that they are "knowledgeable about the basic concepts of physics and they are able to solve physics problems" (p.185). However, it is also clear that Fischler views science as a method of enquiry in that he suggests that pupils should be allowed to "carry out experiments they have planned themselves" (p. 184).

2. View of learning

The dominant view of learning that emerges from a study of the various theoretical frameworks is one that involves an understanding of subject matter. For example, Borko et al. (1992) clearly view learning in terms of understanding of subject matter. They quote extensively from the "expert" teachers and focus on the understanding gained by pupils:

> "I think we got the point across. I feel good that they understood forces"
>
> (Borko et al., 1992 p. 61).

> "I'll see their confusion and I'll realise I need another way to say the same thing, or make it visible to them..."
>
> (Borko et al., 1992 p. 67)

Although the research of Wilson et al. (1987) places more emphasis on the study of teaching rather than learning, their view of learning is also referred to in terms of the pupils coming to terms with understanding of subject knowledge:

> "Teachers must find ways to communicate knowledge to others. In a sense, they must have two types of subject matter knowledge: knowledge of the subject field, both *writ large* and in it particulars, and knowledge of how to help their students come to understand the field"
> (Wilson et al., 1987 p. 105).

At a later stage, Wilson et al. (1987) also emphasise the role of the teacher in the fostering of understanding of subject matter:

> "Teachers must have a knowledge of the subject matter that includes a personal understanding of the content as well as knowledge of ways to communicate that understanding, to foster the development of subject matter knowledge in the minds of students" (p. 110).

In the model developed by Peterson and Treagust (1995), the view of learning is also interpreted in terms of the pupils' understanding of the subject matter. This is discussed in the "Transformation" stage of their model where they examine the data gathered from the student teachers. The authors describe how the student teachers were concerned about the teaching sequence, the science content, the curriculum knowledge, the explanations they would use for the activities, etc. in this Transformation stage:

> "I also learned that you need to sequence ideas that you are going to teach. You need to plan the right demonstrations to go with your explanations and you need to have other explanations ready other than the scientific explanations. It is important that you choose the right information for the learner to learn"
> (Peterson and Treagust, 1995 p. 300)

It is clear from the description of the Peterson and Treagust model (1996) that this view of learning incorporates the constructivist approach to learning:

> "A review of their journals indicated that 19 of the 21 class members recognised the importance of having some understanding of the prior knowledge of their peers in deciding on a starting point for their teaching"
> (Peterson and Treagust, 1995 p. 301)

Fischler (1999) presents a view of learning in which more control is given to the pupils. One of the categories that Fischler used in his data analysis was "action oriented principles". He discusses this in terms of a view of learning in which control and choice is offered to pupils: "Student-teachers think that if students [pupils] have a propensity to act on their own, then they are motivated to learn" (Fischler, 1999 p. 184). As an example of this, he states that pupils should be allowed to carry out experiments they have planned themselves.

Dreyfus and Dreyfus (1986) present a more simplistic view of learning in terms of following a set of rules that help one to progress from one stage to the next in the model of skills acquisition:

> "The beginning students wants to do a good job, but lacking any coherent sense of the overall task he judges his performance mainly by how well he follows learned rules.......Like the training wheels on a child's first bicycle, these first rules allow the accumulation of experience, but soon they must be put aside to proceed"
>
> (Dreyfus and Dreyfus, 1986 p. 22).

As outlined earlier in this chapter, Brown and McIntyre (1993) discuss a view of learning in terms of the Normal Desirable State of Pupil Activity (NDS). They describe how the teachers were happy that the pupils were engaged in purposeful learning when the NDS was achieved. Brown and McIntyre (1993) divided this into two categories: (i) activities where the teacher was interacting with the whole class and (ii) activities where the pupils were working independently on tasks of various kinds. The view of learning that takes places in a laboratory practical class is described by Brown and McIntyre as follows:

> "One of them [the expert teachers] described her NDS in terms of pupils settling down quickly into the laboratory routine, knowing where and when to seek help from the teacher and technician, and getting on with 'working independently using the worksheets, doing everything so much on their own'. Her goal was that they would be interested, working hard at their own pace and making their own discoveries: 'They're all doing it in their own time.......you can see each one coming to something in the worksheets and discovering something new'.
>
> (Brown and McIntyre, 1993 p. 55).

In addition, Brown and McIntyre (1993) also discuss learning in terms of understanding of subject matter when they describe the emphasis placed by the teachers in the classroom in terms of "pupils' cognitive learning, acquisition of concepts, picking up ideas and developing skills (Brown and McIntyre, 1993 p. 62).

Eraut (1995) takes a rather unique view of the learning process in that he points out that the "pupils exercise a degree of consumer control" and that "the relationship with pupils comes closest to the ideal of expert professionals determining the needs of their clients" (Eraut, 1995 p. 228). He acknowledges the important place of understanding of subject matter by the pupils and emphasises the importance of teachers ensuring that they succeed in "matching learning activities to students' capabilities" (Eraut, 1995 p. 229).

3. **View of teaching**

The dominant view of teaching that emerges from a study of the framework encompasses aspects like the use of repertoires of routines and the importance of representing subject matter in such ways as to make it comprehensible to others. For example, Brown and McIntyre (1993) describe the teaching of the experienced and expert teachers in terms of "routines" that teachers bring into play spontaneously in their everyday classroom teaching. These routines have been developed through experience in the classroom. In their theoretical framework, Brown and McIntyre (1993) define a routine as follows:

> "A Routine is a standardised pattern of action which a teacher undertakes, recognising that certain conditions are impinging on his or her teaching, in order to maintain particular desired states of pupil activity or to promote specific kinds of progress"
> (Brown and McIntyre, 1993 p. 83).

Brown and McIntyre (1993) then proceed to describe how the experienced and expert teachers arrive at the class with clear goals to ensure that the Normal Desirable State be established and that Progress be made by the pupils. These teachers then make "rapid initial judgements" (p. 83) about the Conditions that exist and take into account knowledge they have about the curriculum, the pupils and themselves. Brown and McIntyre (1993) then describe how the teachers "quickly select from their repertoire of actions those which their experience tells them are best suited to achieve their goals in the given Conditions" (p. 83).

In a similar way, Dreyfus and Dreyfus (1986) place great emphasis on the concept of repertoire of routines and learning from experience. They view teaching in terms of instruction being used to help the novice acquire new skills.

> "Elements of the situation to be treated as relevant are so clearly and objectively defined for the novice that they can be recognised without reference to the overall situation in which they occur. .....The novice nurse is taught how to read blood pressure, measure bodily outputs, and compute fluid retention, and is given rules for determining what to do when these measurements reach certain values".
> (Dreyfus and Dreyfus, 1986 p. 21-22)

In addition, Dreyfus and Dreyfus (1986) place great emphasis on the fact that "experts" in level 5 of their model of skills acquisition have an intuitive grasp of situations. They describe the proficient chess player as having the ability to recognise "a very large repertoire of types of positions" (p. 29). They refer to this type of intuition as "the sort of ability we all use all the time as we go about our everyday tasks" (p. 29).

> "Similarly, the expert business manager, surgeon, nurse, lawyer or teacher is totally engaged in skillful performance. When things are proceeding normally, experts don't solve problems and don't make decisions; they do what normally works".
> (Dreyfus and Dreyfus, 1986 p. 30 –31).

The view of teaching put forward by Eraut has many similarities with the Dreyfus and Dreyfus model and the Brown and McIntyre model. Eraut (1995) emphasises that the "teacher must have a repertoire of teaching approaches and activities from which to make an appropriate selection. Similarly, the choice from this repertoire can only be appropriate if there is a good understanding of the students' needs and an adequate conceptualisation of the decision-making process – for example, of matching learning activities to students' capabilities". (Eraut, 1995 p. 229). The latter point bears great similarity to Shulman's concept of pedagogical content knowledge (ways of representing the subject to make it comprehensible to others) put forward by Wilson et al. (1987).

The overlap between Eraut's views (1994) and those of Dreyfus and Dreyfus are obvious when Eraut describes the competent teacher in the model developed by

Dreyfus and Dreyfus as having developed "standardised and routinised procedures" (Eraut, 1994, p 124) to deal with any problems that arise in the classroom:

> "Professionals who work under severe time pressure are forced to routinise most of what they do because there is too little time for deliberation. Those who cope well may even come to regard deliberation as a waste of time..... When teachers are in the classroom they are mainly engaged in what I call "hot action" with very little time to stop and think. Much of what they do is necessarily routinised, the words come out with little thought or effort. But they also have to make hundreds of rapid decisions in response to unanticipated events and a rapidly changing situation (Jackson 1971). Such decisions are best described as intuitive but they are not without some small degree of thought. The analogy which comes to mind is that of riding a bicycle in heavy traffic. Little though goes into the activity of riding which is virtually automatic, but the mind is fully engaged in monitoring the traffic and responding rapidly whenever it appears to be necessary"
>
> (Eraut, 1996 p. 18).

Eraut expands on his view of teaching (Eraut, 1995, p. 230) when he states that "at least four kinds of process knowledge play a critical part in the work of a classroom teacher". He describes these kinds of process knowledge as follows:

1. **Process for acquiring information, especially information about students.** These range from deliberate searches to the almost intuitive "reading of an emergent situation".
2. **Routinised action and skilled behaviour.** Much classroom teaching falls into this category, intuitive yet following discernible patterns and still under some overall cognitive control.
3. **Deliberative processes such as planning, decision-making, and problem-solving.** These involve analysing the context, devising options, mulling over them, and eventually choosing a course of action.

4. **Meta-processes such as assessing, evaluating, and controlling**. These processes concern, first, how teachers assess the impact of their actions and evaluate their personal practice; then, second, how they make use of this information to modify or rethink their decisions and work patterns.

An alternative view to the "repertoire of routines" view discussed above is the view of teaching put forward by Wilson et al. (1987). This view of teaching may be summarised in one phrase: **pedagogical content knowledge.** They describe this as a new type of subject matter knowledge that is enriched and enhanced by other types of knowledge – knowledge of the learner, knowledge of the curriculum, knowledge of the context, knowledge of pedagogy. This term was first introduced into the literature in 1986 by Shulman who defined it as a form of content knowledge that:

> "embodies the aspects of content most germane to its teachability. Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations – in a word, the ways of representing and formulating the subject that makes it comprehensible to others. Since there are no single most powerful forms of representation, the teacher must have at hand a veritable armamentarium of alternative forms of representation, some of which derive from research whereas others originate in the wisdom of practice."
>
> (Shulman, 1986 p. 9)

A similar view of teaching is held by Borko et al. (1992) who clearly state their view of teaching in terms of a "complex cognitive skill". Whilst this view encompasses the pedagogical content knowledge model developed by Shulman (1986), it also includes schemata and pedagogical reasoning:

> "Schemata, pedagogical reasoning and pedagogical content knowledge – three concepts central to the characterisation of teaching as a complex, cognitive skill – provide a framework for interpreting differences between expert and novice teachers".
> (Borko et al., 1992 p. 50)

Their view of teaching is more complicated than many of the other models discussed in this study and appears to be an attempt to build on and extend the work of Wilson et al. (1987).

A similar view of teaching to that of Borko was put forward by Peterson and Treagust (1995). Their view of teaching (1995) is based on the concept of "pedagogical reasoning ability. This is based on Shulman's (1987) six-stage model and is defined by Peterson and Treagust as follows:

> "An alternative approach for improving the ability of preservice teachers to teach primary science is to focus on the development of their pedagogical reasoning ability. Teachers not only need to develop a knowledge base for teaching science, but also need to use their understanding of science content, curriculum and the learner when making decisions regarding their classroom teaching"
> (Peterson and Treagust, 1995 p. 291)

Peterson and Treagust (1995) believe that pedagogical reasoning should be given a higher priority in teacher education programmes and that these programmes should encourage preservice teachers to develop their reasoning ability and to apply this to teaching situations. They emphasise that "this process is important so that teachers will learn to use their knowledge effectively in making decisions on particular actions they will take when teaching" (p. 292). They quote Reynolds (1992) to support this statement when he stated that beginning teachers in their first year of teaching should have developed "knowledge of strategies, techniques and tools for creating and sustaining a learning community, and the skills and abilities to employ these strategies, techniques and tools" (p. 292)

Fischler (1999) puts forward a view of teaching that emphasises what takes place in the classroom during the lesson. He refers to the selection of teaching content that has applications in everyday life as "content-related principles". This view of teaching by the student teachers involved them taking examples of topics from everyday life and showing the relevance of science in our lives. Fischler also refers to "principles related to nature of presentation" (Fischler, 1999 p. 184) and describes the view of teaching held by the student teachers in terms of the need to have clear presentations which could be understood by the pupils – "a methodically well-arranged presentation of the topics" (Fischler, 1999 p. 178). From the analysis of his data, Fischler devised a category called "principles referring to classroom climate" in which he emphasised that the "student teachers are convinced that a positive classroom climate contributes to successful processes of teaching and learning and that the teacher's behaviour is crucial in creating this climate" (p. 184)

4. View of science teaching. View of how to teach particular science topics.

The view of science teaching that emerges from the various frameworks encompasses the concept of professional craft knowledge as its cornerstone. The concept of professional craft knowledge is explored in detail in Brown and McIntyre's study (1993). This study was a cross-curricular one and did not deal specifically with science teaching. Brown and McIntyre found this to be an advantage in that there was a relative lack of emphasis in the experienced teachers' accounts on the particular subject topics they were teaching. This gave the researchers the opportunity to concentrate on "a framework within which professional craft knowledge was explored" (Brown and McIntyre, 1993 p. 110). In discussing this professional craft knowledge, they refer to Shulman's (1986) concept of pedagogical content knowledge in terms of the teachers' attempts to facilitate learning related to specific topics and to their own research findings:

> "Teachers routinely achieve a great deal which they so take for granted as not even to notice; and the craft knowledge implicit in these more taken-for-granted achievements may also be rather different in kind......these 16 teachers revealed to us, in a wide variety of lessons, professional craft knowledge in which some strongly pervasive patterns were apparent".
>
> (Brown and McIntyre, 1993 p. 110)

They discuss this professional craft knowledge in terms of the overall theoretical framework developed and admit that the "professional craft knowledge which teachers have revealed to us is highly complex, providing no simple generalisations about how to do anything well in teaching" (Brown and McIntyre, 1993 p. 113).

Eraut (1995) goes to considerable lengths to explain his view of science teaching. This view of science teaching emphasises "the need to enhance teachers' knowledge of subject matter ...even if the complex nature of the task is concealed by the use of terms like *updating*". (Eraut, 1995 p. 235). Eraut also emphasises the need to use everyday examples, practical work and discussions in teaching science:

> "In science, for example, there is considerable divergence between book knowledge (as tested by typical examination questions) and a working knowledge that allows people to explore and understand real-world phenomena as they encounter them. When science education is successful, both forms of knowledge are acquired, but not necessarily in the same way. Formal teaching develops only book knowledge, while working knowledge is developed through an informal process of

> socialisation into the discipline through practical work and discussions. This requires a working scientific context of a kind that is only developed by imaginative teachers with adequate facilities; and these teachers can benefit from so-called updating courses if given the scope and encouragement to develop their ideas. But teachers with a low knowledge base and little working knowledge of the subject will find it difficult to digest and use new subject matter presented in a traditional way".
>
> (Eraut, 1995 p. 235 – 236)

The development of professional craft knowledge plays an important role also in the research of Wilson et al. (1987). Some of the student teachers that they tracked through their professional training were science teachers. Although they found that some of their primary concerns were focussed on survival and classroom management, they also found that these student teachers were "forced to examine their personal understanding of content" (Wilson et al., 1987 p. 112) and were challenged to present this subject matter in a way that could be understood by pupils:

> "They generate representations of the subject matter that will facilitate the development of understanding in their students. These representations or transformations of subject matter take many forms – metaphors, analogies, illustrations, examples, in-class activities and homework assignments"
>
> (Wilson et al., 1987 p. 112).

A similar study by Borko et al. (1992) involved some expert and novice science teachers in their study. The view of science teaching discussed in their theoretical framework is one in which science is related to pupils' everyday experiences. One of the expert teachers is quoted as saying:

> "I always try to think of some way that what we are studying is related to their lives and how it's fun too. And so I usually try to introduce things so that they can see that there's some meaning in their lives."
> (Borko et al., 1992 p. 55)

In addition to this view of science teaching, Borko et al. (1992) describe one of the expert teachers in the group in terms of his efficiency with demonstration experiments in the classroom:

> "To be able to teach flexibly, he kept handy a variety of 'props' including a spring scale, fulcrum, meter sticks and weights. In all cases the flexibility and responsiveness of the expert's teaching seemed to depend upon quick access to an extensive, well-developed system of knowledge"
> (Borko et al., 1992 p. 68)

The concept of professional craft knowledge (or lack of it!) is also discussed by Peterson and Treagust (1995) in which they report on the view of science teaching held by the student teachers in terms of "knowledge of science content and their ability to explain science concepts" (Peterson and Treagust, 1995 p. 297). They discuss how many of the student teachers found it difficult to explain scientific ideas:

> "Explaining the ideas was difficult and so was encouraging a clear understanding of the concept. Further clarification was needed than what I was able to provide"
> (Peterson and Treagust, 1995 p. 303).

Some of the student teachers attributed their inability to explain ideas because of their lack of understanding of the science content knowledge:

> "When I went over the notes I understood what I was going to teach, but I found it a lot more difficult to explain to others. In my mind it seemed clear, but when I verbalised it, I could tell myself that it wasn't all that clear. The more I tried to clarify points, the more difficult it became".
> (Peterson and Treagust, 1995 p. 303).

Fischler (1999) does not refer to professional craft knowledge directly but the problems encountered by the student teachers clearly show that they had problems in this area. For example, student teachers reported on the difficulty they had in getting the pupils interested in the lesson. They emphasised the need for the pupils to be actively involved in the lesson but were unsure of the best ways to achieve this. They emphasised the importance of practical work in what Fischer terms "principles aimed to activate pupils" (Fischler, 1999 p. 184).

Dreyfus and Dreyfus (1986) make no distinction between mastering the skills necessary to become a proficient teacher and mastering the skills necessary to fly a plane, play a game of chess, etc.

> "The expert driver becomes one with his car and he experiences himself simply as driving. Rather than as driving a car.....Airplane pilots report that as beginners they felt that they were flying their planes but as experienced pilots they simply experience flying itself. Chess grandmasters, engrossed in a game, can lose entirely the awareness that they are manipulating pieces on a board and see themselves rather as involved participants in a world of opportunities, threats, weaknesses, hopes and fears"
>
> (Dreyfus and Dreyfus 1986, p. 30)

Thus, Dreyfus and Dreyfus (1986) view teaching simply in terms of skill acquisition and make no reference to the concept of professional craft knowledge being an integral part of the teaching profession.

The theme of encompassing the method of teaching particular science topics emerged from almost all of the theoretical frameworks studied. This theme is best encapsulated in the framework described by Borko et al. (1992). When discussing the teaching of specific topics by the novice teachers involved in their study, they were critical of the lack of time devoted to explaining the details of a particular concept. Their comments on specific lessons observed for one novice teacher emphasise this point strongly:

> "He relied heavily on the text during class sessions and did not seem to know how to explain concepts to others. In fact, fieldnotes for the entire observation cycle do not contain a single example of explanation of a concept, although there were several occasions on which such an explanation would have been appropriate"
>
> (Borko et al., 1992 p. 65).

In addition, Borko et al. (1992) were critical of specific classes observed in which the novice teacher did not spend enough time interacting with the whole class:

> "Steve spent very little time interacting with the whole class. For more than 40 per cent of class time, students worked independently at their desks and Steve walked around the room, stopping to talk with individual students. Typically, many students were off task during these activities. ....During the process he provided only procedural comments and no conceptual explanation".
>
> (Borko et al., 1992 p. 65 – 66)

When discussing the various classroom observations of the novice teachers, Borko et al. (1992) frame their explanations for what they observed in terms of the fact that the novice teachers do not have well-developed schemata to help them teach these particular lessons:

> "Many of the characteristics of experts' and novices' teaching can be understood using the conceptual framework of teaching as a cognitive skill. That is, if novices' cognitive schemata are less elaborate, interconnected and accessible than experts', we can account for several of the differences in their planning, teaching and post-lesson reflections. Experts' planning can be interpreted as a process of combining information from existing schemata to fit the particulars of a given lesson. Because experts have well developed and easily accessible schemata for such aspects of teaching as content, students and instructional activities, they are able to plan quickly and efficiently. Further, once they select the desired activities, they need only pull the appropriate materials from their extensive activity files"
>
> (Borko et al., 1992 p. 66)

Similarly, when discussing the teaching of specific topics, Wilson et al. (1987) refer to the work of Shulman (1986) who advocated the adoption of a constructivist approach to teaching in his discussion of pedagogical content knowledge:

> "Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students [pupils] of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganising the understanding of learners, because these learners are unlikely to appear before them as blank slates".
>
> (Shulman, 1986 p. 9 – 10).

When studying lessons taught by student teachers, Peterson and Treagust (1995) classified the science lessons given by the student teachers into two broad categories: "discovery approach" and "theory first approach". In the discovery approach, the pupil explored the activity first and then followed with a discussion of the science idea:

> "I moved onto the activities pretty much before the explanation....do the activity, things like mass, volume, elasticity – the properties of air – before we came to the explanation, go through "What do you think happened?". And if they don't know, then I will explain, well this is what happened...."
>
> (Peterson and Treagust, 1995 p. 302)

They also found student teachers using a "theory first" approach, i.e. they provided some information on the concept, and then reinforced the science ideas through a practical activity and further discussion. Peterson and Treagust (1995) point out that the teaching strategy was not the most important thing in the process. They viewed the important factor as being "how the strategy was reviewed in the subsequent stages of the pedagogical reasoning process" (Peterson and Treagust, 1995 p. 302), i.e. they put more emphasis on the Evaluation, Reflection and New Comprehension stage of the model they followed.

Fischler (1999), when discussing the teaching of particular science topics, points out the need to allow pupils to carry out their own investigations and handle apparatus – he describes this approach to science teaching as "action oriented principles" (Fischler 1999, p. 184). He points out that when teaching certain topics, it is necessary to allow pupils to carry out experiments they themselves have planned and to give them "time to fully conduct their activities", i.e. pupils should be allowed extra time when being taught certain topics in science.

In the theoretical framework developed by Brown and McIntyre (1993), a more general view was taken of the teaching of particular science topics. They introduced the concept of Progress and found that it was generalisable across all sixteen expert teachers in their study. One of the categories into which they divided progress was that of "progress through the work" (Brown and McIntyre, 1993 p. 61). They explain that the teachers' goals were concerned with progression through the material or activities which they had planned for the lesson. Teachers used various strategies and resources to ensure that these goals were met, e.g. using everyday examples, explaining concepts, using practical activities, making out worksheets and various other activities to ensure the Normal Desirable State of pupil activity was maintained. For example, one of the science teachers in the sample spoke to the researchers about the need for a class on independent learning prepared by him to be carried out in a calm working atmosphere. He spoke of the importance of a quiet steady delivery on his part:

> "I had to have a very, very calming influence.....coupled with my voice....It seemed to make things quieter and I think they seemed to respond in a similar way....I imagine if I'd been shouting at them it would have kept....a more intense atmosphere than it was".
> (Brown and McIntyre, 1993 p. 65).

Eraut, when discussing the teaching of particular topics, emphasises the need to bring about "the transformation for subject matter into forms which are comprehensible to pupils and capture their interest". (Eraut 1996 p. 3).

The model proposed by Dreyfus and Dreyfus (1986) for the development of expertise was a general one and applicable to all professions. Therefore, Dreyfus and Dreyfus (1986) did not express any views on how to teach particular science topics.

5. Subject knowledge

The theme of subject knowledge occupies a key role in all of the theoretical frameworks discussed. It is rooted in the model of Dreyfus and Dreyfus (1986) who place considerable emphasis on subject knowledge in their description of moving from novice to expert. They describe how a group of student nurses were taught a "hierarchical procedure of decision-making" when carrying out clinical examinations in an effort to ensure that each nurse becomes "a competent performer with a goal in mind [and] sees a situation as a set of facts" (Dreyfus and Dreyfus, 1986 p. 24). Their own view of the importance of subject knowledge is summarised in their statement that "in general, a competent performer with a goal in mind sees a situation as a set of facts". In other words, a level of competence cannot be reached without the acquisition of factual knowledge.

Subject knowledge is also at the heart of the theoretical framework developed by Wilson et al. (1987). As discussed in section 3.3, "knowledge of subject matter" is one of the cornerstones of their framework (Figure 3.1). There are numerous references in their framework to the importance role that subject matter plays in teaching:

> "Teachers draw upon many types of knowledge when they are making decisions... Teachers use their content knowledge – their understanding of the facts or concepts within a domain- as well as their grasp of the structures of the subject matter.... Teachers must have knowledge of the substantive structures – the ways in which the fundamental principles of a discipline are organised."
>
> (Wilson et al, 1987 p.113)

They also state that "the transformation of subject matter knowledge is at the heart of teaching in secondary schools" (Wilson et al, 1987 p.117) and, when speaking about the progress being made by the student teachers, refer to the fact that they "are constantly acquiring new knowledge that contributes to the transformation of content". (Wilson et al., 1987 p.118).

Subject knowledge plays a central role in the theoretical framework proposed by Borko et al. (1992). As already discussed, they represent pedagogical content knowledge in terms of "an understanding of how to represent specific subject matter topics" (Borko et al, 1992 p. 50) and pointed out the weakness found in some student teachers who had difficulty knowing how much subject matter to cover in class:

> "I'm very weak in knowing how much kids can handle....I mean as far as the amount of content... how much detail to go into things, am I going way over their heads...."
>
> (Borko et al., 1992 p. 63).

A number of other references to the importance of subject knowledge in the framework proposed by Borko et al. (1992) have already been discussed.

As outlined previously, one of the key areas of Brown and McIntyre's theoretical framework (1993) was the concept of Progress. Within this area of Progress, one of the categories was "the development of pupils' knowledge, understanding, skills, confidence or other attributes" (Brown and McIntyre, 1993 p. 61). Brown and McIntyre found that the expert teachers placed great emphasis in these areas in their teaching – particularly an "emphasis on pupils' cognitive learning, acquisition of concepts, picking up ideas and developing skills". As an example of this type of emphasis, they quote one of the mathematics teachers as saying:

> "Well, they've done quite a good period's work and now they at least know about this new number system and can transfer between one and the other...Most of them had grasped the concept of the binary system...It was only after a transformation between the binary and decimal and the way we go about it".
>
> (Brown and McIntyre, 1993 p. 62)

In the theoretical framework devised by Peterson and Treagust (1995), they view subject knowledge as being an integral part of their framework. On several occasions, the importance of subject knowledge is emphasised by them:

> "Beginning teachers should have developed knowledge of the subject matter they will teach"
>
> (Peterson and Treagust, 1995 p. 292).

> "They considered that an understanding of science content knowledge was necessary to ensure that primary school students obtained the correct scientific information"
> (Peterson and Treagust, 1995 p. 295).

> "Concept maps drawn at the beginning and on the completion of the unit, in addition to comments made in the journal, were used to ascertain preservice teachers' science content knowledge"
> (Peterson and Treagust, 1995 p. 297).

When discussing his own theoretical framework, Eraut sees **subject matter knowledge** and **education knowledge** as the two cornerstones of teacher education (Eraut, 1996 p. 3) and questions the amount of attention that should be devoted to each one.

As mentioned above, Fischler in his theoretical framework emphasised the learning of the subject knowledge and referred to this as "content related principles" (Fischler, 1999 p. 184) as well as the ability to solve problems. He used "physics knowledge" as one of the headings in his construction of repertory grids that were used to analyse the responses of the student teachers. Pupils were also expected to use this knowledge to solve physics problems.

6. Local conditions

The theme of local conditions and its effect on teaching is one of the most dominant themes that emerges from a study of the various theoretical frameworks. Of all the theoretical frameworks studied, the most detailed analysis of the effect of conditions on teaching is outlined by Brown and McIntyre (1993). They found that this concept was generalisable across all the teachers and was a crucial element in the teachers' accounts of their teaching. They found that these conditions lead to a variation in the teachers' actions taken on any occasion to achieve their goals. Brown and McIntyre found that the teachers' descriptions of the conditions impinging on their teaching fell into five categories: pupils, time, content, material environment and teachers themselves (Brown and McIntyre, 1993 p. 70). An outline of each of these conditions has already been given in section 3.3.1. As an example of how one of these conditions (time) impinged on the teaching, Brown and McIntyre quote from an interview carried out with a science teacher who described the impact of the school timetable on his teaching:

> "Today they didn't need to be calmed down.....because they come in at the *beginning* of the day.....They come in at the *end* on Wednesday and I find with a lot of classes this does make a big difference. The last two periods they're tired, they've done a lot of things, they want to go home, whereas in the morning they do have different attitudes."
>
> (Brown and McIntyre, 1993 p. 74)

Local conditions are also discussed by Borko et al. (1992) in their definition of pedagogical reasoning. They emphasise the importance of taking into account both the ability and individual characteristics of the pupils:

> "Pedagogical reasoning is the process of transforming subject matter knowledge into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students. Pedagogical reasoning includes the identification and selection of strategies for representing key ideas in a lesson and the adaption of these strategies to the characteristics of learners"
>
> (Borko et al., 1992 p. 50).

In addition, when interpreting the differences between the expert teachers and the novice teachers, Borko et al. (1992) point out that the expert teachers were able to use their repertoire of schemata to take account of local conditions encountered:

> "The benefits of well-developed knowledge systems were evident in the expert teachers' introductions to laboratory activities as well. These teachers drew upon their pedagogical content knowledge, which

> includes knowledge of students and content, to anticipate difficulties the students were likely to encounter and to devise introductory explanations and demonstrations to minimise the difficulties"
>
> (Borko et al, 1992 p. 66)

Also, when analysing data with the aid of the theoretical framework developed, Borko et al. (1992) refer to the different ways in which the experts and novices dealt with problems encountered at the classroom level. Once again, they use the concept of schemata to explain the differences:

> "Difficulties that novices encounter when they do not make or follow detailed lesson plans can be understood as the result of limitations in their knowledge systems. In comparison to experts, novices do not have as many potentially appropriate schemata for instructional strategies to draw upon in a given classroom situation. Nor do they have sufficiently well-developed schemata for pedagogical content knowledge to enable the construction of explanations or examples on the spot."
>
> (Borko et al, 1992 p. 67).

Eraut (1996) discusses the concept of local conditions at some length but does not use the term "local conditions" in his writing. Instead, he refers to a form of knowledge called "situational knowledge" which he states is child specific and situation specific. He describes this type of knowledge as follows:

> "Their reading of this stream of situation relies on situational knowledge which is child specific and situation specific. This knowledge may be affected by more general understandings and schemata developed by previous experience in similar situations, but remains situationally specific in many important aspects. Because every child is unique and no two classes are the same, the teacher's more general knowledge has to be reinterpreted to suit each situation."
>
> (Eraut 1996 p. 4).

In another paper (Eraut, 1995) he emphasises the importance of teachers reaching a certain level of competence to enable them to cope with the conditions faced in the classroom as a result of the variation among pupils:

> "Since in most classes there is significant variation among students, this implies that the teacher must be able to organise different activities simultaneously. Research suggests that a substantial minority of teachers cannot do all these things; and even those teachers who have this competence do not always make use of it. .....Nevertheless, the concepts of repertoire, appropriate provision and differentiation according to students' needs are fundamental to professional practice; and I believe it is possible to expect the majority of current teachers and all our future teachers to reach this level of competence".
>
> (Eraut, 1995 p. 229).

The term "situational knowledge" was used some years earlier by Dreyfus and Dreyfus (1986) when discussing the transition from novice to advanced beginner. In their paper Dreyfus and Dreyfus (1986) refer to "the need for the advanced beginner to acquire situational knowledge", i.e. the ability to apply the rules learned in the novice stage ("context free rules") to real situations. They refer to the need to acquire "practical experience in concrete situations" (Dreyfus and Dreyfus, 1986 p. 22) and refer to the example of the advanced beginner driver using the sound of the engine ("situational") as well as rules about the speed of a car ("context-free") to decide on when to change gears.

The concept of local conditions is also discussed by Wilson et al. (1987). In this paper they give many examples of how their model of pedagogical content knowledge can be applied to deal with particular situations within the classroom. They include a "Transformation" stage (Figure 3.2 page 95) in the development of their model of **pedagogical reasoning**. They describe this Transformation stage as consisting of four sub-processes: critical interpretation, representation, adaptation and tailoring. The adaptation and tailoring stages are used when devising teaching strategies for the specific local conditions encountered in the classroom. The authors give numerous examples of how the student teachers in their study used various analogies, activities and assignments that suited the circumstances encountered in the classroom:

> "Alan wanted to find a meaningful way to introduce Caesar to his students. After considering several alternative approaches to the play, he decided that an appropriate goal for teaching Shakespeare in this context was to emphasise the theme of moral conflict. However, because his students had little understanding of the nature of moral conflict, Alan anticipated having some difficulties teaching that theme....The next day in class, Alan introduced Julius Caesar as the Captain Kirk of the Roman Empire. He transformed his understanding of the play, as a piece of literature that deals with the issues of moral conflict, into an activity that would allow his students to experience the emotional and intellectual struggles that are involved in moral conflict".
>
> (Wilson et al., 1987 p. 111 – 112).

In the model developed by Peterson and Treagust (1995), the authors refer to local condition in terms of the fact that the student teachers recognised the importance of having some understanding of the prior knowledge of the pupils when deciding on a starting point for their teaching:

> "What the person already knew about the topic was very important information. It allowed us to view *what* [her emphasis] the person knew, how much they knew and it also allowed us to determine in which areas, if any, the learners were misinformed and in which area we didn't have to go into great detail because they already had some prior knowledge".
>
> (Peterson and Treagust, 1995 p. 301).

Finally, Fischler (1999) in his study highlights the problems caused by the local conditions. He reports that the student teachers who participated in his research felt constrained in what they were able to achieve due to restrictions put on them by their mentors and also by the syllabus. One of the problems that this caused was the fact that "the goal of demonstrating to the students the connection between physics and everyday life was not achieved" (p. 186).

7. Personal reflection and other feedback

Whilst the concept of personal reflection appears in all of the theoretical frameworks discussed, different authors place different emphasis on this area of their theoretical frameworks. For example, Peterson and Treagust (1995) place considerable emphasis on reflection in their model and list reflection as one of the four characteristics that beginning teachers should have developed:

> "...among other abilities, beginning teachers should have developed....(4) the disposition to reflect on their own actions and students' responses in order to improve their teaching and the strategies and tools for doing so".
>
> (Peterson and Treagust, 1995 p. 292).

Peterson and Treagust (1995) used reflections as one of the key methods for gathering data. From studying these reflections, they concluded that "the preservice teachers believed their knowledge of curriculum materials was weak and still needed to be developed". They quote from one of the student teachers: "I would like to look at resources....I don't think many people know of all the recent scientific [curriculum] resources" (Peterson and Treagust, 1995 p. 296). Some of the reflections of the student teachers provide a good insight into the problems encountered by them. For example, the authors say that the majority of the student teachers "were concerned with their knowledge of science content and their ability to explain science concepts":

> "I'm hopeless at planning. How to start. Where we're having a sequence of lessons, I don't know where to start. And that's what messes me right up. Because I have all of these ideas and I think where are they going to go. I know last year when I had planned one lesson, and when I wrote it out, I realised that it should have been the other way round"
>
> (Peterson and Treagust, 1995 p. 297)

Also, Peter and Treagust (1995) found that the student teachers reflected on a variety of issues in relation to their own teaching and planning of lessons. The comments that were made by the student teachers focussed on the need to improve their "personal understanding of the science content, being better prepared when teaching, having more activities and student discussions during lessons, improving their explanations of ideas and establishing ways of evaluations what the learner has understood through the lesson" (Peterson and Treagust, 1995 p. 303)

In a similar way, Brown and McIntyre (1993) make considerable use of the personal reflection of teachers when drawing up their theoretical framework. In fact, the theoretical framework summarises "the concepts which teachers use in evaluating their own teaching" (Brown and McIntyre, 1993 p. 70). However, whilst acknowledging the usefulness of "reflection-in-action" (i.e. "thinking about what one is doing while one is engaged in doing it"), they do question the helpfulness of it in relation to classroom teaching:

> "However, it is not yet clear how helpful a concept 'reflection in action' will be in relation to classroom teaching, and in particular whether the distinction between 'reflection-in-action' and 'knowing-in-action' is helpful in this context. In this respect, Schon's ideas can usefully be contrasted with another increasingly influential theoretical account of professional thinking in general, that of Dreyfus and Dreyfus (1986) whose model of a five-stage progression from novice to expert has been used, perhaps most tellingly by Benner (1984) in relation to nursing. In the Dreyfus-Benner model too, the expert practitioner does not characteristically depend on analytic thinking; but here, no distinction similar to that between 'knowing-in-action' and 'reflection-in-action' is found to be necessary".
>
> (Brown and McIntyre, 1993 p. 7)

In keeping with this view of teaching, the model developed by Dreyfus and Dreyfus (1986) does not place great emphasis on personal reflection - their model places more emphasis on skills acquisition. Their description of an expert is a good introduction to their views on personal reflection:

> "An expert generally knows what to do based on mature and practised understanding. ....We usually don't make conscious deliberative decisions when we walk, talk, drive or carry on most social activities. An expert's skill has become so much a part of him that he need be no more aware of it than he is of his own body"
>
> (Dreyfus and Dreyfus, 1986 p. 30)

They also point out that fluid performance goes hand in hand with expertise and they give numerous examples from the medical profession and from sport where actions occur automatically and naturally.

> "Excellent chess players can play at the rate of five to ten seconds a move and even faster without serious degradation in performance. At that speed they must depend almost entirely on intuition and hardly at all on analysis and comparing alternatives".
>
> (Dreyfus and Dreyfus, 1986 p. 33)

The only time that Dreyfus and Dreyfus (1986) admit to some form of reflection being necessary is when problems occur. However, they point out that this involves making use of one's own intuition:

> "While most expert performance is ongoing and non-reflective, when time permits and outcomes are crucial, an expert will deliberate before acting. But as we shall show shortly, this deliberation does not require calculative problem solving, but rather involves critically reflecting on one's intuitions".
>
> (Dreyfus and Dreyfus, 1986 p. 32)

Wilson et al. (1987) place greater emphasis on reflection and expand the concept of pedagogical content knowledge to embrace a model of pedagogical reasoning (Figure 3.2 page 95).

> "But pedagogical content knowledge is not simply a repertoire of multiple representations of the subject matter. It is characterised by a way of thinking that facilitates the generation of these transformations, the development of pedagogical reasoning" (Wilson et al., 1987 p.115)

This pedagogical reasoning model incorporates **reflection** and **new comprehension** as part of the model (Figure 3.2 page 95). The authors describe reflection in terms of a process of learning from experience, i.e. "what a teacher does when he or she looks back at the teaching and learning that has occurred and reconstructs the events, the emotions and the accomplishments" (Wilson et al., 1987 p.120). This gives rise to the new comprehension stage where the teacher has a new understanding about the purpose of instruction and the subject matter of instruction.

In a similar fashion, Borko et al. (1992) used personal reflection as part of their conceptual framework and frequently refer to reflection when discussing and analysing the data collected. In designing their theoretical framework they draw on the work of Borko and Livingston (1989) who found that novice teachers showed "less selective post-lesson reflections" than the expert teachers. They explain this by saying that in the case of the novice teachers "their pedagogical reasoning skills are less well developed" (Borko et al, 1992 p. 51). It is worth noting that Borko et al. (1992) when gathering data place considerable emphasis on the post-lesson reflections of the expert and novice teachers.

Eraut (1996) has a rather individual view of reflection and sees the concept of the teacher as a reflective practitioner being woven into a set of assumptions about what is involved in being a professional practitioner:

- "A teacher needs to have a repertoire of methods for teaching and promoting learning.
- Both selection from this repertoire and adaptation of methods within that repertoire are necessary to best provide for particular pupils in particular circumstances.
- Both the repertoire and this decision-making process within it are learned through experience.
- Teachers continue to learn by reflecting on their experience and assessing the effects of their behaviour and their decisions.
- Both intuitive information gathering and routinised action can be brought under critical control through this reflective process and modified accordingly.
- Planning and pre-instructional decision making is largely deliberative in nature. There is too little certainty for it to be a wholly logical process.
- These processes are improved when small groups of teachers observe and discuss one another's work".

(Eraut 1995 p. 231 – 232)

Finally, Fischler (1999) used personal reflection in his framework and reports that only 25 per cent of the student teachers were happy with the progress that they had made in the classroom. They realised that many of the goals that they had set for themselves had not been achieved. The student teachers felt that "under better conditions......different students and better equipment.....these efforts would be more effective". (Fischler, 1999 p.189). Fischler makes it clear that the student teachers realised their own shortcomings:

> "Student teachers to a large extent attribute failure to themselves. In their opinion, increased experience would improve the possibilities for the realisation of their intentions"
>
> (Fischler, 1999 p. 188)

The area of personal reflection will be further discussed in the analysis of the baseline data and post-intervention data in chapters 6 and 7, respectively.

3.5 Summary

This chapter has described the mechanism by which a theoretical framework was developed to assist in the analysis of the data collected in this project. A survey of the literature identified seven frameworks that were selected on the basis of their prominence in the literature and on the basis of their applicability to this study. Each of these frameworks has been discussed and the main areas in each framework that are relevant to this research project have been highlighted.

The framework used in this research has synthesised a number of existing models to identify common themes relating to teachers' actions in the classroom. The framework provides a detailed map of the factors that influence these actions. In this research, the framework is specifically used in relation to the teaching of difficult ideas in chemistry by student teachers. The framework provides the structure which underpins the data analysis, i.e. the data gathered from classroom observations, interviews, questionnaires and lesson plans were mapped on to the framework in order to identify the outcomes of the Intervention Package.

The reason for developing this new framework, rather than using one of the existing framework, was that no one individual framework covered all of the dimensions that were necessary to explore in the research. From a study of the various frameworks identified in the literature, the features they contained could be grouped into seven common themes to help understand and interpret the factors that influence the decisions that teachers make in the classroom, i.e. *view of science*, *view of learning*, *view of teaching*, *view of science teaching and teaching of particular science topics*, *subject knowledge*, *local conditions* and *personal reflection*. These themes emerged from research studies involving a number of models that were developed not only from general studies of acquisition of expertise (Dreyfus and Dreyfus,1986) but also from studying the work of highly experienced teachers (Brown and McIntyre, 1993) and student teachers (Wilson et al., 1987; Borko et al., 1992; Peterson and Treagust, 1995). In addition, one of the models (Eraut, 1996) was developed from a study of the general area of teacher expertise and, hence, is applicable to both student teachers and experienced teachers. Whilst the common themes described in this chapter formed the basis of the framework developed by this researcher to study the actions of student science teachers, it would be appropriate to use the framework for also studying the classroom actions of experienced science teachers, e.g. when teaching difficult areas of science or areas where their craft knowledge is being studied. In addition, the framework could easily be modified for use by both student teachers and experienced teachers in other disciplines. In applying the framework to other disciplines, it should be borne in mind that of the seven themes used in the framework, only two (*view of science* and *view of science teaching*) are specific to the teaching of science. These could be modified to deal with the teaching of other subjects, e.g. *view of language*, *view of language teaching*. The remaining five themes (*view of learning*, *view of teaching*, *subject knowledge*, *local conditions* and *personal reflection and other feedback*) could be directly applied to the teaching of any subject area.

In addition, whilst the seven main themes of the framework were used to study and interpret the variables that influenced the thoughts and actions of student teachers teaching difficult ideas in chemistry, these themes could also be used to help analyse the classroom dynamic in situations other than the teaching of difficult ideas, e.g. the introduction of new teaching strategies like role play, discussions, discrepant events and brainstorming to encourage the pupils to reflect on their own thinking.

Having discussed each framework, an attempt has been made to draw together the different forms of terminology into common features to describe the various factors that influence the decisions that teachers make in the classroom. The seven common features that emerged from a study of the frameworks are: **view of science, view of learning, view of teaching, view of science teaching and view of how to teach particular science topics, subject knowledge, local conditions** and **Personal reflection and other feedback.**

These common features will be used in the analysis of the baseline data (chapter 6) and the post-intervention data (chapter 7). Before considering the details of this analysis, we first describe the research methodology employed in this research study.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

This chapter describes the overall research strategies employed in this study and describes the various research techniques used to gather data: classroom observation, semi-structured interviews, questionnaires and lesson plan analysis. It includes details of the research tools developed and of the approach used to analyse the data collected, as well as the steps taken to ensure the reliability and validity of both the data collection tools and the data analysis.

As this research project is a case study of practice in one institution as well as having aspects of an action research project, a brief overview of the research strategies employed in the study is first given. This is then followed by a discussion of the research techniques and data collection tools used in this study. More specific details about each stage of the research project are then focussed upon and discussed.

4.2 Overall research strategies

In terms of the main strategies used in educational research (case study, action research, ethnography, experiment and survey), this research project may be characterised mainly as a case study as it fulfils all the characteristics of a typical case study:

> "A case study is a specific instance that is frequently designed to illustrate a more general principle (Nisbet and Watt, 1984), it is 'the study of an instance in action' (Adelman et al., 1980). The single instance is of a bounded system, for example a child, a clique, a class, a school, a community. It provides a unique example of real people in real situations, enabling readers to understand ideas more clearly than simply by presenting them with abstract theories or principles.
>
> (Cohen et al, 2000 p. 181)

A more concise definition of case study has been formulated by Bogdan and Biklen (1982) as follows:

> "A case study is a detailed examination of one setting, or one single subject, or one single depository of documents, or one particular event"
>
> (Bogdan and Biklen, 1982 p. 58)

Both definitions point to the importance of the detailed study of one particular event in case study research. In addition, Cohen et al. (2000) point out that one of the main advantages of case studies is that they "can establish cause and effect - indeed one of their strengths is that they observe effects in real contexts, recognising that context is a powerful determinant of both causes and effects" (Cohen et al, 2000 p.181). The research project described in this thesis has undertaken a detailed examination of the teaching of difficult ideas by a group of student teachers in a particular third-level institution in Ireland. Data have been collected from practising student teachers working in a "real context" as described above and learning to come to terms with the demands of teaching – and particularly the teaching of difficult ideas in chemistry. In addition, this study fulfils all of the general characteristics of case study research (Hitchcock and Hughes, 1995, p. 322) as summarised in Table 4.1. on the following page.

General characteristics of case study research (Hitchcock and Hughes, 1995)	Characteristics as applied to this study
1. Concerned with a rich and vivid description of events relevant to the case.	1. The large amount of data gathered gives a detailed picture of student teachers teaching difficult ideas.
2. Provides a chronological narrative of events relevant to the case.	2. Chronological details of events is given in section 4.3.
3. Blends a description of events with the analysis of them.	3. Details of events and analysis are given in chapters 6, 7 and 8.
4. Focuses on individual actors or groups of actors and seeks to understand their perceptions of events.	4. Focus is on student teachers and the study attempts to understand their perspective of events using various research techniques.
5. Highlights specific events that are relevant to the case.	5. The theoretical framework developed is used to analyse the data and highlights the relevant aspects.
6. The researcher is integrally involved in the case.	6. The researcher is the lecturer on the teacher-training course.
7. An attempt is made to portray the richness of the case in writing up the report.	7. Blood, sweat and tears have gone into the writing of this thesis!

Table 4.1 Comparison between the general characteristics of case study research and characteristics as applied to this study.

Whilst case study research has many attractions, it is important to recognise both the strengths and weaknesses of this research strategy. In general, case study research lends itself to obtaining a great depth of data being gathered, along with the possibility of insightful inferences being obtained. In addition, case study research lends itself to multiple approaches to data collection. On the other hand, case study research tends to be very situational and specific and there may be a lack of generalisability of the findings.

Nisbett and Watt (1984) summarise the strengths and weaknesses of case study research as follows:

Strengths

1. The results are more easily understood by a wide audience (including non-academics) as they are frequently written in everyday, non-professional language.
2. They are immediately intelligible; they speak for themselves.
3. They catch unique features that may otherwise be lost in larger scale data (e.g. surveys); these unique features might hold the key to understanding the situation.
4. They are strong on reality.
5. They provide insights into other similar situations and cases, thereby assisting interpretation of other similar cases.
6. They can be undertaken by a single researcher without needing a full research team.
7. They can embrace and build in unanticipated events and uncontrolled variables.

Weaknesses

1. The results may not be generalisable except where other readers / researchers see their application.
2. They are not easily open to cross checking. Hence they may be selective, biased, personal and subjective.
3. They are prone to problems of observer bias, despite attempts made to address reflexivity.

(Nisbett and Watt, 1984)

In the study being discussed in this thesis, multiple sources of data were used in order to enhance the reliability of the data and increase its trustworthiness. (This is discussed in more detail in sections 4.4 – 4.7). In addition, the presentation of detailed data from a number of sources enables the reader to assess the relatability of the findings to their own situation.

Specific strategies that were used by the researcher in the collection and analysis of data in an attempt to overcome some of the general weaknesses in case study research like selective use of data and observer bias and will be discussed in sections 4.4 – 4.7.

It has already been mentioned that whilst this research project is a case study of practice in one institution, it also has aspects of an action research project. A simple definition of action research is that it is "a small-scale intervention in the functioning of the real world and a close examination of the effects of such an intervention" (Cohen et al., 2000 p. 226). A more comprehensive definition of action research (Macintyre, 2000) may be stated as follows:

> "Action research is an investigation, where, as a result of rigorous self-appraisal of current practice, the researcher focuses on a problem (or a topic or an issue which needs to be explained), and on the basis of information (about the up-to-date state of the art, about the people who will be involved and about the context), plans, implements, then evaluates an action then draws conclusions on the basis of the findings."
>
> (Macintyre, 2000 p. 1).

Thus, this project has the main characteristics of an action research project:

- It focuses on the problem of teaching difficult ideas in chemistry.
- It plans and implements an Intervention Package to assist student teachers in their teaching of difficult ideas in chemistry.
- It evaluates the effectiveness of the Intervention Package.
- It draws conclusions that are based on the findings.

As a method of carrying out research, action research has increased in popularity over the past four decades. Since the researcher is involved in the research process in action research, a lot of practitioner research takes the form of action research. Action research is popular among teachers as it enables them to maintain their teaching commitments whilst at the same time carrying out research in order to improve their practice. In addition, practising teachers are seen to be good judges of the educational environment in which they work. As with case study research discussed above, whilst there are advantages of practitioners carrying out research into their own practice, there are also some possible problems that may arise, Table 4.2 (Wellington, 2000).

Potential advantages	Possible problems
Prior knowledge and experience of the setting/context (insider knowledge)	Pre-conceptions, prejudices.
Improved insight into the situation and people involved.	Not as "open minded" as an "outsider" researcher.
Easier access	Lack of time (if working inside the organisations) and distractions/constraints due to being "known".
Better personal relationships, e.g. with teachers, pupils.	"Prophet in own country" difficulty when reporting or feeding back.
Practitioner insight may help with the design, ethics and reporting of the research.	Researcher's status in the organisation, e.g. a school.
Familiarity.	Familiarity.

Table 4.2 Some potential advantages and problems associated with practitioner research (Wellington, 2000).

The steps taken in this research project to overcome problem areas like pre-conceptions, lack of an "open-mind" and prejudices on the part of the researcher are discussed in sections 4.4 – 4.7. One big advantage of action research is that it helps to bridge the gap between educational theory and practice as the practitioners are encouraged to produce theories based on evidence drawn from their own experience in the classroom. This helps to overcome the perceived persistent failure of educational research to improve practice (Somekh,1995).

The purpose of action research may be stated in terms of "to plan, implement, review and evaluate an intervention designed to improve practice/solve a local problem" (Cohen et al., 2000 p. 79). In short, the project carried out by this researcher is in keeping with the general description of action research. It is hoped that, in the light of the research findings, changes will be made to improve the training of science teachers in the institution of the researcher.

4.3 Overview of research methodology

In designing the research methodology involved in this study, it was decided to use a mixture of methods as recommended by Schatzman and Strauss (1973) when referring to the "methodological pragmatism" of researchers. The concept of using a multi-method approach in collecting related data is discussed by many authors (Cohen et al., 2000; Wellington, 2000) under the heading of the term *triangulation*. This is defined by Cohen et al. as "the use of two or more methods of data collection in the study of some aspect of human behaviour" (Cohen et al., 2000 p. 112). A more detailed description of triangulation may be stated as:

> "cross-checking the existence of certain phenomena and the veracity of individual accounts by gathering data from a number of informants and a number of sources and subsequently comparing and contrasting one account with another to produce as full and balanced a study as possible".
>
> (Open University course E811, 1988 p. 54)

In carrying out this research project, great care was taken to ensure that the findings have validity, i.e. that the research tools are measuring or describing what they are supposed to measure or describe. Thus, by using a number of methods to study the same issue, it is hoped that the overall validity of the research is enhanced. This point is stressed by some authors (Cohen et al., 2000 p. 112) who describe how the validity is improved if the data gathered using one research instrument correlates with data gathered using other research instruments. Validity is defined by Wellington (2000) as follows:

> "Validity: the extent or degree to which an inquiry, a method, test, technique or instrument measures what it sets out or purports to measure, e.g. an intelligence test, an interview, a questionnaire. No instrument could ever be said to be valid with total certainty"
> (Wellington, 2000 p. 201)

Most of the data gathered in this study is of a qualitative nature and, in terms of this type of data, Anderson (1998) describes validity simply in terms of "the extent to which the stated interpretations are in fact true" (Anderson, 1998 p. 13).

An overview of the research methodology used in this study is shown in Figure 4.1. The timeframe within which the overall research project was carried out is summarised in Appendix I page 424.

Note from Figure 4.1 and Appendix I that the research techniques used to gather data were lesson observations, carrying out interviews, analysing documents (lesson plans) and administering questionnaires. Details of each of the data collection methods and associated tools as well as the data analysis will now be discussed.

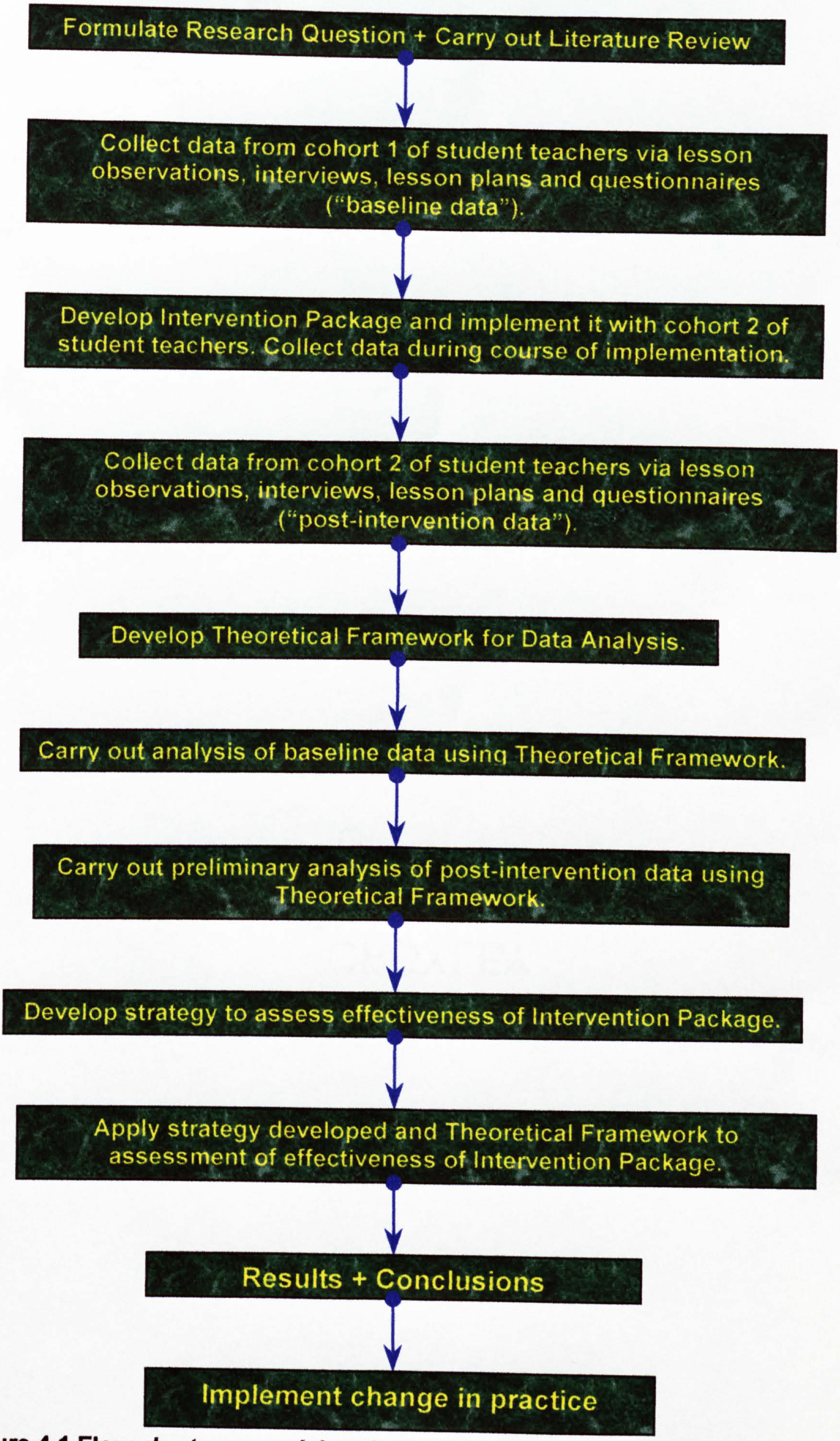


Figure 4.1 Flow chart summarising the methodology used in data collection and analysis

4.4 Observation data

This section describes how the observation data were collected and analysed and the steps taken to ensure the reliability and validity of both the data collection tools and of the data analysis.

4.4.1 Collection of observation data

Observation data were collected in this study in order to get immediate access to what is happening in the classroom in terms of how the student teachers were teaching difficult ideas in chemistry. Also, this direct observation may be more reliable than what the student teachers say in interviews, questionnaires and lesson plans. The researcher was very influenced by the richness of observation data obtained by Brown and McIntyre in their research on gaining access to the craft knowledge of expert teachers (Brown and McIntyre, 1993). On surveying some literature in the area of research methodology (Cohen et al., 2000; Simpson and Tuson, 1995), it is clear that observation data affords the researcher access to data that could not be accessed by other methods. In addition, observation data have the potential to enrich and supplement data gathered by other means. Also, classroom observation gives an insight into the general environment in which the teacher is working so that the researcher has a good understanding of the lesson *in situ* and gives the observer the opportunity to have a permanent record of what has taken place within a short period of time. Observations allow a clear picture to be formulated of the various interactions that take place in the classroom and, because so many unplanned incidents often occur in classroom settings, this gives a certain freshness to the data collected. A total of twelve student teachers were observed teaching difficult ideas in chemistry in the baseline phase of the study and sixteen student teachers observed in the post-intervention phase.

In planning the research strategy, the researcher tried to ensure that the student teachers would not consider the lessons observed for the purpose of research in the same way that they considered the lessons observed by the official supervisor for the purpose of evaluating their teaching practice. Therefore, in both the baseline phase and the post-intervention phase only student teachers **not** supervised by the researcher were asked to participate in the study. Since the researcher would not have any input into the end-of year teaching practice grade awarded to these student teachers, it was hoped that this would increase the reliability of the data collected, i.e. the degree of confidence in the data could be increased in the expectation that the observation would give an accurate reflection of normal classroom practice when teaching difficult ideas rather than a "special" class prepared for the supervisor. Reliability is defined by Wellington (2000) as follows:

> "Reliability refers to the extent to which a test or technique functions consistently and accurately by yielding the same results at different times or when used by different researchers. Research is said to be reliable if it can be repeated or replicated by another researcher and/or at a different time".
>
> (Wellington, 2000 p. 200)

Reliability is also described as "a synonym for consistency and replicability over time, over instruments and over groups of respondents" (Cohen et al., 2000 p. 117). These authors also point out that for research to be reliable, it must demonstrate that if it were carried out on a similar group of respondents in a similar context, then similar results would be found.

The student teachers were asked to make arrangements for the lesson to be videotaped. This was done in most cases by one of the pupils in the class or in some cases by a fellow student teacher in the school. In one case, the videotaping was carried out by the teacher in charge of AV aids in the school. With the advent of hand-held camcorders, the videotaping of the lesson was, in general, carried out quite unobtrusively.

In order to make the lesson observation appear as informal as possible, the researcher did not arrive on the day of the observed lesson with any of the normal documentation association with formal supervisions. In addition, to avoid any possibility of influencing the teaching strategies of the student teacher, no written notes were made by the researcher during the observed lesson. As recommended in the literature, the overall aim of the researcher was to be "as unobtrusive as possible so that observed behaviour is as close to normal as possible" (Bell, 2000 p. 165). Thus, it was hoped that the reliability of the data collected was as high as possible.

4.4.2 Analysis of observation data

Videotapes were collected after each lesson, labelled, catalogued and stored in a metal cupboard for analysis when time permitted. In some cases the videotapes were used in the interviews to ask the student teacher about certain actions that he or she had taken in the lesson. (Since interviews were usually carried out on the afternoon of the same day on which the lesson was given, in most cases it was not necessary to play the videotape.) Due to demands of time, preliminary data analysis did not take place until some time after data collection – typically in the Christmas, Easter and Summer "holidays".

As recommended in the literature (Simpson and Tuson, 1995) analysis of the observation data was carried out in a systematic manner. The same procedure, described below, was followed to analyse each individual videotape:

1. An outline plan of the lesson was recorded on a standard form that recorded the series of events taking place at various times throughout the lesson (Appendix II page 426). Examples of typical events recorded were writing on board, talking to class, asking questions, pupil responses, demonstrating experiments and pupil activities. All events were recorded to aid subsequent "mapping" of observation data on to the theoretical framework. The researcher wrote notes on various events in the third column of the form. This involved stopping the tape continuously to allow time for writing.
2. After step 1 had been completed for all videotapes, each tape was viewed again (after some months) and a summary of the main teaching strategies observed in the lesson was written out by the researcher. This was done as an *aide memoir* for the researcher. An example of this type of summary is shown in Appendix III page 427.

Having obtained a good overall "feeling" for the observation data, each videotape was then viewed again and the various events in each lesson coded and mapped against the factors in the theoretical framework. As suggested in the literature (Hopkins, 1985 p. 95), a tally grid (based on the theoretical framework) was made out for each lesson and evidence noted of the various factors being examined in the lesson, e.g. links to everyday life, exploring pupils' ideas and understanding, classroom climate, etc. All of the data from the baseline lessons were then transferred on to a large electronic "wall chart" that also contained data from the other research instruments. (In size, this was about ten A4 pages in length and two A4 pages in width.) Colour coding was used to separate the subsections within each main area. In summary form, this chart served the purpose of a "tally sheet" commonly used for keeping track of observations (Simpson and Tuson, 1995 p. 69). Once the data were summarised as described above, it was possible to see exactly how many student teachers used items like Concept Cartoons, how frequently practical work was carried out as well as the frequency of other classroom activities. The layout used for the wall chart is shown in Appendix IV page 428. This was repeated for the analysis of the post-intervention observation data.

The main weakness outlined in the literature in analysing observation data (Simpson and Tuson, 1995 p. 18) is that it is susceptible to observer bias. This problem is also discussed by Bell who warns against the observer "deciding on the focus than allowing the focus to emerge" (Bell, 2000 p. 158). In this study, the validity of the research instrument is strengthened by the fact that the areas of focus emerged out of the theoretical framework discussed in Chapter 3 rather than being imposed by the researcher.

In order to ensure the reliability of the data analysis, a sample of two of the videotapes was given to the researcher's supervisor who volunteered to double check the analysis. In addition, six of the baseline videotapes were given to a fellow colleague of the researcher to analyse this data independently of the researcher. In both cases, the data analysis concurred with that of the researcher and only minor modifications needed to be made by the researcher.

It was not felt necessary to pilot the forms and charts used to analyse the observation data since the data were in videotape format and this enabled the forms and charts to be changed easily if found unsuitable.

4.5 Interview data

This section describes how the interview data were collected and analysed and the steps taken to ensure the reliability and validity of both the data collection tools and of the data analysis.

4.5.1 Collection of interview data

Interviews were used in data collection in this study in order to try access areas that other research techniques cannot access. The use of the research technique of interviews was considered to be essential in this research study, as there is ample evidence in the literature of the advantages of interviews. For example, it has been reported (Bennett, 2003; Drever, 1995; Cohen et al., 2000) that the process of interviewing can access areas that other techniques cannot access fully and thus provide rich data and insights into the topic being investigated.

In an attempt to answer the research question of this study, it was important for the researcher to try to investigate and probe the thoughts, views, feelings, perspectives and values of the student teachers in regard to the teaching of difficult ideas in chemistry. Whilst some of these areas may be investigated by means of studying lesson plans and analysing questionnaires completed by the student teachers, none of these techniques would allow the researcher to seek clarification or probe responses. In addition, it was not possible for the researcher to predict the areas of interest worthy of discussion that would arise in the classroom observations – the research technique of interviews allowed the researcher the flexibility to focus on these areas during the interviews. Amongst the earliest definitions of the interview in educational research was that it was a "conversation with a purpose" (Webb and Webb, 1932). This approach looked on interviews as an informal exchange of views. At the other extreme, interviews may be looked upon simply as a method of collecting data by somebody who would not necessarily have a knowledge of the subject being studied, e.g. the type of interview that people in a shopping centre or passing through an airport give to a researcher asking a series of definite questions. This latter type of interview would be very rare in educational research. When using the interview as a research technique in this project, the researcher utilised his background knowledge of the research topic to formulate the relevant questions for the interview as well as the prompts and probes to further access the views of the student teacher.

In devising the style and structure of the interview, the researcher was influenced by the function of the research interview as defined in the literature (Wellington, 2000) as follows:

> "The research interview's function is to give a person, or group of people, a 'voice'. It should provide them with a 'platform', a chance to make their viewpoints heard and eventually read. It offers people, whether they be employers, teachers, young pupils or students, an opportunity to make their perspectives known, i.e. to go public. In this sense an interview empowers people – the interviewer should not play the leading role"
>
> (Wellington, 2000 p. 72)

In order to ensure that the "leading role" was played by the student teachers rather than by the researcher, it was necessary to consider the degree of structure of the interviews. In a **structured** interview, no deviation is made from the wording or the order of a given set of questions. This interview is similar to a "face-to-face questionnaire" (Parsons, 1984). In an **unstructured** interview, there is no set list of questions or rigid order of questions – the interview varies from one interviewee to the next (Richardson et al., 1965). This type of interview creates problems in providing a level of consistency from one interview to another and can cause difficulties when it comes to analysing data. The **semi-structured** interview lies between these two extremes. This type of interview is an attempt to overcome the inflexibility of the structured interview and the problems of the unstructured interview. In a semi-structured interview, the interviewer sets up a general structure by deciding in advance what area is to be covered in the interview and what are the main questions to be asked. The detailed structure of the interview is worked out as the interview progresses. In general, the interviewee answers in his or her own words and the interviewer responds using prompts and probes and follow-up questions to gain clarification or expansion on the answers. The researcher was very impressed by the rich data obtained by Brown and McIntyre (1993) in the semi-structured interviews carried out with the teachers involved in their study and hoped to replicate their success in this study.

The researcher began preparation for the semi-structured interviews by formulating the set of key questions to be asked in the interviews. This is commonly referred to as the **interview schedule** (Patton, 1990). The interview schedule used in this research study consisted of a series of main questions and some prompts and probes. The interview schedule was drawn up by studying guidelines and examining sample interview schedules in the literature (Cohen et al., 2000; Drever, 1995; Scott and Usher, 1999) as well as receiving advice and guidance received from the researcher's supervisor.

The interview schedule was piloted with three student teachers outside the sample and some minor modifications made to the schedule. These minor modifications involved slight alterations in wording to clarify some of the questions. The interview schedule used with the baseline student teachers is given in Appendix V page 429. Some additional questions about the use or lack of use of aspects of the Intervention Package were added to this interview schedule when interviewing the post-intervention student teachers. The interview schedule used with the post-intervention students is reproduced as Appendix VI on page 431.

The overall aim of the series of questions in the interview schedule was to attempt to access the thoughts of the student teachers with regard to their planning of the lesson, their actions in the classroom and their reflections on the lesson. The main areas covered in the interview schedule were:

- Introductory questions dealing with topics like the aims and objectives of the lesson, what the student teachers hoped the pupils would know about the topic at the end of the lesson and the resources consulted by the student teachers in preparing the lesson. These questions were included to try to access areas like the view of science held by the student teachers and how local conditions like assessment of the course affected the priorities of the student teachers.

- Questions on the main body of the lesson dealing with teaching strategies used by the student teachers, pupils' responses and the uses of teaching resources. In the case of the post-intervention students, questions about the use or lack of use of items from the Intervention Package were also included. The questions on the main body of the lesson were included to try to access areas like the student teachers' views of teaching, their views of learning, their views of their own subject knowledge and their views of how to teach particular topics in chemistry.
- Questions of a retrospective nature e.g. the areas they thought were difficult for the pupils to understand, what the student teachers thought was good about the lesson and what changes they would make in the lesson when repeating it. These questions were designed to initiate reflection by the student teachers on the lesson and to gain access to their own personal thoughts about the teaching of difficult ideas in chemistry.

The researcher found the interview schedule of enormous help to the interviewing process. It gave a clear structure to the interview and ensured a consistency of treatment across the range of interviews in both the baseline interviews and the post-intervention interviews. In addition, it ensured that questions were not missed out and that the interviewer did not "dry up" or go off at a tangent. Also, it helped to remind the student teacher being interviewd of the formal nature of the discussion. Finally, it was of enormous help in analysing the responses since it ensured that all the recorded responses were in the same order on each audio tape. (This is discussed in more detail in the next section.)

As suggested in the literature (Drever, 1995, Cohen et al., 2000), when drawing up the interview schedule, the more general questions were placed first, in order to avoid any sequence where the discussion of the first question was likely to influence later answers. In addition, care was taken to avoid jargon and to ensure that the questions made sense and were unambiguous. Although some questions were closed (e.g. age range of class, ability range of class), most questions were left open in order to probe the views, perspectives, experiences etc. of the student teachers. The advice given by one author (Wellington 2000) was found helpful:

> "The knack of developing a good interview schedule is to sequence it with the easy, closed questions early on and the more difficult open questions requiring a good deal of though and introspection towards the end. Start simple and build up to a crescendo!"
> (Wellington, 2000 p. 76 – 77).

It was found that the semi-structured interviews allowed flexibility in the interviews and enabled the researcher to give as much encouragement as possible to the student teachers to articulate their views. This was achieved by using the main questions to structure the interview and using prompts and probes to encourage further elaboration of points made by the interviewees. As mentioned previously, research involving the use of semi-structured interviews with experienced teachers is well documented in the literature (Batten, 1990; Brown and McIntyre,1993). However, since this research was carried out with student teachers, considerably more use was made of prompts and probes than in the studies mentioned above. The reason for this is probably due to the fact that student teachers lack the confidence and experience of teachers who have spent many years in the classroom. The prompts were designed to try to encourage them to talk and jog their memory but care was taken to avoid putting words into their mouths or to pressurise them into coming up with something. The probes were directed at what they had already said in an attempt to get them to clarify and explain some point that had been made, i.e. for an answer to be developed. A probe is defined as "any stimulus which is not a prompt, applied in order to obtain a response from an informant or a more extensive or explicit expression of it" (Atkinson, 1968). The distinction between probing and prompting may be explained (Parsons, 1984) as follows:

> "Prompting the respondent is a dangerous technique for structured interviews, and should be rigorously avoided. Probing, by contrast, is not only permissible but it is doubtful if anything but the simplest interviews could be completed without it. At first sight the distinction between the two may seem marginal, even pedantic. In essence, prompting indirectly leads the respondents: 'Do you mean that....?', which may cause some bias in the reply; whilst probing is neutral: 'Could you tell me more about........?' "
>
> (Parsons, 1984 p. 89)

Clearly, probing can be very valuable in open-ended questions. In this research study, care was taken to avoid directing the interviewees into certain responses (Brenner et al., 1985) by keeping the probing questions open-ended rather than closed and directive. In this way it was hoped to capture a true picture of the practice of the student teachers, i.e. what some authors refer to as "the texture of reality" (Stenhouse, 1979).

In short, the prompts and probes helped to remove ambiguity and helped to clarify the responses of the student teachers. This interactive dimension obviously has huge advantages over the non-interactive nature of a research instrument like a questionnaire.

All interviews were carried out in a room in the Department of Education of the institution in which the research was carried out. A small store room containing a table (similar in size to a standard office desk) and some chairs was used in order to avoid any interruptions from ringing telephones or callers to the office of the researcher. This location was deemed more suitable than carrying out the interviews in a school setting where interruptions would be difficult to avoid. Interviews took place during the evening of the same day on which the class was observed or, in a small number of cases, on the following day. There was no difficulty in arranging interview times for the student teachers as all of the student teachers spend each afternoon in the university. The number of student teachers interviewed was the same as the number of lessons observed (twelve in baseline study and sixteen in the post-intervention study).

All interviews were recorded with the permission of the student teachers. An external microphone attached to a tape-recorder was placed on a stand between the interviewer and the interviewee who sat facing each other across a table. It was found in the piloting phase that this arrangement worked well. The microphone picked up the voices clearly, the interviewer could work from the interview schedule without the interviewee seeing what was written on the schedule and the table allowed lesson plans, overhead transparencies, television/video recorder, etc. to be placed on the table for the purposes of discussion. The external microphone meant that the tape recorder could be placed discreetly at the end of the table and was powered by mains electricity at all times to avoid problems with batteries running low. Back-up copies were made of all tapes.

The interview schedule, typed up and held on a clip board, was used to read out the questions and mark off the points covered – it played an essential part in guiding the interview. As recommended in the literature (Drever, 1995) the questions in the schedule were not revealed to the interviewees in order that the interview would unfold naturally rather than having answers to questions being prepared in advance by the interviewees. Also, no writing apart from ticking off questions was carried out by the researcher lest this would influence the interviewee.

All interviews were recorded on cassette tapes and a new tape was used for each interview. Interviews were generally of 25 –30 minutes duration.

The advice given in the literature (Drever, 1995; Cohen et al., 2000) with regard to conducting the interview was found most helpful and use was frequently made of the following strategies:

- **Eye contact.** Intermittent eye contact was maintained with the interviewee. When asking a question, the interview schedule was consulted, eye contact was established with the interviewee to establish that he or she understood it. Eye contact was then broken to tick off a point on the interview schedule or by nodding or by looking at any material displayed by the student teacher. The frequent use of nodding and eye contact was found to be a useful ploy in encouraging the student teacher to continue talking.
- **Timing of interruptions.** In order to keep the interviews on course, it was necessary to interrupt from time to time. Usually, non-verbal signs were used to warn the student teacher of an intervention, e.g. holding up the hand

had the effect of stopping the student teacher talking if the researcher had not finished the question or if he or she had not understood the question or if going off at a tangent. This non-verbal sign was also used to probe something that the student teacher had just said. The gesture of the interviewer sitting back in the chair and "handing over" to the student teacher helped to encourage the student teacher to give an extended answer to a question.

- **Tone of voice and pace of speech.** These were varied in order to give an indication of the type of answer expected. The short factual questions at the beginning of the interview were asked in a brisk fashion to try to indicate that only brief answers were required. The more searching questions later on in the schedule were asked more slowly in order to indicate that some thought was required in answering them and that the student teacher should take time in giving a considered response.
- **Stock phrases.** The use of stock phrases like "Fine" and "OK" helped to manage the interviews and encouraged the student teachers to talk. These were found to be good verbal tactics which helped to maintain the flow of the interview. In addition, where a student teacher wandered off an answer, the verbal tactic of always blaming oneself was used, "I'm sorry, I did not make myself clear....". This helped to re-state the question and focus the mind of the student teacher on the area being discussed.

The main messages that the researcher received from the piloting phase was the need to make more frequent use of prompts and probes to encourage responses and to also to make more use of neutral phrases like "I see" and "I understand" rather than phrases like "good" and "well done". Some neutral phrases were written into the interview schedule as a reminder to the researcher.

In order to achieve as high a validity as possible, the researcher made a conscious effort in the interviews to avoid leading questions or questions that might be seen to support the "preconceived notions" of the researcher (Cohen et al., 2000 p. 121). In addition, every effort was made by the researcher in the interview to ensure that the student teacher understood the question being asked and clarifying questions were built into the interview schedules. By using neutral phrases and unbiased probing, the researcher tried to avoid expressing his own agreement or disagreement with the views expressed by the student teacher.

It is hoped that the reliability of the research tool was enhanced by the fact that the interview schedule was piloted and revised in the light of the piloting. In addition, by keeping the interview questions brief and to the point it was hoped that each student teacher understood the questions in the same way (Silverman, 1993).

4.5.2 Analysis of interview data

In keeping with recommendations in the literature (Drever 1995, Cohen et al., 2000), it was decided at the outset to carry out a full transcription of the tape-recorded interviews. A full transcription has a number of advantages in that it gives a clearer picture of the interview than a partial transcript and it avoids the criticism of being biased and selective in transcribing only specific parts of the interviews. In addition, it enables exact quotations to be extracted and, if stored in electronic format, it enables the data to be processed more easily in a qualitative analysis package like *Winmax* (the package used by the researcher). In addition, by reading the full transcripts a number of times, the researcher found that it enabled him to become "immersed" in the data as recommended by many authors (Drever, 1995; Miles and Huberman, 1994; Wellington, 2000). Initially, copies of two audio tapes were sent to a professional typist for transcription. However, initial results were unsatisfactory with terminology like *solute*, *solution* and *solvent* causing problems for the typist. Therefore, in the interest of accuracy, all transcriptions were carried out by the researcher himself. Although this was a very time-consuming task for an amateur typist (a half-hour interview taking several hours to transcribe), it did have the advantages of the researcher gaining a very close familiarity with the data. This was of great assistance in the analysis and report-writing stages of the project. In addition, it ensured that the transcription was performed as accurately as possible – especially when it came to the use of technical words. The fact that punctuation has no direct counterpart in speech, that many people have the tendency to speak quite ungrammatically and leave sentences unfinished meant that many of the transcripts looked like "working documents". Each transcript was checked for accuracy by listening to each tape on two separate occasions whilst reading the transcript. Any errors encountered were rectified and each transcript stored in electronic form in two different locations (home and office). A hard copy of each interview transcript was filed away and a working copy used by the researcher.

In view of the fact that a total of 28 interviews were carried out (12 baseline, 16 post intervention), a considerable amount of data were collected. The stages suggested in the literature (Miles and Huberman, 1994; Cohen et al., 2000; Wellington, 2000) for analysis of this data were followed and may be summarised as follows:

1. **Data Immersion.** This involved listening to the tapes, reading and re-reading the transcripts, making notes on the transcripts, highlighting certain points, etc. This process enabled the researcher to become very familiar with the data in an effort to "hear what the data has to say to you" (Rubin and Rubin, 1995).
2. **Reflecting on data.** This stage involved "standing back" from the data and trying to look at it with a clinical and analytical eye in order to assist with the subsequent job of analysing the data for categories and themes that emerge from it. This involved the researcher "sleeping on" the data, discussing it with his supervisor, with his Thesis Advisory Group and with some of his colleagues.
3. **Data analysis.** This involved reorganising, categorising and summarising the text as required by the research question. The computer package *Winmax* was an invaluable tool to use here as great use was made of this software to select passages of text and code them into the appropriate categories. The problems of analysing qualitative date may be summarised as follows (Cohen et al., 2000):

   > "In qualitative data, the data analysis here is almost inevitably interpretative, hence the data analysis is less a completely accurate representation (as in the numerical, positivist tradition) but more of a reflexive, reactive interaction between the researcher and the decontextualised data that are already interpretations of a social encounter. The great tension in data analysis is between

> maintaining a sense of the holism of the interview and the tendency for analysis to atomise and fragment the data – to separate them into constituent elements, thereby losing the synergy of the whole, and in interviews often the whole is greater than the sum of the parts".
>
> (Cohen et al., 2000 p 282)

In order to overcome the above problems, many of the stages suggested in the literature (Miles and Huberman 1994, Cohen et al., 2000) were used in the data analysis and these may be summarised as follows:

- Reading through the data and noting frequencies of occurrences of certain themes. Initially these were simply noted on the hard copies of the interview transcripts.
- Identifying and noting any relationships between the variables.
- Coding the interview responses, i.e. "the translation of question responses and respondent information to specific categories for the purpose of analysis" (Kerlinger,1970). Coding essentially involves assigning a category label to a piece of data. In this research study, the category labels were based on the headings and sub-headings that emerged from the theoretical framework. Coding involved systematically going through each individual transcript, line by line, and coding each item of selected data to a particular category (Drever, 1995). The computer software package *Winmax* was found extremely useful in the coding process as the screen shows a "running total" of how many lines of data have been assigned to each code. Thus, even a cursory glance showed the strong themes around which the student teachers had a lot to say as certain points began to be repeated.
- Clustering, i.e. setting items into categories by grouping the codes into more general clusters.

Once the first round of coding of baseline data was completed, then by noting the frequencies of codes, it was clear that certain patterns and themes began to emerge and hence generalisations began to develop. In order to improve the reliability of the coding process, coding of data from each interview was carried out on two occasions by the researcher with an interval of about a month between each coding procedure. The second independent coding showed up some small amounts of data that had been missed out in the first round. It also showed up two data items that had been wrongly coded. The full set of transcripts and coded data were studied by a colleague to check for errors in coding and some minor changes made to the assignment of data items.

Analysis of the post-intervention interview data was carried out in the same way as the analysis of the baseline data.

Whilst the work of transcribing the interview data was tedious and very time-consuming, the storing and coding of the data in electronic format, greatly facilitated the presentation of the material in written format as quotations made by the student teachers could be directly transferred from *Winmax* to a word-processing document.

The outcome of the analysis of the baseline data is presented in Chapter 6. The order of presentation of material follows the order in which each of the areas tended to be covered in the models which formed the basis of the analysis framework.

Initially, the analysis of the post-intervention data was written up in exactly the same format as the baseline data. This enabled direct comparisons to be made between the two sets of data. However, in order to assess the effectiveness of the Intervention Package, data were re-organised under the heading of three themes that emerged from a study of various models of educational evaluation. The validity of the data analysis is increased by the fact that the categories under which the data are analysed emerged from well known models in the research literature rather than categories assigned by the researcher. Hence, any bias on the part of the researcher is minimised.

The reliability of the data analysis is enhanced by the fact that the stages for qualitative data analysis outlined in the literature were rigorously followed and the coding process was carried out on two different occasions by the researcher and checked on a third occasion by a colleague.

4.6 Questionnaire data

This section describes how the questionnaire data were collected and analysed and the steps taken to ensure the reliability and validity of both the data collection tools and of the data analysis.

4.6.1 Collection of questionnaire data

Questionnaires were used in data collection in this study in order to try to access the views of the wider group of student teachers. Whilst the lesson observations and interviews focussed on specific groups of student teachers, it was also of interest to the researcher to gain the views of those student teachers not involved in the survey. (A total of twelve student teachers in the baseline study and six student teachers in the post-intervention study were **not** involved in the observation/interview component of the study.) The use of questionnaires also had the advantage of anonymity for the student teachers and, by using standardised questions, it was hoped that this would improve the reliability of the data collected.

Written feedback was obtained from the wider group of student teachers in the form of either formal questionnaires or responses to activities incorporated into the Intervention Package. A total of nine sets of written items were obtained. Data collected via written feedback (items 1, 5, 6, 7, 8, 9, 11, 15 and 16) as well as all data collected in the course of this study are listed in Table 4.3. The three "formal" questionnaires issued to the students are listed as items 1, 15 and 16 in Table 4.3 These are reproduced in Appendix VII (item 1) page 433, Appendix VIII (item 15) page 434 and Appendix IX (item 16) page 437. The first questionnaire (Appendix VII) sought the views of the student teachers on what they consider teachers need to do to promote effective learning. The second questionnaire (Appendix VIII) obtained feedback from the student teachers on their opinion of the Intervention Package. The third questionnaire (Appendix IX) required the student teachers to rank various factors that they consider important in bringing about effective learning in science. The content and analysis of these questionnaires will be considered in more detail in Chapter 7. Examples of the type of "informal" feedback forms used during the implementation of the Intervention Package are reproduced in Appendix X (item 5) page 438 and Appendix XI (item 8) page 438. The remaining "informal" feedback items are discussed in the course of data analysis (Chapters 6 and 7).

ITEM	DETAILS
1. Baseline questionnaire (2000 – 2001 group)	Students asked to list out in order of importance what they see as the characteristics of effective teaching.
2. Baseline videotapes (2000 - 2001 group)	Videotapes of 12 students teaching difficult ideas in chemistry.
3. Baseline interviews (2000 - 2001 group)	Interviews with 12 students whose classes were videotaped.
4. Lesson plans baseline (2000 - 2001)	Lesson plans used by 12 students whose classes were videotaped and who were interviewed.
5. Session 1, activity 1 Intervention Package	Written feedback from students on results of diagnostic tests they carried out with pupils before formal teaching began.
6. Session 1, activity 2 Intervention Package	Students response to cartoons: written comments / drawings of their image of what teaching and learning in science is all about.
7 Session 1, activity 3 Intervention Package	Students look at paired statements about teaching and learning, and pick out the ones with which they agree.
8. Session 2, activity 1 Intervention Package	Students give written feedback on research paper from journal on pupils' misunderstandings.
9. Session 2, activity 2 Intervention Package	Written feedback from each group on key points that emerged from group discussions on presentations re research papers.
10. Session 2, activity 3 Intervention Package	Students build up hierarchy of topics (in order of difficulty) in Junior Certificate chemistry course.
11. Session 3, activity 1 Intervention Package	Each student uses written assignment to discuss implications for teaching arising out of session 2.
12. "Post intervention" videotapes (2001 – 2002 group).	Videotapes of 16 students teaching difficult ideas in chemistry after Intervention Package implemented.
13. "Post intervention" interviews (2001 – 2002 group).	Interviews with 16 students whose classes were videotaped after Intervention Package implemented.
14. Lesson plans (2001 – 2002 group)	Lesson plans used by 16 students whose classes were videotaped and who were interviewed.
15. End-of-year questionnaire.	Questionnaire issued to all 24 science methodology H.Dip.Ed. students re feedback on Intervention Package
16. Final H.Dip.Ed. questionnaire	Questionnaire to H.Dip.Ed. students re factors to bring about effective learning in science.

Table 4.3 Summary of data collected during course of research project.

All questionnaires were typed by the researcher. In designing the questionnaires, the guidelines outlined in the literature were followed as closely as possible (Cohen et al., 2000; Munn and Drever, 1996; Wellington 2000). Care was taken to ensure that the questions asked were relevant to the objectives of the research study, that the questionnaire looked attractive and that it could be completed in a reasonably short time. In addition, every effort was made to ensure that the wording was clear and unambiguous so that the respondents understood what was being asked.

In keeping with advice in the literature, the emphasis in designing questionnaires was placed on the gathering of qualitative data:

> Though there is a large range of types of questionnaire, there is a simple rule of thumb: the larger the size of the sample, the more structured, closed and numerical the questionnaire may have to be, and the smaller the size of the sample, the less structured, more open and word-based the questionnaire may be..............If a site-specific case study is required, then qualitative, less structured, word-based and open-ended questionnaires may be more appropriate as they can capture the specificity of a particular situation. "
>
> (Cohen et al., 2000 p. 247 – 248).

The additional general advice given in the literature was also followed, e.g. avoiding items like leading questions, double questions, presuming questions, complex questions, irritating questions, double negatives, offensive questions, sensitive issues and jargon.

When designing the questionnaire on the evaluation of the Intervention Package (item 15), the researcher followed the advice given in the literature (Wellington, 200a p. 104) regarding its structure, i.e. that where a questionnaire had to be broken down into different sections, the closed, matter-of-fact questions were placed first and this was followed by the open-ended questions that required the opinions and judgements of the respondents. As Wellington (2000) predicted, this type of questionnaire did yield very good quality data. The first draft of each questionnaire was discussed with the researcher's supervisor before being piloted with a group of nineteen MEd(Sc) students in the researcher's university.

The following questions (Bell, 2000) were attached to the questionnaires and completed by those involved in piloting:

1. How long did it take you to complete the questionnaire?
2. Were the instructions clear?
3. Were any of the questions unclear or ambiguous? If so, please indicate on the questionnaire.
4. Did you object to answering any of the questions?
5. In your opinion, has anything major been omitted?
6. Was the layout of the questionnaire clear/attractive?
7. Any other comments? In so, please write these on the questionnaire.

None of the feedback received suggested that any major changes should be made in the questionnaires. Some minor changes were made to the wording and layout of some of the questions.

All questionnaires (except the final one) were issued to the student teachers in the university so a 100% response rate was obtained in each case. The final questionnaire was posted to student teachers in September of the following academic year. To maximise the response rate, a stamped-address envelope was sent and a raffle ticket for a prize of €100 was offered for all completed questionnaires returned by the end of that month. Of the 22 questionnaires issued, 21 were completed and returned by the due date, i.e. a response rate of 95.5%. (The prize was won by a young teacher in the "Kingdom" of Kerry!). It was hoped that the validity of the questionnaires was improved by their anonymity and it was hoped that this would lead the student teachers to complete them honestly. In addition, since, the researcher made a conscious effort to design the questionnaires in accordance with the advice given in the literature, it is hoped that the student teacher understood the questions being asked and hence completed them as accurately as possible.

It was also hoped that the reliability of the questionnaires was enhanced by the fact that the questionnaires were piloted and revised in the light of the piloting. In addition, by designing the questionnaires in accordance with standard procedures as outlined in the literature, it was hoped that each student teacher understood the questions in the same way.

4.6.2 Analysis of questionnaire data

All qualitative data from the completed questionnaires were transcribed by the researcher. The data were stored in electronic format and analysed using exactly the same procedures as outlined in the analysis of the interview data. Data analysis was greatly facilitated by the fact that the software package *Winmax* was already set up with all the appropriate codes specific to this research project. Thus, the validity and reliability of the analysis of the questionnaire qualitative data are the same as discussed for the analysis of the interview qualitative data.

The quantitative data were analysed by the researcher using the spreadsheet package *Excel*. This helped to ensure that the number of items of data transferred to the spreadsheet tallied with the number of items of data on the hard copies of the completed questionnaires. The spreadsheet was used to calculate percentages and generate graphical representations such as pie charts and bar charts. The correct transfer of data and the graphs produced were double-checked by a colleague working in the area of ICT. In view of the relatively small sample size, this research study did not gather a great deal of quantitative data. However, for ease of comparison, some percentage figures will be quoted from time to time when comparing baseline data with post-intervention data.

Since quantitative data are being analysed, there is a very high validity in using a spreadsheet package like *Excel* for analysis. The fact that the data transfer was double-checked by a colleague adds to the reliability of the data analysis.

4.7 Lesson Plan Data

This section describes how the lesson plan data were collected and analysed and the steps taken to ensure the reliability and validity of the data analysis.

4.7.1 Collection of lesson plan data

Lesson plans were used as a data source in this research study because they serve as documentary evidence of the planning that each student teacher put into the lesson on teaching difficult ideas in chemistry. Whilst the lesson observation data showed what actually took place in the classroom, the lesson plan data showed the activities that the student teachers intended to carry during the lesson. In many cases, it was found there was disparity between the intentions of the student teachers and the reality of what was observed. This is discussed in more detail in chapter 7.

Each student teacher was asked to bring along to the interview a copy of the lesson plan used in the teaching of the observed lesson. Each lesson plan was photocopied and the original returned to the student teacher. These lesson plans typically are 2 – 3 pages of notes that help to guide the student teacher through the lesson..Each page contains two columns: the left-hand column contains the heading “Content” and the right-hand column the heading “Methodology”. The lesson plans tend to be very content orientated with the subject content listed in teaching order on the left-hand side and the methods used by the student teacher to teach that topic listed on the right-hand side. Each student teacher is expected to write a short reflection at the end of each lesson plan. The lesson plans served as a useful point of reference when discussing aspects of the lesson in the interview.

In addition to the lesson plan, items like overhead transparencies and flash cards are usually included in the plastic pocket folder for each lesson plan. All lesson plans are kept in a lever arch file that is inspected when formal supervisions are made.

4.7.2 Analysis of lesson plan data

Each individual lesson plan was analysed using the headings in the theoretical framework. For example, under the heading *Nature of presentation*, evidence was looked for in the lesson plan of details of items like audio visual aids listed for use in the lesson; under the heading *of Links to everyday life* evidence was looked for of the use of items/examples that the pupils would have met in their daily lives; under the heading of *Exploring ideas and understanding*, evidence was looked for of items mentioned like Concept Cartoons, diagnostic questions and brainstorming. All information was entered on the electronic "wall chart" described earlier in section 4.3.2 (Appendix IV page 428). By having the summarised lesson plan data placed in the column next to the summarised observation data, it was possible for the researcher to see for each student how the strategies listed in the lesson plan compared with what was actually observed when the lesson took place. This is discussed in more detail in chapter 7.

To ensure the reliability of the correct transfer of data from the lesson plans to the electronic format, the transfer was double- checked with the assistance of a student helper.

The reflections in each lesson plan were analysed in the same way as the qualitative data gathered in the interviews and questionnaires. Hence the validity and reliability of the analysis should be very similar to that of the analysis of interviews and questionnaires. The validity of the analysis is enhanced by the fact that the headings used to analyse the lesson plan data have emerged from the theoretical framework rather than the researcher imposing his own categories on the analysis. The reliability of the data analysis is enhanced by the double-checking procedure that was used.

In general, the reflections did not give the same richness of data as was found in the interviews. Many of the reflections on the lessons simply concentrated on what the student teacher thought was good about the lesson and what changes they would make the next time he or she taught it. The results of the analysis of the reflections are discussed in chapter 7.

4.8 How the individual data sources contribute to the themes in the analysis framework

In considering the research question *How do student teachers draw on the guidance they are given in their training course about dealing with pupils' misunderstandings in chemistry?*, the four data sources (observation data, interview data, questionnaire data and lesson plan data) helped the researcher to build up a picture of the thoughts and actions of the student teachers as they went about the task of teaching specific difficult areas of chemistry. This picture, described in detail in Chapters 6 and 7, made it possible to make a direct comparison between the actions and thought processes of the student teachers before and after the implementation of the Intervention Package. Thus, it was hoped that the analysis of the data gathered using the framework would help to characterise the effects of the Intervention Package in terms of the extent to which the student teachers embraced the guidance given during the implementation of the Intervention Package.

In analysing the data to build up a clear picture of the effects of the Intervention Package, data from the four sources were mapped on to the themes that emerged from the theoretical framework. Table 4.4 shows the matrix used to cross-tabulate data sources against the themes used to report baseline data in chapter 6. The lesson observation data, interview data and lesson plan data yielded information on the **view of science** held by the student teachers, e.g. the emphasis placed by the student teachers on learning definitions and facts, the emphasis on scientific terminology, the view of science as a method of enquiry, the use of practical work and the placing of science in its historical or social context.

	OBSERVATION DATA	INTERVIEW DATA	QUESTIONNAIRE DATA	LESSON PLAN DATA
1. View of science	√	√		√
2. View of learning	√	√		
3. View of teaching.	√	√	√	√
4. View of science teaching including particular topics	√	√	√	√
5. Subject knowledge	√	√		
6. Local conditions		√		
7. Personal reflection		√	√	√

Table 4.4 Summary showing how the four data sources related to the framework used in the data analysis in Chapter 6 (baseline data)

An insight into the **view of learning** possessed by the student teachers was obtained from a study of the lesson observation data and interview data, e.g. if the students held a "transmission" view of learning or a more "active" view of learning. Also, the lesson observation data and interview data allowed the researcher to see if control and choice were offered to the pupils over activities or whether the lessons were driven by the teacher with instructions being rigidly followed by the pupils.

Data obtained from the observations of lessons, interviews, questionnaires and lesson plans yielded information on the **view of teaching** possessed by the student teachers, e.g. the type of presentation used by the student teachers (AV aids, resources, textbooks, teaching methods, models and analogies), the classroom climate (enthusiasm of teacher, encouraging of pupil opinion, discipline) and links to everyday life (use of everyday examples in teaching).

Insights into the **view of science teaching** and **view of how to teach particular science topics** were obtained from a study of the lesson observation data, the interview data, the questionnaire data and the lesson plan data, e.g. efforts made to explore pupils' ideas and understanding and strategies for teaching particular topics (everyday examples, practical activities, recognition of pupil difficulties, content versus understanding, analogies).

The lesson observation data and the interview data provided good evidence for the degree to which the **subject knowledge** of the student teachers posed a problem for them in their teaching, e.g. the fact that the lack of subject knowledge among the student teachers introduced misunderstandings into lessons, the reluctance of the student teachers to get involved in discussions with the pupils and the inability of the student teachers to answer questions from the pupils.

The interviews with the student teachers yielded data on the **local conditions** that impinged on the classroom teaching, e.g. the degree of importance given by the student teachers to the mode of assessment/examination system, the help that the student teachers received from other teachers and specific problems associated with the pupils in the classroom.

Finally, the interviews, questionnaires and lesson plans of the student teachers allowed the researcher to collate data on the personal reflections of the student teachers themselves in areas like their appraisals of the lessons, their own subject knowledge, their lack of confidence and the realisation of their own shortcomings.

The matrix used to cross-tabulate data sources against the themes used to report post-intervention data in chapter 7 is shown in Table 4.5.

	OBSERVATION DATA	INTERVIEW DATA	QUESTIONNAIRE DATA	LESSON PLAN DATA
1. Awareness re provision of information and resources	√	√	√	√
2. New teaching strategies and skills	√	√	√	
3. Attitudinal factors		√	√	

Table 4.5 Summary showing how the four data sources related to the framework used in the data analysis in Chapter 7 (post-intervention data).

The lesson observation data, interview data, the questionnaire data and lesson plan data provided information on the **awareness** of the student teachers regarding the provision of information and resources, e.g. diagnostic tests, Concept Cartoons, research papers in the area of pupil misunderstandings and strategies relating to eliciting pupils' prior understanding.

Insights into the **new teaching strategies and skills** developed by the student teachers were obtained from the lesson observation data, the interview data and the questionnaire data, e.g. the extent of the shift from the emphasis on "teacher talk" to other activities like discussions, role play, brainstorming exercises, model building, practical work and use of analogies. In addition, the interview data made it possible to probe areas like the level of reflection among the student teachers of what is involved in teaching and learning science, the ability of the student teachers to make suggestions for classroom practice to help overcome misunderstandings, and the ability to transfer their knowledge and skills on the teaching of difficult ideas in chemistry to the biology and physics areas of the curriculum.

The interviews and the questionnaires were the main sources of data on the **attitudinal factors** relating to the student teachers, e.g. their views of the Intervention Package sessions, their views of science, their views on learning and their own personal reflections on misunderstandings.

4.9 Methodology for developing Intervention Package

The development of the Intervention Package took place over a period of several months between Easter of Year 2 and October of Year 3. It was implemented in November of Year 3 in three sessions of 1.5 hours duration each.

The general concept of the Intervention Package was discussed on several occasions by the researcher with his supervisor and with the member of his Thesis Advisory Group. Arising out of these discussions, the aims listed in Table 4.6 were formulated.

- To encourage student teachers to reflect on what is involved in learning and teaching science.
- To introduce some of the main views on learning in science.
- To introduce student teachers to some of the main research findings on pupils' misunderstandings in science.
- To encourage student teachers to reflect on some misunderstandings in science that they have studied in the research literature.
- To make students aware of the problem with misunderstandings in chemistry.
- To encourage the student teachers to reflect on the types of teaching strategies that are of assistance in overcoming children's misunderstandings of ideas in science.
- To introduce the student teachers to the research literature findings that inform us about the teaching strategies required to tackle the problem areas of misunderstandings in science – and chemistry in particular.

Table 4.6 Aims of Intervention Package

The material used in the production of the Intervention Package came from various sources. The activities used in the package were drawn on those used on the science initial teacher-training course of the University of York. The diagnostic questions also came from the same source as well as from work done by Osborne and Freyberg (1996). The materials on the constructivist view of learning were drawn from the standard works in this area (Driver et al., 1986, 1994, 1997). The Concept Cartoons were drawn from the main publication on Concept Cartoons (Naylor and Keogh, 2000) and some of the worksheets were taken from a publication by the Royal Society of Chemistry (Taber, 2002).

Overall, the thrust of the Intervention Package was influenced by the course material that the researcher encountered as a student on the Masters in Science Education course at the University of York.

To avoid the necessity of writing up a detailed description of each of the three sessions of the Intervention Package, a summary of these sessions is given in Appendix XII page 440 (session 1), Appendix XIII page 441 (session 2), Appendix XIV (session 3) page 442.
In designing each of the sessions, care was taken to include various activities for the student teachers in order to try to reflect the approach that the researcher was hoping to encounter when lesson observations would take place. In addition, to avoid any problem with bias in the research, it was not pointed out to the student teachers that the three sessions on the teaching of difficult ideas constituted a form of intervention in the course.

Three drafts of the Intervention Package were produced in the light of comments received from the researcher's supervisor and his Thesis Advisory Group. Full details of the Intervention Package are given in Appendix XV page 445.

No major ethical issues arose in the course of this study. All of the student teachers were volunteers, none of the schools in which lessons were observed have been identified and the names of all the student teachers have been changed to preserve anonymity.

4.10 Summary

This chapter has described the methodology used to collect and analyse the significant amount of data required for this research project. The decisions made about choice of research tools and methods of analysis have been discussed in the light of the literature in this area. In addition, the steps taken to ensure the reliability and validity of both the data collection tools and of the data analysis have been outlined and discussed. Finally, an overview of the aims, structure and content of the Intervention Package has been given.

Before considering the results of the analysis of data (Chapters 6 and 7), the strategy used to assess the effectiveness of the Intervention Package is discussed in Chapter 5.

CHAPTER 5

Strategy for Assessing the Effectiveness of the Intervention Package

5.1 Introduction

This chapter considers the strategy to assess the extent to which the Intervention Package has been successful in achieving its aims. Many involved in educational research trace curriculum evaluation as a distinct field of educational research back to Tyler (1949) who defined it as "the process of determining to what extent the educational objectives are realised by the program of curriculum and instruction" (Tyler, 1949). In order to produce a model to examine the extent to which the aims of the Intervention Project have been achieved, a number of key research projects in the area of curriculum innovation are first examined. The findings from these research projects are then used to establish the model within which the evidence gathered in this study may be analysed and discussed.

In addition to the baseline data analysis and post-intervention data analysis reported in Chapters 5 and 6 respectively, data gathered from the student teachers in the course of the presentation of the Intervention Package and in end-of-year questionnaires will also be discussed in terms of the model used for analysis.

5.2 Models for educational evaluation

A study of the literature in the area of curriculum evaluation, shows that a number of models have been developed to describe the effects of curriculum implementation. The term more commonly used when referring to curriculum evaluation in the literature of the USA is *programme evaluation*.

Two main models (Bennett, 2003) were felt to be of particular relevance to this research as they focussed on empirically derived models to assess the effects of curriculum intervention. These two models, *the Concerns Based Adoption Model* and the *Harland and Kinder Model* gathered data from practising teachers in the USA and the UK, respectively, on the effectiveness and impact of INSET courses on their professional practices. Whilst these research programmes gathered data from full-time practising teachers, the models are nevertheless still felt to be relevant to student teachers since the factors that are likely to influence the classroom practice of full-time teachers are also likely to have a similar impact on student teachers. In addition, both models have in-built flexibility, i.e. they can be applied to innovations of different types and scales and tailored to fit varying needs.

5.2.1 Concerns-Based Adoption Model (CBAM)

The CBAM model was developed by The Research and Development Centre for Teacher Education at the University of Texas at Austin, USA (Hall et al., 1973). The model was the result of over a decade of intensive, school-based research. The driving force for the development of the model was the concern that many new programmes introduced into schools appeared to meet with little success and often were simply discarded. The work of Hall et al. (1973) in developing this model is described in detail in a book written for practising teachers (Hord, 1987). In this book the CBAM model is described as follows:

> "The Concerns-Based Adoption Model is an empirically-based conceptual framework which outlines the development process that individuals experience as they implement an innovation".
>
> (Hord,1987 p. 93)

From an analysis of the research data carried out in the above project, seven fundamental assumptions about change and how it can best be facilitated were formulated. These assumptions are the foundations on which the CBAM model is built and may be summarised as follows:

1. Change is a process, not an event, i.e. instead of looking at change as being a discrete, identifiable event it should be looked on as a process occurring over a period of time.

2. Change is made by individuals first, i.e. rather than consider programmes in broad, impersonal terms, the primary focus of actions taken to promote change must be on individuals. It is only when a sufficient number of individuals have genuinely embraced a change, can it be said that the programme has been successful.

3. Change is a highly personal experience, i.e. individuals react differently to change in accordance with various personalised factors. Therefore, it is important to take account of the differences rather than expecting teachers to behave in a collective fashion.

4. Change entails multilevel developmental growth, i.e. during the process of change there are identifiable stages of feeling and levels of skill with respect to the innovation that individuals pass through as part of their experience of change over time.

5. Change is best understood in operational terms. Care must be taken to avoid creating a gap between theoretician and practitioner when introducing educational innovations. Innovation programmes conceived by developers in abstract conceptual terms can appear alien to the concrete, practical concerns of the classroom teacher. Change is best understood if presented or described to teachers as it would appear when fully in use (operational terms). Thus, teachers encountering a new programme will relate to it in terms of what it will mean or do to their current classroom practice.

6. Change facilitation must suit individual needs, i.e. actions taken to promote the implementation of changes are most likely to succeed if they are geared to the needs of the individual users. This approach to implementing change can help to maximise the prospects for success while minimising the problems the individuals may have with the innovation.

7. Change efforts should focus on individuals, not innovation. The concrete items of an innovation package (books, charts, handouts, etc.) do not make change – only people can make change by altering their behaviour. Therefore, preconceived ideas like the speed with which implementation can be achieved may have to be altered or set aside.

Arising out of the perspective framed by the above assumptions, the CBAM programme has developed a model for implementing innovation and evaluating the change. There are three main components within this model: (i) Stages of Concern, (ii) Levels of Use and (iii) Innovation Configuration.

(i) Stages of Concern

This stage is described as "the cornerstone of the whole CBAM model" (Hord, 1987 p. 97). Essentially, it is a technique for gathering information and for formative evaluation of innovation. The "stages of concern" is a seven-level description to identify teachers' concerns about an innovation at a given point in time, Table 5.1.

Stages of concern	Expressions of Concern
6. Refocusing	I have some ideas about something that would work even better.
5. Collaboration	I am concerned about relating what I am doing with what other instructors are doing.
4. Consequence	How is my use affecting students?
3. Management	I seem to be spending all my time getting material ready.
2. Personal	How will using it affect me?
1. Informational	I would like to know more about it.
0. Awareness	I am not concerned about it (the innovation).

Table 5.1 The stages of concern in the Concerns-Based Adoption Model (Hord, 1987 p. 101).

The concerns of the teacher are **zero** when the innovation is not a part of their lives, i.e. there is little or no awareness of the innovation. However, as soon as the innovation becomes imminent, **informational** concerns (stage 1) arise. Teachers begin to show in interest in learning more about the innovation and ask questions like "What is it?". Teachers realise that the innovation will become part of their professional lives and ask questions like "What does this innovation mean for me?" and "How will using it affect me?". These are **personal** concerns (stage 2) in response to new demands and expectations. As the teacher begins using the innovation, they reach the stage of **management** concerns (stage 3).

At this stage, they ask questions like "Where can I find the time to prepare new materials?" and tackle problems associated with logistics, paperwork and organisation. This stage can be very problematic and "there is no guarantee that individuals using an innovation will ever progress beyond management concerns" (Hord, 1987 p. 103).

Teachers who pass on to stage 4, the **consequence** concerns stage, begin to move away from self-focused concerns and direct more of their energy towards their pupils. They ask questions like "Is my use of this innovation helping my pupils?", "If so, how is it helping my pupils?", "What adjustment could I make to increase student benefit?". By stage 5, the **collaboration** concerns stage, teachers express a desire to share ideas and work with other teachers involved in the innovation. Thus, the teachers pool their energies and resources in an attempt to help each other to discover ways to improve pupil outcomes. The final stage, called the refocusing concerns stage involves the teachers modifying the innovation and asking themselves the question "What can I do that will take my pupils even further?". Hord describes this creative approach which stresses continual improvement as "the hallmark of the very best in teaching" (Hord, 1987 p.104).

(ii) Levels of Use

Although it is very likely that teachers' feelings about an innovation will influence the effect of that innovation, in practice what is important is what happens in the classroom, i.e. the behaviour and skills demonstrated in relation to the innovation. To answer the question, "How is the individual teacher using the innovation?", the CBAM model has developed a series of eight levels of use, i.e. based on their behaviour with respect to an innovation, people are said to be at one of the levels of use indicated in Table 5.2.

	Level of Use	Behavioural Indices of Level
VI	Renewal	The user is seeking more effective alternatives to the established use of the innovation.
V	Integration	The user is making deliberate efforts to co-ordinate with others in using the innovation
IVB	Refinement	The user is making changes to increase outcomes.
IVA	Routine	The user is making few or no changes and has an established pattern of use.
III	Mechanical Use	The user is making changes to organise better use of the innovation
II	Preparation	The individual is preparing to use the innovation.
I	Orientation	The individual shows interest in innovation and seeks information about the innovation.
0	Non-use	No action is being taken with respect to the innovation.

Table 5.2 The levels of use in the Concerns-Based Adoption Model (Hord, 1987 p. 111)

Level 0 or **non-use** level describes the situation where the new programme has no place in the teacher's life and the person is taking no action with respect to it. As soon as the teacher begins showing interest in the innovation and starts looking for information about it, the person is described as being at Level I, the **orientation** level. The next level, Level II, is called the **preparation level** and is used to describe the stage when the teacher indicates an intention to use the innovation and begins ordering the necessary materials.

Once Level II is passed, the teacher changes from being a non-user to a user of the innovation. At level III, **mechanical use,** the teacher begins experimenting with the innovation and tries to make it work. At this stage the main preoccupation is still with self and how the innovation can be made easier to operate. After a certain period of learning about and using the innovation with adequate support, the person reaches level IVA or **routine**, i.e. the various practical problems have been resolved and the teacher breathes a sigh of relief as a level of stability settles into the adoption of the innovation.

Beyond level IVA, the teacher begins to try to find ways to help pupils use the innovation more fruitfully, i.e. there is a change from the teacher making efforts to come to terms with the innovation to the teacher trying to improve pupil outcomes. This stage, Level IVB, is called **refinement.** If the teacher collaborates with one or more other teachers on the programme, pooling their ideas and resources to produce better results for their students (e.g. team teaching), they are said to be at Level V, called **integration.**

Finally, some teachers may see limitations to the innovation and make some major fundamental changes. These teachers are said to be at level VI, the **renewal** stage and are very creative individuals who are always looking for ways to make further improvements.

(iii) Innovation Configuration

Both the *Stages of Concern* component and the *Level of Use* components of the CBAM model are concerned with the user of the innovation, i.e. the person is the centre of attention and the innovation is rather peripheral. In the third component of the model, the innovation itself is the focus of attention and the teacher's behaviour is seen mainly as a means of gauging what the innovation is in the context of that person's use of it.

Hord introduces the concept of Innovation Configuration as follows:

> "The fact is that no two teachers, whether within the same building or across schools, use an innovation in precisely the same way. Rather, different teachers will incorporate into their practice different

> portions of the new programme, used in conjunction, in most cases, with some percentage of whatever they were doing before – which will also show considerable variation. Thus, both the content and extent of new programme use will vary tremendously, even among individuals within the same institution. As for researchers, change facilitators and others with a need to evaluate innovation use, this means that not only the "how" but also the "what" of innovation use must be taken into consideration. It simply is not possible to assume that we know what an innovation looks like in practice in a given classroom, however well versed we may be in its theoretical form and appearance".
>
> (Hord, 1987 p. 119)

Thus, *Innovation Configuration* involves a set of judgements about the effectiveness of an innovation set in the context of what the innovation means in practice. The *Innovation Configuration* checklist is drawn up by interviewing the key people involved in the innovation, i.e. the developers of the innovation and those providing the training and support for the innovation. Those in the second category are referred to as change facilitators and these may or may not be the developers. Based on experience in developing the CBAM model (Hall and Loucks, 1981) the following three questions were found to be the most useful in the interviews:

- What would you hope to observe when the innovation is operational?
- What would teachers and others be doing?
- What are the critical components of the innovation?

A small number of the teachers involved in the innovation are also interviewed to elicit their views on the innovation and their lessons observed to see what is happening in practice. The *Innovation Configuration* checklist, based on the key components of the innovation, is then further refined. The items on the checklist are geared to giving a detailed description of behaviour in the classroom i.e.

items relating to variables like structure of lesson, materials used by the teacher, forms of assessment, etc.

The *Innovation Configuration* is described by Hord as "the sum total of all of an individual's specific response to the various items on a check list" (Hord 1987, p. 121). One of the advantages of the Innovation Configuration is that it helps to focus on the classroom practice and thus helps to build a picture of the progress and status of an innovation.

What are the advantages of the CBAM model? Firstly, those involved with the implementation of any innovation can readily identify with the various **stages of concern** and **levels of use** as described in the model. Secondly, it is flexible, i.e. it can be applied to innovations of different scales and tailored to fit varying needs and expectations. Thirdly, by means of the stages of concern, levels of use and innovation configuration checklists, it allows data to be gathered which can inform both summative and formative evaluation.

5.2.2 Harland and Kinder Model

Similar to the CBAM model, the Harland and Kinder model (1997) emerged from school-based research in the area of in-service training (INSET) and continuing professional development (CPD) in the UK. The data on which their model is based were gathered over a period of four years from a staff development programme for the introduction of science into primary schools. Harland and Kinder were influenced in their work by the existing models of in-service training developed by Fullan (1982, 1991, 2001) and Joyce and Showers (1980).

Fullan (2001, p. 39) believes that there are three dimensions involved in implementing a new programme:

1. The possible use of **new or revised materials**, e.g. instructional resources like curriculum materials.

2. The possible use of **new teaching approaches**, i.e. new teaching strategies or activities.

3. The possible **alteration of beliefs**, e.g. assumptions and theories underlying particular new policies or programmes.

He also suggests that four phases are involved in change: initiation, implementation, continuation and outcome. These are summarised in Table 5.3

Phase	Meaning
1. **Initiation**	The processes leading up to the decision to adopt a new programme.
2. **Implementation**	The first experience of using the new programme
3. **Continuation**	The time when the programme is either integrated into the system or discarded.
4. **Outcome**	The degree of improvement in teacher satisfaction, pupils' learning and attitudes, etc.

Table 5.3 The phases involved in change. (Fullan, 2001 p. 39)

Harland and Kinder were also influenced by Joyce and Showers (1980) who developed a model that focussed on staff development as an important element of successful change. They suggested that there are four categories of levels of impact in in-service training:

1. **Awareness.** At this level we realise the importance of an area and begin to focus on it. Joyce and Showers (1980 p. 380) give the example of inductive

teaching and explain that the road to competence begins with awareness of the nature of inductive teaching, its probable uses and how it fits into the curriculum.

2. **The acquisition of concepts or organised knowledge.** At this level various concepts or subject knowledge is acquired about the particular topic. As an example, Joyce and Showers (1980, p. 380) give the example of areas that are essential to inductive teaching, e.g. knowledge of inductive processes, how learners at various levels of cognitive development respond to inductive teaching, knowledge about concept formation, etc.

3. **The learning of principles and skills.** These are described by Joyce and Showers (1980, p. 380) as the "tools for action". As an example, they talk about learning the skills of inductive teaching, i.e. how to help students collect data, organise it and build concepts and test them. The potential for action exists at this level. The teacher is aware of the area, can think effectively about it and possess the skills to act.

4. **The ability to apply those principles and skills in the classroom.** The final stage involves the transfer of the concepts, principles and skills to the classroom. Teachers start using the teaching strategy they have learned and combine the strategy with the others in their repertoire.

They argue that it is only after this fourth level has been reached that teachers can expect an impact on the pupils.

In their more recent work, Joyce and Showers (1995) identified the following key components as being necessary for effective in-service training:

- Describing new skills to teachers through talks, lectures, etc.
- Demonstrating new skills and techniques to teachers.
- Providing opportunities for teachers to develop and practice these skills and techniques in simulated and real settings
- Giving teachers feedback on performance.
- Coaching teachers on the job.

Arising from their research, Harland and Kinder proposed a typology of nine in-service training outcomes. This typology of outcomes and some explanatory notes are summarised in Table 5.4 (pages 216 – 217). They suggest that this typology shows how existing models of in-service training such as those of Fullan and Joyce and Showers could be enhanced.

Harland and Kinder (1997) contrast their model with Fullan's (1991) model of change as discussed above. Whilst Fullan's model has initiation (involving acquisition and new materials) as the first phase, Harland and Kinder keep the aspects of acquisition and new materials separate from each other. They suggest that it is possible for teachers to acquire new materials but not use them – changes in practice can be problematic if teachers do not have the necessary resources to support the changes.

TYPOLOGY OF INSET OUTCOMES	
1. Material and provisionary outcomes.	• Physical resources (worksheets, handbooks, equipment, etc.) • Research indicates that these can have a positive influence on classroom practice. • To ensure impact on practice, other outcomes like motivation (6 below) and new knowledge and skills (7 below) are required.
2. Informational outcomes	• Being briefed about background facts and news about curriculum and management developments. • Includes management and implications for practice.
3. New awareness	• Conceptual shift from previous assumptions about appropriate content and delivery of curriculum. • Type of comment like "Science is not about chemical formulae and test-tubes but about children investigating" • New awareness alone is no guarantee of changed practice – value congruence required.
4. Value congruence outcomes	• How far the individual codes of practice of the teachers coincide with the INSET providers' messages about good practice • Crucial factor in influencing the extent of classroom implementation. • A difficult outcome to establish. • Research (Kinder et al., 1991) clearly showed that where values of those attending the INSET were compatible with those of course leaders, there was increased likelihood of impact on classroom practice.

Table 5.4 Typology of nine in-service training outcomes proposed by Harland and Kinder (1997).

5. Affective outcomes	• Refer to teachers' initial response to the in-service training. • Initial positive affective outcomes (excitement and elation) could be followed by negative affective outcomes (feeling of demoralisation by INSET experience) if they do not gain the appropriate expertise in areas like knowledge and skills to support their teaching. • If teachers demoralised, innovation unlikely to be successful
6. Motivational and attitudinal outcomes	• Enhanced enthusiasm and motivation to implement the ideas received during INSET experience. • Teacher inspired by observing advisory teacher working. • These outcomes are important precursors for impact on practice. • May be short lived if other outcomes like provisionary or new knowledge and skills are not present.
7. New knowledge and skills	• Deeper and more critical understanding of curriculum understanding and teaching approaches – essential for success of innovation • Development of deeper levels of understanding with regard to curriculum content and pedagogy. • Teachers pointed to lack of development in this area as a major obstacle to significant changes in their classroom practice.
8. Institutional outcomes	• In-service work can have collective impact on groups of teachers and their practice • Benefits of collaboration and mutual support, consensus, etc. can contribute to success of innovation.
9. Impact on practice	• Ultimate intention is to bring about changes in practice – new strategies and activities • Focus of this outcome is on teacher behaviour rather than beliefs.

Table 5.4 (continued). Typology of nine in-service training outcomes proposed by Harland and Kinder (1997).

Harland and Kinder (1997) in their research project studied the teachers' accounts of the impact of the INSET courses on their classroom practice and compared this with their own classroom observations. This led them to conclude that the presence of certain outcomes was more likely to achieve an impact on classroom practice than others. Therefore, they proposed a hierarchy of INSET outcomes as shown in Table 5.5.

INSET input	
3rd order	Provisionary Information New Awareness
2nd order	Motivation Affective Institutional
1st order	Value congruence. Knowledge and skills
Impact on practice	

Table 5.5 A hierarchy of in-service training outcomes (Harland and Kinder, 1997)

Note from Table 5.5 that the evidence of Harland and Kinder's work suggests that in-service experiences which focus on (or are perceived as offering) only third order outcomes are least likely to impact on practice. In other words, in-service experiences that only raise awareness and provide materials and information are unlikely to have an impact on practice unless some of the other outcomes are already present. The second order outcomes (motivational, affective and institutional) are important in contributing to success. However, substantial impact on practice is consistently associated with the presence of the first order outcomes: value congruence and new knowledge and skills. Harland and Kinder (1997) summarise the situation in a concise manner as follows:

> "Our tentative conclusion is that in order to maximise the chances of CPD leading to a change in classroom practice, all nine outcomes (prioritised in the order suggested above) need to be present as pre-existing conditions or be achieved by the INSET activities".
>
> (Harland and Kinder, 1997 p.77)

In the next section, we will use the above models for educational evaluation to help us assess the effectiveness of the Intervention Package

5.3 Strategy to assess the effectiveness of the Intervention Package

If one takes an overview of the various models for educational evaluation discussed in this chapter, it is clear that there is considerable overlap between them in terms of the foundations on which the model is built. This overlap is to be expected since all four models discuss the area of evaluation in education. The overlap may be more clearly seen when the four models are summarised in the same table, Table 5.6.

CBAM (Hord, 1987)	**Fullan (1982, 1991, 2001)**	**Joyce and Showers (1980)**	**Harland and Kinder (1997)**
0. Awareness	1. Use of new or revised materials	1. Awareness.	1. Material and provisionary outcomes
1. Informational	2. New teaching approaches	2. The acquisition of concepts or organised knowledge	2. Informational outcomes
2. Personal	3. Alteration of beliefs	3. The learning of principles and skills	3. New awareness
3. Management		4. The ability to apply those principles and skills in the classroom	4. Value congruence outcome
4. Consequence			5. Affective outcomes
5. Collaboration			6. Motivational and attitudinal outcomes
6. Refocusing			7. Knowledge and skills
			8. Institutional outcomes

Table 5.6. Summary of models of educational evaluation showing overlap between areas of awareness and provision of information and resources, new teaching strategies and skills and attitudinal factors.

If one examines Table 5.6 closely, it is possible to reduce the various categories of levels of impact into three broad themes:

(i) Awareness and provision of information and resources

In the CBAM model (Hord, 1987), the first two stages of concern (*awareness* and *informational*) describe how the teacher moves from zero awareness about an innovation to the stage where he or she would like to know more about it. This is very similar to the first level of impact of the Joyce and Showers (1980) model (*awareness*) where the teacher realises the importance of a curriculum area and begins to focus on it. It is also similar to the *informational outcomes* (stage 2) of the Harland and Kinder (1997) model where teachers are briefed or become aware about new developments relating to the curriculum. Allied to this awareness, Harland and Kinder (1997) talk about the physical resources (*material and provisionary outcomes*) that are generated in INSET activities, e.g. worksheets, handbooks, equipment, etc. This outcome is similar to the first component of Fullan's model of change (*use of new or revised materials*) in which he associates the acquisition of new or revised materials with their use in the classroom. Harland and Kinder disagree with this in that they make the distinction between procurement of materials and the impact of these materials on practice in the classroom. They point out (Harland and Kinder, 1997 p. 73) that ensuring an impact on practice usually requires other outcomes listed in their typology of outcomes like *motivation* (component 6) and *new knowledge and skills* (component 7).

(ii) New teaching strategies and skills

The area of acquisition of new teaching strategies and skills is a strong component of all the models of educational evaluation under discussion. As already discussed, *knowledge and skills* is one of the components of the Harland and Kinder model and is described by them in terms of the development of deeper levels of understanding with regard to curriculum content and pedagogy. The Joyce and Showers model places a heavy emphasis on this general area with three of the four components devoted to the *acquisition of concepts of organised knowledge* (component 2), *the learning of principles and skills* (component 3) and *the ability to apply those principles and skills in the classroom* (component 4).

These three areas are very similar to *knowledge and skills* (component 7) in the Harland and Kinder model as Joyce and Showers (1980, p. 380) refer to teachers having to master both the relevant concepts and knowledge and also the necessary teaching skills for effective classroom practice. Harland and Kinder also cover this area of classroom practice in component 9 of their model entitled *impact on practice* which recognises that the ultimate intention of INSET is to bring about changes in practice in the classroom. The area of classroom practice is widened further by component 6 of the CBAM model. This component involves the teacher looking beyond the innovation itself, in an attempt to take the pupils even further. When discussing the area of teaching strategies and skills, Fullan uses the more all-embracing term *new teaching approaches* to describe this component of his model and simply explains the term as "new teaching strategies or activities" (Fullan, 2001 p. 39).

The CBAM model is the only one of the models that focuses specifically on management skills (component 3). It discusses this concept in the context of the ability of the teacher to handle the implementation of the innovation in terms of time management, logistics, paperwork and general organisation (Hord, 1987 p. 102). The other models appear to assume that this is part of the overall pedagogical skills of the teacher.

(iii) Attitudinal factors

Of the four models under discussion, the Harland and Kinder model is the one that deals with the attitudinal area in the most detail. In stage 3 of the Harland and Kinder model, they define *new awareness* in terms of “a perceptual or conceptual shift from previous assumptions of what constitutes the appropriate content and delivery of a particular curriculum area” (Harland and Kinder, 1997 p. 73). However, they point out that changed awareness is no guarantee of changed practice. In order for changed practice to occur they argue that there must be *value congruence* present. This concept is described by Harland and Kinder in terms of “the personalised versions of curriculum and classroom management which inform a practitioner’s teaching and how far these ‘individuated codes of practice’ come to coincide with the INSET providers’ messages about good practice” (Harland and Kinder, 1997 p. 73). Although Fullan (1991, 2001) does not use the term *value congruence* he does note that sustaining shifts in value positions among teachers is a very difficult INSET outcome to accomplish and admits that “structural changes are easier to bring about than normative ones” (Fullan, 1991 p. xiii). Harland and Kinder (1997, p. 74) acknowledge that the concept of value congruence as an INSET outcome is similar to Fullan's third component needed for implementing a new programme, i.e. “the possible alteration of beliefs, e.g. pedagogical assumptions and theories underlying particular new policies or programmes” (Fullan, 2001 p. 39).

This third outcome clearly recognises that for change in practice to be achieved, the teachers have to adopt a positive meaning and value of the changes being proposed, i.e. they must be "on the same wavelength" or in close harmony with the message of those providing the in-service training.

The model proposed by Harland and Kinder maintains a sharp focus on the area of teacher attitudes in stages 5 and 6 of their model: *affective outcomes* and *motivational and attitudinal outcomes*. In the *affective outcomes* area they stress the importance of ensuring that the initial positive affective outcomes (e.g. the feeling of excitement caused by the new approaches) are not short-lived due to a lack of knowledge and skills. Stage 6 of the Harland and Kinder model, *motivational and attitudinal outcomes*, is a direct follow-on from the previous stage and refers to the enhanced enthusiasm and motivation needed to implement the ideas received during the INSET experience. Stages 5 and 6 of the Harland and Kinder model have a strong resonance with stages 2 (*personal*) and 4 (*consequences*) of the CBAM model. These stages of the CBAM model are concerned with the attitudes and beliefs of the teachers when introduced to the innovation. The personal concerns take a dominant position and, to quote Hord, " 'What does this innovation mean to me' and 'How will using it affect me?' are the almost inevitable expressions of this intense personal response to new demands and expectations" (Hord, 1987 p. 100). The teachers also start thinking about the consequences of the use of the innovation in the classroom in terms of its effects on their pupils (stage 4).

Interestingly, only two of the models discuss the importance of teachers having an attitude of sharing and co-operation with their colleagues. Harland and

Kinder's model describes this under the heading of *institutional outcomes* (component 8) and explain it in terms of teacher collaboration and mutual support when engaging in curriculum innovation. The CBAM model discusses this area using the terminology of *collaboration concerns* (component 5). It explains this in terms of the desire of the teachers to share ideas and work with other teachers using the same innovation. The *collaboration* phase in the CBAM model (component 5) is described as follows:

> "Collaboration means pooling of energies and resources in an attempt mutually to discover ways to improve student outcomes. For many people, this step, which might have seemed unduly threatening when they were first introduced to the innovation, may become increasingly appealing once they have achieved a basic level of competence with it and thus feel strong or confident".
> (Hord, 1987 p.103).

In short, whilst Harland and Kinder's model discusses in some detail the overall attitude and value congruence of teachers when introduced to an innovation, aspects of the attitudinal responses are also covered by Fullan's model and the CBAM model. Joyce and Showers (1980) make no reference to attitudinal factors and value congruence in any of the stages of their model.

5.4 Relating the three themes to the Intervention Package

Having identified the three themes common to the models for educational evaluation discussed, this next section considers how they relate to the Intervention Package in terms of providing a context for assessing its effectiveness. This has been achieved by looking at the aims, intended learning outcomes and content of the Intervention Package and mapping these onto the three themes. The aims of the Intervention Package are summarised in Table 5.7.

Session 1

- To encourage student teachers to reflect on what is involved in learning and teaching science.
- To introduce some of the main views on learning in science.

Session 2

- To introduce student teachers to some of the main research findings on pupils' misunderstandings in science.
- To encourage student teachers to reflect on some misunderstandings in science that they have studied in the research literature.
- To make students aware of the problem with misunderstandings in chemistry.

Session 3

- To encourage the student teachers to reflect on the types of teaching strategies that are of assistance in overcoming children's misunderstandings of ideas in science.
- To introduce the student teachers to the research literature findings that inform us about the teaching strategies required to tackle the problem areas of misunderstandings in science – and chemistry in particular

Table 5.7 The aims of the Intervention Package

The intended outcomes of the Intervention Package are summarised in Table 5.8

Session 1

At the end of this session the student teachers should:

- Be able to describe some of the aims of science teaching
- Be able to describe some models of learning as they apply to science.
- Be aware that constructivism is the dominant view of learning among science educators today and appreciate that pupils' learning in science is affected by their own ideas that they bring to science lessons.
- Be able to describe key features of constructivism.

Session 2

At the end of this session the student teachers should:

- Be aware of the fact that children have many misunderstandings in science – and particularly in the area of chemistry.
- Be able to describe some of the misunderstandings children have.

Session 3

At the end of this session the student teachers should:

- Be able to describe some of the learning difficulties associated with misunderstandings in chemistry
- Be capable of making suggestions for classroom practice which help to overcome these misunderstandings in chemistry.
- Be capable of developing teaching strategies to help overcome children's misunderstandings of ideas in chemistry.
- Be aware of the fact that the misunderstandings may still persist after the lesson and know that further developmental work may be required.

Table 5.8 The intended outcomes of the Intervention Package

Chapter 7 will consider the effectiveness of the Intervention Package in terms of the three themes common to the educational evaluation models discussed in the previous section. Clearly, some areas of the Intervention Package relate to raising awareness, other parts relate to new teaching strategies and skills whilst other components focus on aspects relating to attitudinal factors. Some of these areas are summarised in Table 5.9.

	Aspects relating to awareness and provision of information and resources	**Aspects relating to new teaching strategies and skills**	**Aspects relating to attitudinal factors**
Session 1	Information on learning and view of learning in science, including the constructivist view of learning.	Examples of diagnostic tests.	Discussion on cartoon drawings relating to views of science teaching and discussion of results of diagnostic tests carried out prior to Intervention Package.
Session 2	Information on research findings in relation to difficult ideas.	Outline of factors common to areas of misunderstanding in literature and implications for teaching.	Group discussions and activities relating to misunderstandings.
Session 3	Materials prepared for classroom use to help overcome misunderstandings and preparation by students of own resources.	Study and discussion of generic teaching strategies of assistance in overcoming misunderstandings.	Realisation that misunderstandings persist after lesson and positive attitude re further developmental work

Table 5.9 Summary showing how some aspects of the Intervention Package relate to three themes common to educational evaluation models.

Aspects relating to awareness and provision of information and resources and aspects relating to new teaching strategies and skills are reasonably easy to identify in the Intervention Package. However, aspects relating to attitudinal factors are less tangible. Some examples are given in Table 5.9 and it is hoped to identify more in the detailed analysis of the post-intervention data in Chapter 7. Hopefully, the overall enthusiastic approach of the tutor to the Intervention package and the inclusion of a “constuctivist view of learning” during the Intervention Package was also of some assistance in creating a positive attitude among the student teachers towards the programme.

The effectiveness of the Intervention Package in achieving it aims and outcomes will be studied in more detail in Chapter 7.

CHAPTER 6

ANALYSIS OF BASELINE DATA

6.1 Introduction

As discussed in Chapter 3, the theoretical framework for analysis of the baseline data was developed by drawing on a number of other related frameworks. The theoretical framework used in this study has been constructed around the seven categories listed in Table 6.1. These categories arose from an analysis of various other theoretical frameworks (discussed in Chapter 3) and from preliminary attempts to categorise aspects of the data collected under these categories.

This chapter reports and discusses the data gathered in the baseline study under each of the headings listed in Table 6.1 on the following page, i.e. the items arising from the data gathered are mapped on to the categories in the theoretical framework. In order to achieve this, the data were first analysed in detail for recurrent themes. For example, Figure 6.1 (page 231) shows the main themes that arose from the question in the baseline questionnaire "Write down what you think teachers need to do to bring about effective learning in science". The ten most popular themes are summarised graphically in Figure 6.2 (page 232).

The order of presentation of material follows the order in which these areas tended to be covered in the models which formed the basis of the analysis framework. In practice, the majority of student teachers' comments lay in areas 3 and 4 of the framework. However, the data are presented and discussed in accordance with the original order of the seven sections.

Factor	*As exemplified by ...*	*Location*
1. View of science	Body of principles Method of enquiry A practical subject Important social institution (STS)	Section 6.2.1 Section 6.2.2 Section 6.2.3 Section 6.2.4
2. View of learning.	Transmission versus active learning Control and choice offered to pupils over activities	Section 6.3.1 Section 6.3.3
3. View of teaching.	Nature of presentation Classroom climate Links to everyday life	Section 6.4.1 Section 6.4.2 Section 6.4.3
4. View of science teaching View of how to teach particular science topics	Exploring pupils' ideas and understanding. Relevant strategies for teaching particular topics or sub-topics Approach to teaching a particular topic	Section 6.5.1 Section 6.5.2 Section 6.5.3
5. Subject knowledge	Subject specialisation. Sense of confidence in teaching Ability to handle questions	Section 6.6
6. Local conditions	Assessment of course. Backup help from school. Type of pupils	Section 6.7.1 Section 6.7.2 Section 6.7.3
7. Personal reflection and other feedback.	Student teachers imperfect subject knowledge and inexperience.	Section 6.8

TABLE 6.1 Summary of factors that might influence decisions that student teachers make about what to do in science lessons

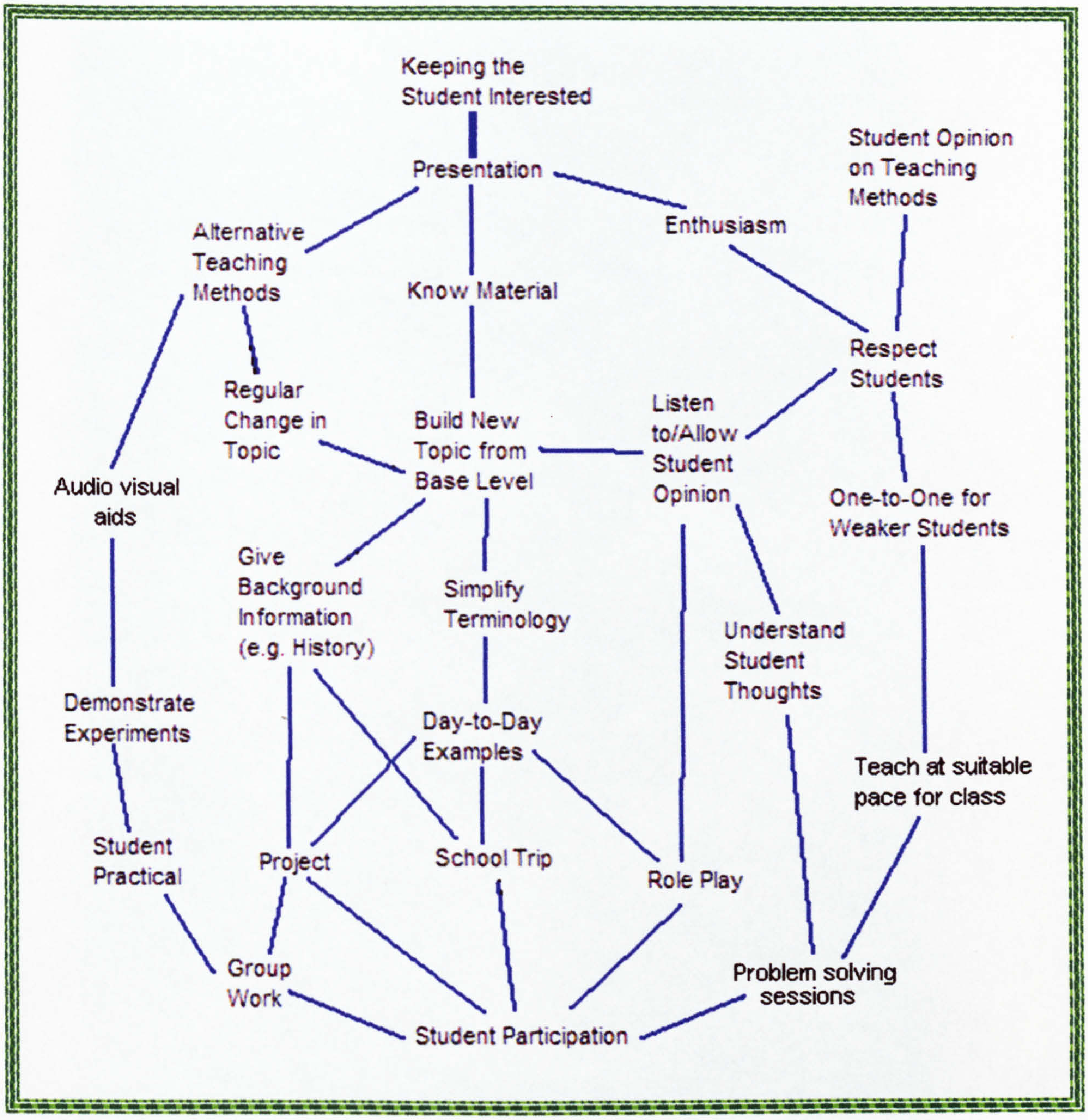


Figure 6.1: Chart summarising response of students to question: "Write down what you think teachers need to do to bring about effective learning in science".

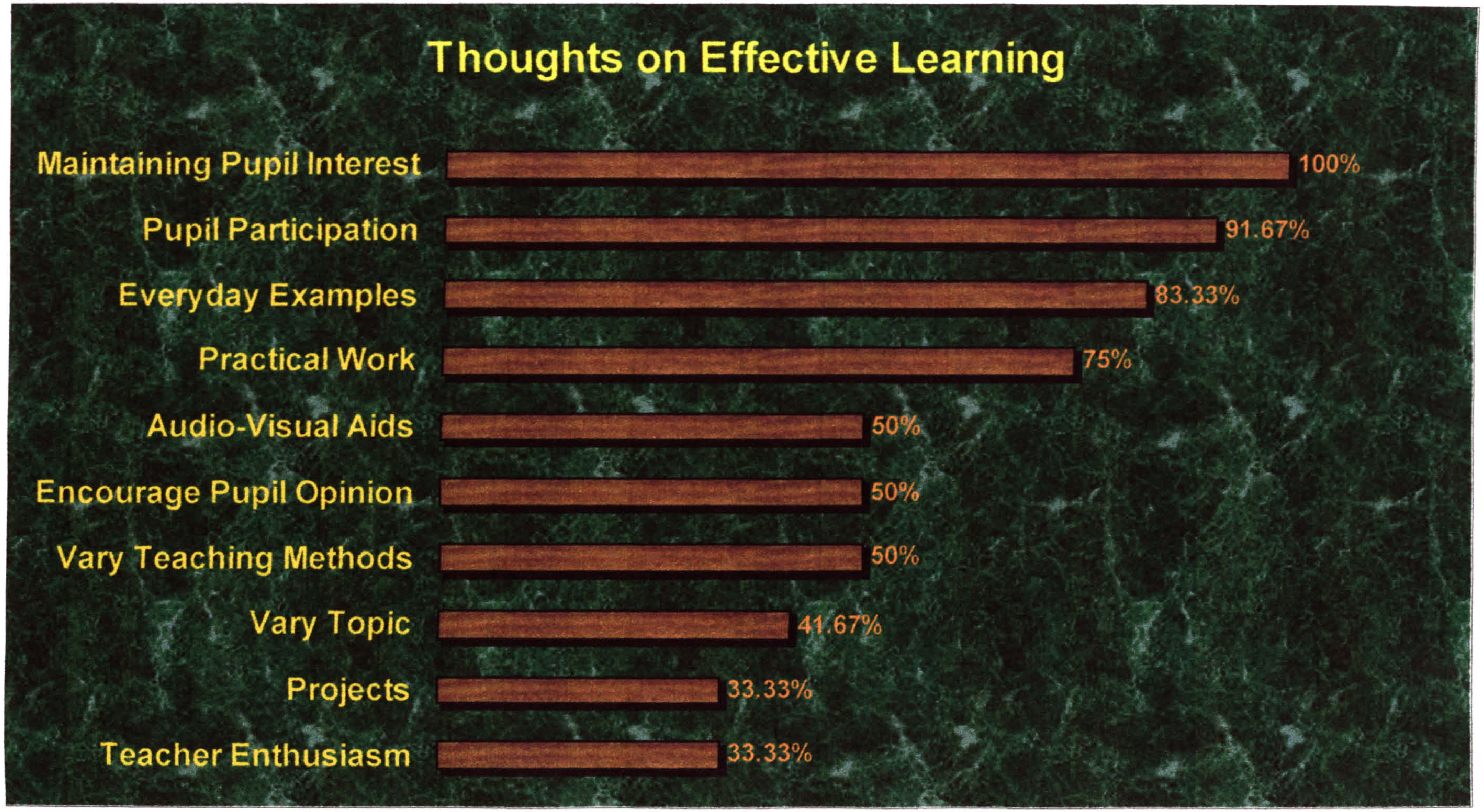


Figure 6.2: Responses from student teachers on what they think teachers need to do to bring about effective learning in science.

6.2. View of science

The view of learning as exemplified by the student teachers will be discussed under the categories that have emerged from the data: body of principles, method of enquiry, a practical subject and an important social institution.

6.2.1 Body of principles

The majority of student teachers taught their classes with a great emphasis on learning definitions and facts, i.e. they appeared to view science as a body of principles. A study of the lesson plans prepared by the student teachers clearly illustrates that the majority of the lesson plans (83.3%) placed a very high emphasis on scientific content. When questioned about this in the interviews, it was clear that covering scientific content was seen by most of the student teachers as the main aim of the lesson. For example, when Fiona was teaching the concept of dissolving to a group of twelve year-old pupils, it was observed that she made frequent use of flash cards with terms written on them and placed great emphasis on repeating the terminology. No attempt was made to discuss the importance of solutions in our everyday lives or even to discuss some common household solutions. When questioned about this emphasis in her teaching strategy, she was absolutely clear in her mind about her own aims for the lesson:

> "What strategy? – bar having the words there for them so that they could see them when I was talking about them, that is number one - and having the definition written up so they did not have to take them down cause it is all in the book and repeating and repeating, salt is a solute, water is a solvent etc .... but I suppose the main thing was to get across the technical terms solute, solvent and solution and know the difference between the three of those. That was one of my key aims."

A similar observation was made when Fiona was teaching atomic structure to a group of 14 year-old pupils. Most of the emphasis in the lesson was on getting the pupils to learn how to write electron configurations and draw atomic structures for each of the first twenty elements in the Periodic Table. No effort was made to put this in the wider context of chemical reactivity or even to explain the importance of understanding electron configurations. When questioned about the direction of the emphasis in her lesson, Fiona clearly felt that it was important to get across the scientific facts by going over and over the material:

> "I think it was just a case of maybe sitting down and learning, it off really, repetition, I kept going over and over it and reinforcing it, and recapitulating. So I suppose so reinforcement might be the best way."

Fischler (1999) reports similar findings in research carried out by him using a group of student teachers. He found that the student teachers placed a heavy emphasis on science as a body of principles and refers to this as "Content related principles".

> "Content related principles. Student-teachers regard the selection of content, which is applicable in everyday life and therefore interesting to students, as a means of giving students insights into the various fields for the application of physics and to make them interested in understanding the physics basis of these applications".
>
> (Fischler 1999, p. 184)

Similar findings are reported by Koballa et al. (2000) into a study of the views held by student teachers on the teaching of chemistry.

6.2.2 Method of enquiry

The view of science as a method of enquiry was not mentioned by any of the student teachers when asked in the questionnaire what they thought teachers need to do to bring about effective learning in science. In addition, in the baseline interview data no student teachers commented on the advantages of an enquiry-led approach - in fact, analysis of the baseline observation shows that only one student teacher in the sample used any form of enquiry in their teaching. One of these was Cian who set up an apparatus to help pupils deduce if an equation was balanced or could be balanced by the pupils. This involved using snooker balls of various colours to represent different atoms. These were placed on a large home-made balance and pupils asked to deduce if the equation could be balanced by adding various balls to the balance. This "predict-and-explain" approach worked well. When Cian was questioned about the used of this type of enquiry approach it was clear that he felt quite positively about it:

> "The idea I was trying to reinforce with that was that equations must balance so that the reactants and the products must total the same. I had different coloured balls representing different atoms and I said that if you put in one atom of nitrogen and three atoms of hydrogen, different coloured balls for each, you must have the exact same on the other side.........they could see physical representation of what was happening and they could move it on then into the actual balancing of it".

None of the other student teachers used any enquiry-based approach. A similar finding is reported by Borko et al. (1992) who described lessons observed by student teachers as consisting of the student teachers providing "only procedural comments and no conceptual explanation". (Borko et al., 1992 p. 66) and did not probe the pupils' thinking along the lines of an enquiry-led approach.

6.2.3 A practical subject

In the baseline questionnaire data the majority of student teachers (75%) listed practical work as one of the factors needed to bring about effective learning in science. However, analysis of the baseline observation data shows that only about half (58%) of student teachers used any form of practical work in their teaching – the majority of which was teacher demonstration and very little of which appeared to attempt to develop pupils' thinking. For example, Aishling, teaching the concept of solution concentration to a group of 12-13 year old pupils, used concentrated orange squash and a jug of water to make up solutions of various concentrations. When questioned about this, she emphasised the link between practical work in science and our everyday lives:

> "DK In the course of the lesson you did some interesting demonstrations using concentrated and diluted orange squash. Why did you use that?
>
> MS I used that because it was something that they would be familiar with, I thought it's even written on the bottle, "dilute to taste" or "concentrated orange drink", I suppose to make it more relevant to their everyday lives really."

Jessica gave a class on the particulate nature of matter to a group of 12-13 year old pupils and used a lot of teacher demonstrations in her very well-prepared lesson. When questioned about some of the practical demonstrations, she spoke in an animated fashion about some of the experiments:

> "Diffusion - I thought that might be a bit dodgy so I got spraying with the air can at the top of the room. Then I got litmus paper as well and I put it inside a tube just to show that the hydrochloric acid when it diffused it turned the litmus paper from blue to red. And then I did the same with the ammonia - that turned from red to blue then I did the white cloud test. They liked the litmus paper and they didn't see it before as well."

The lack of pupil practical work in the lessons of these student teachers is in contrast to the findings of Fischler (1999) who found a great willingness among the student teachers in his sample to allow pupils to carry out practical work. He gives two reasons for the high level of practical work in his sample:

> "Two reasons account for the intention to give students [pupils] the chance to do laboratory work. Firstly, student-teachers remembered doing experiments on their own as a most attractive part of science lessons from their school days. Secondly, the introduction of Piagetian theory (in method classes) and the influence of concrete-operational actions on learning fell on fertile ground"
>
> (Fischler, 1999 p. 190)

In the case of student-teachers in Ireland, the non-existence of laboratory technicians and the lack of a formal system of mentoring could be responsible for lower amounts of pupil practical work being carried out and hence a lowering of esteem for the place of practical work in science education.

6.2.4 Important social institution

A minority of student teachers (16.6%) in the baseline questionnaire mentioned the importance of science as a social institution, i.e. referred to putting science in its social or historical context, emphasise benefits of science to mankind, etc. This low percentage was also reflected in the baseline observation data and the lesson plan data. Clearly, the student teachers do not see this area as being an important factor in bringing about effective learning in science.

Ciara, when preparing a lesson on the particulate nature of matter for a class of 12-13 year old girls, used a historical approach in her notes:

- "throughout ages people wondered what matter was made up of...
- Ancient Greeks
- John Dalton."

At a later stage, when introducing the term "element", she referred to Robert Boyle and later on referred to Mendeleev when referring to the Periodic Table of the Elements. However, Ciara was the exception in the class. Apart from a brief reference to Michael Faraday by Fiona when teaching electrochemistry to a class of 13-14 year old girls, attempts to put science in its social context were non-existent.

Similar findings are reported by Fischler (1999) who explains the observation in terms of the student teachers own subject knowledge. The student teachers in his study were confident in teaching the physics but lack of confidence prevented them from widening the lesson content to incorporate social issues:

> "However, student-teachers themselves selected topics which were oriented towards the scientific body of knowledge because these topics gave them a certain self-confidence during teaching which they would not have had with everyday and technical [technological] topics which they did not encounter in teacher education."
>
> (Fischler, 1999 p. 189)

6.3 View of Learning

The view of learning as exemplified by the student teachers will be discussed under the categories that have emerged from the data: *Transmission versus active learning* and *Control and choice offered to pupils over activities.*

6.3.1 Transmission versus active learning

In the analysis of the baseline questionnaire data, a majority of student teachers (92%) stated that pupil participation in class was an important element in teaching and learning. However, an analysis of the baseline observation data showed that only half of the student teachers adopted strategies that promoted some form of active learning, i.e. situations other than where the pupils were simply sitting passively listening to the teacher. Frequently, this active learning simply involved some form of questioning on material already covered in the lesson – only about half (58%) of the lessons observed used practical work. In the baseline interviews, slightly more that half of the student teachers (58.3%) indicated that pupil involvement was an issue in the teaching of their classes.

In the baseline questionnaire data, student teachers were unanimous that maintaining pupil interest was an important aspect of teaching and learning. Evidence from observation of lessons revealed that pupils seemed to be motivated in about half (58%) of classes. The motivation was identified from pupils questioning but mostly from the level of interest shown in the lesson and their responses to the teacher's questions.

Similar findings are reported by Borko et al. (1992) who found that the ideas of student teachers with regard to learning were not clear or well developed:

> "A number of the patterns in the thinking and actions of the novice teachers contrasted with patterns in the experts' teaching. For example, in no case did a student teacher reveal clear, well-developed beliefs about teaching and learning during the course of the data collection."
>
> (Borko et al., 1992 p. 62)

6.3.2 Control and choice offered to pupils over activities

All classes observed were of Junior Certificate Level standard (12 – 15 year old age group). This course is a very well prescribed one and there was no evidence of the student teachers deviating from any of the activities outlined in the standard textbooks. The clear evidence from the baseline lesson plan data was that in the case of the majority of student teachers (83%), the emphasis was on delivering content. In the case of half of the baseline lessons observed, pupils were involved to some extent in the lesson. This contrasts with the statements of the student teachers in the baseline questionnaire data where a large majority (92%) of the student teachers felt that pupil participation was necessary to bring about effective learning in science. In the baseline observation data, the involvement of pupils took the form of assisting with a demonstration experiment, doing some practical activity, using worksheets, etc. However, in no case was a choice offered to pupils over the activities – in all cases, the work was prescribed by the teacher and the instructions rigidly followed by the pupils.

A similar finding was made in research carried out by Fischler (1999) on the impact of teaching experience on student teachers' conceptions of teaching and learning science. For example, he found that many of the activities devised by the student teachers for the pupils were "dominated by the activity-flow orientation", i.e. the student teachers concentrated on a continuous flow of activities with "the prevailing intention to keep the lesson moving". He concluded that these activities were not very effective in inducing pupil learning and describes the work of the student teachers as "mere activity". He also found that there was not sufficient interaction between the student teachers and the pupils as the student teachers were too focussed on "getting through" their lesson plan.

> "It is understandable that the teaching plans became the deciding factor in the educational phase, routines to lighten the instructional load have still not been developed. The consequence in this orientation are that a large amount of the teacher's attention is drawn away from the students. Students' statements are, in part, not noticed because a response to these statements would endanger the realisation of the intended teaching plan."
>
> (Fischler, 1999 p. 182)

Fischler (1999) also reports that in the interviews conducted with the student teachers, they "remembered the physics lessons from their own school days that were either dominated by an active teacher or alternatively involved a great length of time as passive students" (p. 185). He also makes the point that, because the student teachers were restricted by the instructions received from their mentors and by the content of the syllabus, the student teachers did not achieve "the goal of demonstrating to the students the connection between physics and everyday life" and the pupils had difficulty in articulating their own ideas about the topic being taught.

> "The time-consuming and detailed planning necessary for experimental presentations and problem solving tasks led to teaching situations in which student teachers disliked deviating from the planned order of activities. Therefore, it is clearly difficult for students [pupils] to bring in their conceptions and to influence the sequence of teaching within such tightly organised lessons. In such teacher-centred teaching, then, feedback to students is most likely missing"
>
> (Fischler,1999 p. 189)

6.4 View of Teaching

The view of teaching exemplified by the student teachers will be discussed under the categories that have emerged from the data: nature of presentation, classroom climate, links to everyday life.

6.4.1 Nature of presentation

(a) Audio-visual aids. In a previous research study dealing with the impact of teaching experience on student teachers' conceptions of teaching and learning science (Fischler, 1999), one of the "principles" that arose out of the data analysis dealt with the nature of presentation of the lesson. This aspect of teaching is also very prominent in the research under discussion here and it clearly is an important factor in influencing the decisions that student teachers make in the classroom.

When the student teachers were asked in the baseline questionnaire to write down what they thought teachers need to do to bring about effective learning in science, half of them mentioned the need to use audio visual aids in the presentation of the lesson.

> "Presentation has to keep them interested and busy, (active). When they are passive, they are more inattentive and easily distracted" – Pat and Michael
>
> "Increased use of visual aids, in order to abstain from over talking/monologue" - Eamonn and Oisin
>
> "Visual aids – flash cards, charts models making the learning process fun" – Ellen and Claire

When the student teachers were observed teaching lessons on difficult ideas in chemistry, ten of the twelve students used some form of audio visual aid in their teaching. (The most common form of audio visual aids used were the overhead projector, charts and flashcards.) Two of the student teachers used models in their teaching. The emphasis on audio visual aids by the majority of students observed was also obvious in the lesson plans written by these students. These lesson plans typically contained three or four overhead transparencies and/or some flash cards and posters.

When the student teachers were questioned in the interviews about how they planned for the difficulties that pupils might encounter in the lesson, they all referred directly or indirectly to the aids they prepared for the lesson. For example, Ciara spoke enthusiastically about the home-made audio visual aids and props she had collected when teaching atomic structure to a class of 14 year old pupils:

> "I had a poster with one big example on it and I said we'd refer to that one all the time and I had the flashcards to highlight and help them focus on the new words and I hoped that the two of those would gel together and make it fall into place. ......I was delighted with all the props I had collected to bring in. I thought that was good and they were real-life examples and I think atoms are a very difficult thing to explain and to pin down and I was trying to show how useful they were which was a hard thing to do. I thought that was good".

Jessica was happy that the plasticine models she brought into the class, helped to explain the process of boiling in terms of the particulate nature of matter.

> "Maybe as well the arrangement of the particles, that could be hard enough as well so I brought in the visual examples of the plastic model plasticine and things like that, how they're arranged and when you're heating them, they move apart and I was trying to bring in that in the classroom that they're stuck together, they're sitting down and then they get up, they're moving around and they're more like a gas, things like that."

When Tara was questioned about why she started the class on Electrochemistry with various definitions written on flash cards, she was quite positive about the advantages that flash cards have over the traditional use of the blackboard.

> "I find that when writing on the blackboard it works well for me but at other times you can put things everywhere. I used flash cards so that it was neat and concise and they can read it. It keeps the amount of written material to a minimum."

Ciaran when talking about a class he gave on acids and bases, stressed the importance of using overhead transparencies that were attractive to pupils.

> "..........I tried to make the overhead transparencies as clear as possible, not make the language too complicated and to include some pictures in the transparencies."

Molly explained that the use of atomic and molecular models helped to explain the particulate nature of matter to her class of twelve year old pupils.

> "I think if you've got as much visual content as possible instead of just saying, "This is the way it is and deal with it", I had the polystyrene model for the solids, liquids and gases and they could see the whole idea of the space between the particles and stuff".

It is clear that the student teachers in this study placed great emphasis on the use of audio visual aids when teaching difficult ideas in science. This is in keeping with the model of professional development proposed by Dreyfus and Dreyfus (1986). In their five stages of skill acquisition, they describe the first stage as the novice stage where people at the beginning of their career will rigidly follow instructions and adhere to certain procedures without having a deep understanding of the wider context or reflecting on the effectiveness of their actions:

> "The beginning student wants to do a good job, but lacking any coherent sense of the overall task he judges his performance mainly by how well he follows learned rules. After he acquires more than just a few rules, the exercise of his skill requires so much concentration that his capacity to talk or listen to advice is severely limited".
>
> (Dreyfus and Dreyfus, 1986 p. 22)

There is no doubt that the use of audio visual aids was considered an important teaching "prop" by most of the student teachers in the baseline study. The evidence gathered in the questionnaire data, in the observations data, in the semi-structured interview data and also in the lesson plan data all suggests that the student teachers believe that well prepared audio visual aids would overcome the problems encountered by the pupils when dealing with difficult ideas in chemistry. Hence, there is a consistently high use of audio visual aids

(83%) in the lesson observation data and the data obtained from a study of the lesson plans of the student teachers.

(b) Resources and textbook reliance

Analysis of the data gathered clearly shows that there was a great reliance by the student teachers on the use of the textbook in the classroom and that the material covered rarely strayed outside of what was covered in the textbook. All student teachers revealed in the semi-structured interview that they greatly relied on the textbook when preparing and delivering the lesson. When asked about the resources the student teachers used when preparing lessons, there was unanimous agreement among them: the textbook was the single resource that guided all lessons!

Ciara spoke enthusiastically about the class she prepared on atomic structure.

> "DK Firstly, when you were preparing that class, what resources did you consult?
>
> SOD Textbooks, loads of textbooks.
>
> DK Did you find that you got plenty of ideas from the textbooks?
>
> SOD I did, I suppose, they were all saying pretty much the same thing. I suppose I got all those examples of the elements from the different textbooks, I just picked out all the examples that the different textbooks gave."

Ciaran stuck almost exclusively to the textbook when teaching acids and bases to a first year science class.

> "DK When you were preparing that class what reference sources did you consult to help you put together your lesson plan notes?
>
> GQ The textbook that I was using, I also used some of my own background knowledge."

Molly referred to the fact that as well as using textbooks when preparing the lesson, she also made use of the internet for ideas and resources for her class on the particulate nature of matter:

> "I suppose various textbooks from the normal textbooks that are available for secondary schools anyway. I used the internet to get different ideas and stuff, there's a few good different internet sites that have various things like lesson plans."

Aishling was one of only two student teachers who mentioned that she consulted the syllabus to guide her in the preparation of a lesson on dissolving which she taught to a class of twelve-year-old pupils.

> "The main thing I looked up really was a few different textbooks that covered the topic..........I referred back to the syllabus firstly about what they were meant to know about solutions and I just worked from there really what they needed to know about them and just to try and fit as much of it as I could into the 40 minute class."

The situation is very similar to that described by Dreyfus and Dreyfus (1986) when discussing the first step in moving from novice to expert. In this stage they paint a picture of a novice in terms of a person who follows a set of rules and does not stray outside this narrow perspective.

> "Elements of the situation to be treated as relevant are so clearly and objectively defined for the novice that they can be recognised without reference to the overall situation in which they occur. We call such elements 'context free'........ The beginning student wants to do a good job but lacking any coherent sense of the overall task, he judges his performance mainly by how well he follows learned rules. After he acquires more than just a few rules, the exercise of his skill requires so much concentration that his capacity to talk or listen to advice is severely limited."
>
> (Dreyfus and Dreyfus,1986 p. 21 - 22)

Eraut (1994) when referring to the first stage described by Dryefus and Dreyfus (1986) summarises it in terms of the novice having a "rigid adherance to taught rules or plans" and having "no discretionary judgement" (p. 124). Fischler (1999) also found that the student teachers showed little discretionary judgement and stuck so closely to the lesson plans when teaching that "the teaching plans become the deciding factors in the educational phase" (p. 182)

(c) Vary teaching methods

In the baseline questionnaire, half of the student teachers indicated that varying the teaching methods was an important factor in bringing about effective learning in science:

> "Devise a mixture of theory with practical work, to keep up interest." - Micheal and Pat

> "Pupils undertake more practical work. Demonstrations by the teacher to effectively demonstrate a definition not just simply theory. More use of charts and videos. Get students to relate back on what they saw. Active student participation i.e. mini role-plays." – Jessica and Bridget

> "Have variety in teaching styles, e.g. show video, slides, blackboard, worksheets etc". – Karen and Ciara.

In the analysis of the baseline classroom observation data, it is clear that eleven out of twelve student teachers used more than one teaching method during the lesson. The more common teaching strategies included explaining theory, with items like practical work, teacher demonstration, questioning, and worksheets also interspersed into didactic type classes. The worksheets consisted mainly of the "fill in" type questions in which the pupils wrote in the answers to short questions. Typically, the answers involved filling in the appropriate words, phrases or definitions. Thus, the variety of teaching methods was quite limited with the vast amount of time spent explaining theory (estimated at around 90% from analysis of classroom videos). Since the student teachers tended to follow their lesson plans very closely, these strategies are also reflected in the analysis of the content of the lesson plans.

Fischler (1999) found that a similar pattern emerged from analysis of his data and refers to it in terms of "principles related to nature of presentation" (p. 184). He found that 75% of the student teachers spoke about their failed attempts to motivate pupils by using such limited teaching techniques. He quotes one of his student teachers talking about the difficulties encountered in teaching problem solving to the pupils:

> "Presenting a problem to the students [pupils] was not successful because they are not willing to think about physics problems".
> (Fischler,1999 p.187)

Fischler attributes this to the "narrow limits" (p.187) of the teaching strategies adopted by the student teachers.

(d) Simulations and models

Observation of teaching practice revealed that simulations were used by only two student teachers (16.6%) in their lessons. This was also reflected in the lesson plans.

The only type of simulation used was role-play. For example, Ciara used this when explaining about the structure of atoms with pupils acting out parts as protons, neutrons and electrons:

> "DK What did you feel was good about the lesson, Ciara?
>
> SOD I thought that the little demonstration at the beginning with the three girls, running around.
>
> DK A sort of role play.
>
> SOD Yes, it got them moving a little bit. I liked that...........

> Definitely the activity. As I said the activity at the beginning was good but more of that.
>
> DK More role play?
>
> SOD More role play or even more of them figuring things out in the worksheet."

Jessica also used simulations when explaining to a group of 12-year-old pupils what happens (in terms of the particulate nature of matter) when ice melts.

> "And then getting them to do a role model as well for them to act as a solid, they stuck together and then I got them to separate apart a bit. And then another girl that was interested in hockey and sports, I got her to act it out as well so I thought that was useful, to involve them all."

Similar findings are reported by Borko et al (1992) when they compared the classroom practice of novice teachers and expert teachers. There was a distinct lack of variety of classroom activities in the lessons on the novice teachers:

> "All the novices engaged in planning that was much more detailed and time-consuming than the experts' planning. None incorporated into lessons the variety of activity types utilised by the experts"
>
> (Borko, et al., 1992 p. 62)

Only one student in this study used a home-made model when teaching a difficult topic. Cian used a home made balance in the teaching of balancing chemical reactions. He was questioned about this in the interview.

> "DK You had an interesting piece of apparatus which was a sort of an elementary type of balance. You had a piece of stick and a basket on either side into which you could put various items.
>
> PC If I was doing it again I would come in a few days beforehand and make sure that the thing balances perfectly.
>
> DK Why did you use that piece of apparatus, what gave you that idea?

> PC I actually saw a diagram in the book. When people see things in the book it actually pushes their understanding to an extent but I thought if I could actually show them in real life something balancing, what's on one side has to be equal to what's on the other side. I said to myself that it would push their understanding further again as they would actually see that it's happening. "

The use of models and analogies in devising effective scientific explanations for the classroom is discussed by Treagust and Harrison (1999). In this paper they stress the importance of science teachers knowing how to effectively use analogies and models in the classroom. This is because pupils do not have a command of the correct scientific terms and have limited science experiences to call upon. The problem of student teachers making poor use of simulations and models in the classroom when discussing scientific concepts has been well documented by a number of authors (Taber and Watts, 1996; Treagust, Harrison and Venville, 1998). Treagust and Harrison (1999) argue that only expert teachers "use imaginative and expressive devices to make sense of abstract, difficult and non-observable science concepts....in so doing, providing explanations that accommodate the explainer, the audience, the content and the context". (p. 34).

(e) Analogy

In the baseline questionnaire, the use of analogy in teaching was not indicated by any student as being important. However, the classroom observation data shows that in practice one sixth of student teachers used analogies to assist with their teaching. It is clear from the baseline interview data that the student teachers who used analogies in their teaching were quite enthusiastic about the important role that analogies play in teaching. Fiona spoke in a very animated way about her idea of using the formation of a soccer team to explain electronic configuration to a class of 15 year old pupils.

> "Because the formation or electronic configuration that has 2,8,8, or whatever and I said if there is any way that I could explain it in terms of an everyday situation. And then soccer came into my mind where you would hear on television where the manager tonight is going for a 4, 4, 2 formation or whatever. I know that most of them are into premier leagues teams like Man United and all these - and those who wouldn't would know it from GAA or basketball. You would always have your backs, mid fields and forwards so I though that might be the best way to explain it and put it in everyday setting because they tend to learn better from an everyday situation cause they are a mixed ability class."

Although the above explanations and analogies may appear perfectly acceptable, Harrison and Treagust (1999) caution that "an explanation's viability is determined by its context". They give an example of a Year 8 class discussing kinetic theory being told that "air molecules are like tiny elastic balls that continually move around in a random fashion and bounce off each other and the walls of their container". While this explanation in terms of tiny elastic balls may be acceptable for Year 8, this explanation would be classified as incorrect when the structure of atoms and molecules is covered in a Year 11 chemistry class. In other words, the topic, the context and the age of the pupils must be taken into account and the viability of the explanation depends on whether the concept is central or peripheral to the topic. In Year 11 chemistry, describing molecules as "tiny elastic balls" could be tolerated as a supporting comment but not when the structure of molecules is the teaching focus

(f) Terminology

Evidence from the semi-structured interviews indicated that terminology was a problem area in the teaching of the topic. In fact, two thirds of student teachers interviewed indicated that terminology in science was a difficult area.

> "DK So, having taught the lesson, what would you say were the main problem areas encountered by the students?
>
> AC Well, I think the terminology is a big problem, the main one. I think they understand some things dissolve and other things don't dissolve. I think they can understand that all right. But, I think that with a lot of the topics we would be studying, terminology would be a big problem for them. I don't know in some cases is it absolutely necessary, and in other cases, not absolutely necessary for them. I know when we were doing the seven characteristics of life we have terrible trouble with terms like excretion, respiration, - those long big words are off-putting for them."
>
> "MS: I knew they'd find the whole idea of trying to introduce the words to them, the solute and the solvent and the solution, I figured that that would be the most difficult part.

When asked about what the student teachers thought would be the difficult part of the lesson, **all** of the student teachers referred to the problems posed by the terminology when explaining various concepts to the pupils. Observation of student teachers during their teaching revealed that student teachers spent a lot of time concentrating on definitions and terminology. Aishling gave a detailed explanation of the problems she encountered teaching the concept of dissolving to a class of twelve year old pupils:

> "I knew they'd find the whole idea of trying to introduce the words to them, the solute and the solvent and the solution, I figured that that would be the most difficult part. ....I suppose firstly from a simple point of view the words are very alike, I can see how you'd get mixed up with them if you weren't very clear about them in your own mind and I suppose for them it's putting

> fancy words on things they already know, they'd say that's the thing you dissolve instead of saying the solute, so maybe that's why............They might know in their head, and think well that's the thing you use to dissolve but they still can't...., I don't know is it a thing of memory or a problem with associating the correct name with it. Even after what we did in class, it still had not sunk in."

In teaching electrochemistry to a group of 15 year old girls, Tara commented that she thought the terminology was a big problem and felt she should have tried to solve this problem before going on to the more difficult concept of the mobility of ions.

> "DK. So do you think the terminology is a big problem?
>
> AB Yes, I should have introduced the terms earlier, but I did not. I left out the definitions and the movement of ions caused problems, they did not know what I meant by ions. I just said that they conducted electricity and left it at that."

Definitions were always presented to the class as a *fait accompli.* There was little effort by the teacher to build up the definition from the pupils' own observations and thoughts

6.4.2 Classroom climate

In the research study carried out by Brown and McIntyre (1993) one of the characteristics which teachers and pupils associated with good teaching was the creation of a relaxed and enjoyable atmosphere in the classroom and a sense of order in the classroom. One of the main areas around which their theoretical framework was constructed was the normal and desirable patterns of classroom activity. This "Normal Desirable State of Pupil Activity" fell into two categories: in one category the teacher is interacting with the whole class; in the second category the pupils are working independently on various tasks.

Fischler (1999) in developing his framework to analyse the actions of the student teachers in his study, also emphasises the importance of classroom climate and uses the term "principles referring to classroom climate" to describe the atmosphere "in which students (pupils) are willing to express and discuss their ideas" (p. 173). He points out that teacher behaviour in the classroom has a crucial role in the creation of this positive classroom climate especially in terms of fairness in dealing with pupils, informality, creation of a friendly and informal climate:

> "Student teachers are convinced that a positive classroom climate contributes to successful processes of teaching and learning and that the teacher's behaviour is crucial in creating this climate. Examples: creating a friendly classroom climate, dealing with students in an informal way, being fair and just in dealing with students".
>
> (Fischler, 1999 p.184)

In the present research study, the aspect of classroom climate was also given a high rating by the student teachers. When student teacher were asked in the baseline questionnaire to write down what they needed to do in order to bring about effective learning, the following were the main areas highlighted to create a good classroom atmosphere:

(a) Teacher enthusiasm

Teacher enthusiasm was cited by one third of student teachers as being important. Typical comments were:

> "Show enthusiasm yourself and this will motivate students."
>
> -Karen and Ciara

The enthusiasm of the student teachers was very obvious from the lesson observation data and also from the animated way in which the student teachers spoke about their lessons in the baseline interviews.

> "Also, when I was demonstrating things, I think I'd also be better asking for volunteers – I think it is a better approach and gets them more enthusiastic about it" – Aishling

> "I've done two great lessons where I've explained it and they they've done a solubility test and that's the secret to that class" – Ciara.

(b) Encourage Pupil Opinion

Encouragement of pupil opinion was cited by six out of twelve student teachers as playing an important part in bringing about effective learning.

> "Encourage students to put forward their opinions on a topic before you tell them about it."- Leah, Maria and Bryan.

> "Create fun where possible. Encourage student's views."
> -Bridget and Jessica

Although this aspect of teaching was rated highly by half of the student teachers, in practice over 80% of the lessons observed showed little attempt to encourage pupil opinion. A similar finding was reported by Borko et al. (1992) when reporting on the classroom practice of the novice teachers in the study.

> "Steve spent very little time interacting with the whole class. For more than 40 per cent of class time, students worked independently at their desks......When Steve did work with the class as a whole, he typically had students work problems independently and then asked one student to explain what he or she had done. Usually only the student explaining the problem and a very few others attended to the discussion......it was almost like a private conversation between the student and the teacher"
>
> (Borko et al., 1992 p. 65).

(c) Strict but fair discipline.

In the baseline questionnaire strict but fair discipline was cited by 25% of student teachers as being important for classroom climate. Typical comments were:

> "Get them to respect you and listen to you so you don't have to keep repeating yourself" – Ellen and Claire.

> "Treating students with respect and also listening to them.... Strict but fair discipline (being consistent)" – Tina and Ciaran.

In general, the classroom observation data clearly shows that the classroom atmosphere was well organised and pupils well behaved and attentive. A common strategy used by the student teachers to assist in the management of the pupils was the use of worksheets. Oisin taught in a large school in a disadvantaged area and worked hard at classroom management when teaching atomic structure to a group of 14 year old pupils

> "I felt that with the worksheet they are all going to be doing questions whereas if I go around and ask just one young fellow, the others in the class might not be listening but with the worksheet in front of them, they would have to write it down and think about it for themselves."

Although Tara was not happy with the worksheet she had prepared, she felt that the worksheet prevented the pupils being distracted and helped them to learn the terminology.

> "I was not happy with the worksheet. I thought it was fairly boring, but I didn't want them to be fidgeting with their books, I just wanted to hand them out something quick to see if they had understood the terminology and the difference between solutes and solvents........."

Ciaran realised that the practical class on the extraction of indicator from red cabbage was a bit chaotic with too much pupil movement around the laboratory in an attempt to get the items of apparatus and chemicals together and set up the experiment.

> "I probably would begin to train the students to set up the apparatus if it's simple enough or not too dangerous. And building a kind of routine to the classroom in future so that I say, 'Right folks the apparatus is here, I want you to collect one of these apiece, bring them down and set them up as per the diagram in the notes I gave you or on the projector' and basically over a period of time get them

> into the idea that they're the people who do the work, not myself or the technician or whatever."

It is worth mentioning that although discipline is usually one of the major problems encountered by students teachers, no discipline problems were noted in any of the lessons observed. In fact, Molly was the only one to mention a discipline problem in a lesson on the expansion of gases given to a class of twelve year pupils. It would be unusual to find discipline problems in the 12 – 13 year old age group in schools in Ireland.

> "There was only one thing that happened in the lesson that I should have nipped in the bud. There were a few fellows playing with the empty bottles and trying to warm them up while I was still talking. I corrected them but I should have just swiped the bottles there and then."

In the analysis of the interview data, a minority (33%) of the student teachers commented on their concern for maintenance of discipline during the lesson. In addition, in the reflections that student teachers are required to write on each lesson, the comments show a general satisfaction with the classroom climate. In the majority (90%) of the lessons observed, no discipline problems were encountered by the student teacher.

6.4.3 Links to everyday life

When student teachers were asked in the baseline questionnaire to write down what they though teachers need to do in order to bring about effective learning in science, the majority of them (83%) felt that giving everyday examples was important.

> "Relating science to everyday life to generate more interest"
> -Stephanie and Judith

> "Relating science to real life, where the pupils can associate with it" - Eamonn and Oisin
>
> "Relate topic to everyday life. (Why they are learning the topic.)" -Karen and Ciara
>
> "Introduce topic by general conversation about everyday events that arise and are similar to the topic." -Lisa and Cian

In an analysis of the classroom observation data, two thirds of student teachers used everyday applications during their teaching and this was mirrored in the lesson plan data.

In the follow up interview data, these student teachers were questioned about the use of everyday examples. All of the student teachers who used everyday examples in their teaching felt that their use was an important element in the lesson.

> "I used that because it was something that they would be familiar with, I thought it's even written on the bottle, 'dilute to taste' or 'concentrated orange drink', I suppose to make it more relevant to their everyday lives really" - Aishling .
>
> "I tried to look for everyday examples and I went to the Resource Centre then first and got a few books out - Osbornes, I found that book good, science encyclopaedia and these two books and I took two of them. Then I used your own textbook, [Title of book 1] and then [Title of book 2] and [Title of book 3] as well. I took a few coloured pictures from books and I enlarged them" -Jessica
>
> 'The main thing I tried to do was to bring in the different teaching aids such as the iron and sulfur for the mixture and then for the solute and solvent and solution I just brought in everyday things such as tea and coffee and salt. We had these cards on the board and we put the different things under the different headings.' – Aishling.

A similar observation was made by Fischler (1999) who found that the student teachers in his study placed a high priority on the use of everyday examples in their teaching. In his data analysis (p. 184) he summarised this area under the heading of "content related principles" which he explained in terms of the student teachers using everyday examples to give the pupils a greater insight and understanding of physics:

> "Student-teachers regard the selection of content, which is applicable in everyday life and therefore interesting to students, as a means of giving students insights into the various fields for the application of physics and to make them interested in understanding the physics basis of these applications".
>
> (Fischler, 1999 p.184)

6.5 View of Science Teaching. View of how to teach particular science topics

The view of science teaching shown by the student teachers will be discussed under the categories that have arisen from the theoretical frameworks discussed in Chapter 3.

6.5.1 Exploring Pupils' Ideas and Understanding

Observation of the lessons conducted by student teachers indicates that there is considerable emphasis on the teacher talking and pupils listening. In addition there is poor questioning of pupils to ascertain their level of understanding of the topic. Any questioning that takes place emphasises the recall of previously-learned material. Analysis of the baseline classroom observation data indicates that the student teachers did not tend to ask open-ended questions that would encourage more discussion with pupils, but rather asked closed questions with short, factual answers. Questioning tended to be used to revise material already covered by the teacher and there was little provision for questioning to encourage pupils' ideas and understandings or discussing pupils' ideas (only one student teacher was observed doing this). Analysis of the baseline interview data and baseline lesson plan data showed that only one student teacher mentioned the fact that she tried to find out the prior knowledge of her pupils about the topic being taught.

> SD I asked the kids had they heard of the word "atom", ever before I did that topic, so at least then I knew where they were coming from as well and then just filled out a little questionnaire. I got this idea from the chemistry teacher in the school.

Analysis of the baseline lesson plans shows that the above student teacher was the only one to incorporate any discussion of prior knowledge into her planning of the lesson.

Similar findings were reported by Fischler (1999) who found that the student teachers in his study felt restricted by the "scientific orientation of the syllabus" and were unable to go beyond the content of the syllabus to explore pupils' ideas and understanding:

> "However, student-teachers themselves selected topics which were oriented towards the scientific body of knowledge because these topics gave them a certain self-confidence during teaching which they would not have had with everyday and technical [technological] topics which they did not encounter in teacher education"
>
> (Fischler, 1999 p. 189)

A similar point is made by Borko et al (1992) when discussing the fact that the student teachers in their research study concentrated almost exclusively on the scientific content of the lessons and neglected to explore pupils' ideas and understanding or to encourage the pupils to make their ideas explicit.

> "Despite her lack of experience and knowledge, Shari was determined to conduct smoothly running class sessions. To do so, she planned extensively. For the frog dissection unit, the preparation of procedural guidelines, activity sheets, overhead transparencies and quizzes comprised a large portion of her planning time and effort."
>
> (Borko et al, 1992 p. 63).

Borko et al. (1992) also point out how one student teacher "thought through details of procedures and classroom management strategies" (p. 63) and became engrossed with classroom management to the detriment of a more holistic view of science teaching:

> "For cleanup, I'm going to discuss that at the beginning of the class. We're going to stop earlier than I did yesterday, because I think that I was rushed at the end. So I'm going to stop a little bit earlier, give more specific directions on cleanup. Like 'This side, one side of the room, all right, you guys can start with this table, working back towards the end, two at a time at the sink. When they come back, you can go'. That kind of thing, much more clear directions on the cleanup and washing hands and that kind of thing".
>
> (Borko et al., 1992 p. 63 – 64)

6.5.2 Relevant strategies for teaching particular topics

In general, it was found that the teaching strategies used by the student teachers were confined to those found in the textbooks. The strategies for teaching particular topics are now examined under the headings discussed in the framework: (a) everyday examples, (b) practical work, (c) recognition of pupil difficulties, (d) content versus understanding and (e) analogy.

(a) Everyday examples

One relevant strategy in common use by the student teachers for teaching particular topics was the use of everyday examples. From the baseline questionnaire data, the majority of student teachers (83%) indicated that the use of everyday examples is an important aspect of science teaching. Even though not all topics were easily associated with everyday examples (e.g. writing chemical formulas, explaining ionic and covalent bonding, etc), as mentioned in the previous section, two thirds of student teachers used everyday examples in their lessons. The importance of everyday examples was also stressed by the student teachers in the baseline interview data (already discussed in the previous section).

A similar finding is noted by Fischler (1999) who, when discussing "Content related principles", points out that the student-teachers in his study tried to select content that is applicable to everyday life in the hope that this would interest the pupils:

> "Student teachers regard the selection of content, which is applicable in everyday life and therefore interesting to students, as a means of giving students insights into the various fields for the application of physics and to make them interested in understanding the physics basis of these applications."
>
> (Fischler, 1999 p. 184)

A similar finding was made by Borko et al (1992) when analysing the patterns in "Expert's Science Teaching". For example, one of the teachers interviewed by them stressed that the instruction must be related to students' everyday experiences:

> "I always try to think of some way that what we are studying is related to their lives and how fun it's too...........And so I usually try to introduce things so that they can see that there's some meaning in their lives."
>
> (Borko et al., 1992 p. 55)

(b) Practical work

From the analysis of the baseline questionnaire data and baseline interview data, it is clear that the student teachers recognised the benefits of practical work. In the baseline questionnaire data, the majority of student teachers (75%) listed practical work as an important factor in science lessons. This emphasis on practical work was also apparent in the interview baseline data. Tara was very enthusiastic about practical work when asked about the class she gave on electrochemistry.

> "DK You brought a lot of practical work, a lot of demonstrations into the lesson even though it was only a forty-minute lesson. Was that deliberate on your part?
>
> Tara Yes, I can remember when I learned electrochemistry, I never knew how the Activity Series was all linked up. Seeing things in practice, it reinforces the ideas, and showing things brings it to life but you could not do this for every lesson.
>
> DK. So do you feel they may not remember the underlying theory in your demonstration, but at least they will remember your demonstration?
>
> Yes, and hopefully they will remember the order the metals went in the Activity Series."

Three quarters of student teachers indicated in the baseline questionnaire data that practical work was an important aspect of science teaching. However, analysis of the classroom observation data showed that a smaller number of student teachers (25%) included practical activities for pupils in the lesson. Analysis of the lesson plan data shows that only one sixth of student teachers had planned practical work as part of their lesson plans.

The student teachers who were observed using practical work in their lesson plans were clearly enthusiastic about it in the follow-up interviews. For example, when one student teacher was asked what he thought was good about the lesson he gave on chemical changes to a group of twelve year old pupils, he immediately referred to the practical demonstration of iron filings reacting with sulfur.

> "For a start, ... the experiment. Like they go into Maths, into Geography and they go into English and they are listening, or writing or reading, like science can attract them you are always

> trying to attract them to it by doing an experiment for most of the class there, very different - any person would be attracted to it."
> - Oisin

In practise student teachers were more likely to use teacher demonstrations in their teaching. Slightly more than half (60%) were observed using demonstrations of practical work in their teaching. In Ireland there is no provision for technical assistance in the majority of school laboratories and this acts as a barrier to practical work in many schools. Another general observation is that during practical work, the level of laboratory organisation needs to be improved – the lack of a school mentoring system to assist student teachers in this regard was very apparent.

Field trips were identified by one sixth of student teachers as being important in science teaching but none were observed in practice.

Fischler (1999) also found that practical work was under-utilised by the student teachers involved in his research. He found that the student teachers felt that there was not sufficient reward (in terms of examination results) from the practical work carried out. He discusses this in terms of the need for the student teachers to take a wider view of the advantages of practical work.

> "Student teachers judgements about the influence of students' laboratory work changes during teaching practice. The impression that the learning outcomes are not sufficient with regard to the effort, results from student-teachers focusing on an under-achievement in students 'testable knowledge'. A widening of perspectives towards other functions for students' laboratory work would allow for cognitive achievements in a more realistic manner and would turn the student-teacher's attention to other teaching goals associated with laboratory work. Experimental skills, independent planning, conducting and evaluating experiments, and the ability to work co-

> operatively in groups are goals worthy of a teacher's energy and efforts"
>
> (Fischler 1999, p. 192)

Finally, he recommends that "the preparation and design of laboratory work related to these aspects should therefore be increasingly a part of teacher education" (Fischler, 1999 p. 193).

(c) Recognition of pupil difficulties.

In the baseline interview data, one sixth of the student teachers indicated that the recognition of pupils' difficulties was an important strategy that teachers need to use to bring about effective learning in science. However, it is clear from the interview data that there was a lack of recognition among the student teachers of the problem persisting beyond the lesson. It was very obvious from the interviews that the student teachers felt that, once the topic was well covered by them in class, they were happy that pupils understood the concepts covered. When Stephanie was asked about a class on the particulate nature of matter that she gave to a group of twelve year old pupils, she was quite confident that she had managed to overcome the difficulties experienced by the pupils.

> DK You obviously had some idea that the students would find the whole topic quite difficult and then you taught the topic. Having taught the topic, do you think the difficulties that you perceived them to have are still there or do you think that you managed to get around them?
>
> GD I think I managed to get around them. I asked them afterwards and they seemed to enjoy the class, number one and number two I thought they had a fair idea of the material. As well, they really enjoyed the ball and ring experiment - that solids expanded even though it didn't work out too well.

Cian was also quite confident that the class he gave on chemical formulas and bonding to a 14 year old class went well and that the pupils understood the concepts.

> "I really wanted to push the atoms and the bonding together at the start. I thought it might have taken them a bit longer to grasp that but they got that straight away............I thought they got the formulas fairly OK".

Molly taught a class on the particulate nature of matter to a group of twelve-year old pupils. Although a very dynamic and hard-working student teacher, she was happy that the concept of the particular nature of matter as applied to gases did not cause a problem.

> "I think they all had a fair idea of a solid by looking at its properties and by looking at a liquid, its properties. Now maybe not by looking at a gas, but they know all that, it's taken for granted anyway so they would know the reason why they've got these properties."

Killian taught a class on acids, bases and indicators to a group of 14 year old pupils. It was clear from his replies that he believed there were no conceptual problems encountered by the pupils in this lesson.

> "I think, there's no real conceptual problems, you boil up the leaf and see the colours coming out, there's no real problem and because they had done a bit about litmus and colour changes with acids and bases, I wouldn't have expected too many problems with understanding."

This lack of recognition of the fact that pupils' problems in understanding may persist beyond the lesson was noted in all of the interviews carried out. Not one of the student teachers felt that the difficulties that the pupils had persisted beyond the lesson. In addition, an analysis of the baseline observation data showed that only a minority of student teachers (16%) displayed any recognition of pupil difficulties in their teaching.

This problem is discussed by Peterson and Treagust (1995) in terms of the limited pedagogical reasoning of student teachers. The lack of recognition among the student teachers of the persistence of pupils' difficulties may be explained using the six-stage model of pedagogical reasoning developed by Wilson, Shulman and Richert (1987). This model is discussed in detail by Peterson and Treagust who found that only two of the student teachers in their study recognised that the views of pupils need to be taken into account. The problem is interpreted in terms of the limited pedagogical reasoning of the student teachers who had not progressed beyond the first two stages of the model of pedagogical reasoning, Table 6.2 .

1. Comprehension	Teacher understanding of the ideas to be taught and the educational purposes of the topic/subject
2. Transformation	Comprehended ideas are transformed by the teacher for use in a particular classroom setting. This includes critical interpretation of text materials, identifying ways of representing ideas, selecting appropriate teaching methods, adapting and tailoring ideas to the particular class group.
3. Instruction	The act of teaching. This includes organising and managing the class and students, presenting clear explanations, interacting with students, questioning and evaluating.
4. Evaluation	This includes both the evaluation of student learning and the teacher's own teaching performance, materials employed, etc.
5. Reflection	The review of the events and accomplishments that occurred during the lesson.
6. New Comprehension	New understanding of subjects, learners, purposes and pedagogy through the process of teaching.

Table 6.2 Six stages of a model of pedagogical reasoning (from Peterson and Treagust 1995, p. 292)

Peterson and Treagust (1995) summarised the type of problem discussed above as follows:

> "It was evident from the interviews with the seven pre-service teachers at the beginning of the unit that they only discussed the comprehension and transformation stage of the pedagogical reasoning process and indicated a teacher-centred approach in discussing the planning of lessons."
>
> (Peterson and Treagust, 1995 p. 304).

In other words, the pedagogical reasoning ability of the student teachers had not progressed beyond the first two stages in Table 6.2

(d) Content versus understanding

Content versus understanding was another theme that rose to a prominent position in the analysis of the interview data. This theme came across most strongly in the interviews due to the emphasis placed by the student teachers on covering the content of the course. For example, Aishling taught a class on solutions in chemistry to twelve-year-old pupils and most of the time was spent on terminology rather than on discussing the actual concept with the pupils.

> "The first thing I wanted them to know was what a solution was, when you get a substance and you dissolve it in something else, that that's what a solution was. Then I wanted them to be aware of the difference between a solute, solvent and a solution, just for them to know exactly what the words meant. Then following on from that the idea of something being dilute or concentrated, a type of solution and soluble and insoluble."

Jessica gave a class on the particulate nature of matter to twelve-year-old pupils and spent the majority of time defining terms like *matter*, *diffusion*, etc. and giving an abundance of examples but never discussed the actual idea of small particles with the class. No attempt was made to give a mental picture of the particulate nature of matter.

> "What was matter first of all and not just the definition of matter but to get an idea of what is matter in the world around them........and then I went on to what were the three states of matter. I brought in then what were they - examples of solids, liquids and gases and to show them then what all this meant, what a definite shape meant or

> what a definite volume meant by using pictures and things like that, everyday items....."

The classroom observation data clearly shows that of the twelve student teachers whose lessons were observed, seven of them (58%) had a clear emphasis on covering content to the detriment of understanding. These student teachers tended to present material without sufficient discussion or questioning or probing to determine levels of understanding.

When the question of "Content versus understanding" was raised in the interviews, a quarter of the student teachers agreed that the emphasis must be on content in order to get the course covered and meet the targets of number of chapters of the textbook laid down for them by the school. A clear message emerged of student teachers having to adopt a very fast teaching pace with emphasis appearing to be on coverage rather than on depth of understanding. The examination system appears to have a major influence on the range and depth of treatment of various parts of the lessons.

A similar observation was reported by Fischler (1999) who found that the student teachers felt restricted by both the syllabus content and the instructions from the mentors. This resulted in the student teachers being dissatisfied with their success in showing the links between physics and everyday life. In addition, the student teachers felt that they were interacting with the pupils to a far greater extent than those observing the lessons felt was the case:

> "Content was the only aspect that they [the student teachers] perceived as restrictive as a result of both their mentor's directions and the syllabus. Therefore, the goal of demonstrating to the students the connection between physics and everyday life was not achieved ....Therefore, they perceived students' [pupils]

> behaviour as reactions to their decisions that they themselves regarded as being much more student oriented than they were perceived to be by the observers, e.g. the mentor and the coaching professor."
>
> (Fischler, 1999 p. 186 – 187)

(e) Analogy

An analysis of the baseline observation data showed that a minority (16.6%) of student teachers used some form of analogy in teaching a particular topic in science. In the baseline interview data, all student teachers referred to the positive aspects of using analogies in science teaching but an analysis of the lesson plans showed that only this small minority of student teachers used analogies when making out the lesson. The example of Fiona using the analogy of the formation of a soccer team to explain electronic configuration has already been quoted. The only other example of analogy used in the baseline study was that of a home-made balance made by Cian when comparing the balancing of equations to the balancing of weights using an ordinary balance.

The use of analogies in teaching was highlighted by Shulman (1986) who used this idea in defining the concept of pedagogical content knowledge:

> "Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others".
>
> (Shulman, 1986 p. 9)

When Wilson, Shulman and Richert (1987) monitored a group of student teachers through their professional training and into their first year of teaching, they focussed on how the subject matter knowledge of these student teachers was translated into classroom practice. The concept of pedagogical content knowledge was used to follow the extent of growth of professional competence of the student teachers and hence to develop the theoretical framework discussed in Chapter 3. Since analogies are, by definition, embedded into the concept of pedagogical content knowledge, it is fair to conclude that the majority of the baseline student teachers in the study under discussion in this thesis would not be considered by Shulman to have developed their pedagogical content knowledge to a satisfactory degree. This point is also made by Borko et al. (1992) who use the idea of schemata for interpreting differences between novice and expert teachers (as discussed in Chapter 3). They make the point that the development of these schemata is a major part of a teacher-training curriculum:

> "Schemata for pedagogical content knowledge seem to be virtually non-existent in novices' knowledge systems. Developing these knowledge structures and learning pedagogical reasoning skills are major components of learning to teach".
> (Borko et al., 1992 p. 51).

The view of how to teach particular science topics was included in the framework as it was one of the dimensions along which it was hoped to see a change after the Intervention Package was implemented. Also, it seemed that the student teachers might have views on how to teach particular topics based on their own experience as pupils having studied science in school. It was of great surprise to the researcher that little emerged from the data analysis to indicate that the student teachers had views on how to teach particular science topics. The only items in this area that did emerge from the data analysis was in the interview with Jessica. This student teacher was observed teaching the particulate nature of matter to a group of twelve year old pupils. She introduced the idea of matter by reminding the pupils of the story of the three little pigs that they had encountered in primary school:

> "As I just said to start it off with something basic like the three little pigs because they used bricks, sticks and hay to build their house so these were all examples of matter. It's just a story and something that they could laugh at, at the start and then I went on to what were the three states of matter."

This was the only lesson in which a student teacher demonstrated his/her own way of approaching a topic. In all other cases, the teaching approach adopted by the student teacher involved following what was outlined in the textbook. A similar finding was reported by Peterson and Treagust (1995) who found that the student teachers in their sample had a very limited input into lesson planning in that they were either told how to teach the lesson or else taught it as they themselves had been taught it as pupils:

> "Lesson planning was either guided extensively by the supervising teacher, or was based on views of teaching from their own experiences. For example, Rebecca had minimal input into the planning of her science lessons as the planning process was directed by the supervising teacher in the school setting. 'The teacher just told me the topic and I had to come up with the idea. The librarian looked up the book and she just handed it to me. Because I had a book and it explained .....dispersal and everything and all I had to do was just go over it'. "
>
> (Peterson and Treagust, 1995 p. 296).

In other cases, Peterson and Treagust quote student teachers as making comments like "The way I explained it was the way I was taught in science at secondary school...." (Peterson and Treagust, 1995 p. 296).

Similar finding are reported by Fischler (1999) who, when discussing the type of lessons given by the student teachers, states that "they remembered the physics lessons from their own school days that were either dominated by an active teacher or alternatively involved a great length of time as passive students" (p. 185). Fischler (1999) also found that the student teachers were hampered in their planning of lessons by the restrictions of the syllabus and the instructions received from the teacher in charge of the class:

> "As mentioned above, most of the student teachers felt restricted by their content-related decision making that had to meet the scientific orientation of the syllabus and their mentor but was opposed to their own conception of good physics teaching".
> (Fischler, 1999 p.189)

The very limited views of student teachers on how to teach particular science topics is also discussed by Borko et al (1992). They point out that the form of thinking that includes the identification and selection of strategies for representing key ideas in a lesson and adapting these strategies for the learners "is unique to the profession of teaching and is relatively undeveloped in novice teachers" (Borko et al. 1992, p. 50). They explain the problems encountered by student teachers when teaching particular topics in terms of the limited schemata of the student teachers compared to expert teachers:

> "When compared to experts, novices showed more time-consuming and less efficient planning, they encountered problems when attempts to be responsive to students led them away from scripted lesson plans.....These differences were accounted for by the assumptions that novices' cognitive schemata, particularly their schemata for pedagogical content knowledge, are less elaborate, less interconnected and less easily accessible than those of experts and that their pedagogical reasoning skills are less well-developed"
> (Borko et al., 1992 p. 51).

6.6 Subject Knowledge

Wilson et al. (1987) place considerable emphasis on the importance of subject knowledge for student teachers:

> "In studying novice teachers, it is clear to us that teachers need more than a personal understanding of the subject matter they are expected to teach. They must also possess a specialised

> understanding of the subject matter, one that permits them to foster understanding in most of their students."
> (Wilson et al., 1987 p. 104)

They also underline the importance of subject knowledge when they state that "teachers must have a knowledge of the subject matter that includes a personal understanding of the content as well as knowledge of ways to communicate that understanding, to foster the development of subject matter knowledge in the minds of students" (p. 110).

A common theme that arose both in the baseline observation data and the baseline interview data was the subject knowledge of the student teachers. In some cases, it was found that the lack of subject knowledge among the student teachers introduced misunderstandings into lessons. For example, when Stephanie was explaining to a group of twelve-year-old girls about the concept of diffusion, she added a large spatula-load of potassium permanganate to a beaker of water and gave that as an example of the purple colour diffusing throughout the liquid. No mention was made of the particulate nature of diffusion or the fact that it often takes a long time for particles to diffuse.

> "DK You then went on to talk about the diffusion of a solid through a liquid and you added some potassium permanganate to water. What point were you trying to get across there?
>
> GD Just that diffusion in liquids is slower than a gas and you can mix particles with the idea behind that."

Oisin, when teaching the difference between compounds and mixtures to a group of twelve year old pupils, ignored the Law of Conservation of Matter and used the "disproof" of this to prove that the iron sulfide was indeed a different compound because it had a different mass than the sum of either the iron or the sulfur.

> "D.K. Now, you did an interesting exercise of weighing the materials beforehand and weighing the material afterwards. What would you hope to get across to the students using that idea?
>
> T.C. Again, the whole idea that the substance at the end was totally different from the two substances at the start, that most of it was not attracted by the magnet. And to copper-fasten that to show them that it was a totally different substance with a different weight."

In a lesson on solutions, Aishling gave a mixture of iron and sulfur as an example of a solution and, even on questioning, appeared to unaware of the problem.

> "DK Another interesting demonstration you did was at the beginning of the class was mixing together the iron and the sulphur. Why did you introduce the concept of solutions using that?
>
> MS I started off from the point of view of a mixture and said right, you mix these two things together and they're not in any fixed amount and that's your mixture - while a solution is a special type of mixture except normally you have a liquid dissolving the other substance. That's why I started off with this."

In a lesson on the topic of Acids and Bases given to a class of twelve-year-old pupils, Killian spoke about the corrosive nature of acids and went on to state that "bases don't burn you"! In fact, of the twelve lessons observed in the baseline study, one quarter of them clearly indicated a lack of subject knowledge on the part of the student teachers presenting the lesson. In each case, incorrect explanations were given to the pupils. This is great cause for concern.

In research carried out by Peterson and Treagust (1995) to develop student teachers' pedagogical reasoning ability, the problems caused by the student teachers' lack of subject knowledge became very clear in the interviews with the seven student teachers.

> "When I went over the notes I understood what I was going to teach, but I found it a lot more difficult to explain to others. In my mind it seemed clear, but when I verbalised it, I could tell myself that it wasn't all that clear. The more I tried to clarify points the more difficult it became." –Tanya
> (Peterson and Treagust, 1995 p. 303)

Peterson and Treagust (1995) clearly realised the problem of lack of subject knowledge among the student teachers in their study and summarised the problem as follows:

> "The preservice teachers believed their knowledge of curriculum materials was weak and still needed to be developed..... their knowledge of curriculum was limited to either material supplied by the supervising teacher during their first year School Experience program or to curriculum materials discussed as part of the first-year science education program......It was evident that the seven interviewees were not aware of the extent or variety of curriculum materials available, and had little experience in evaluating and adapting them to particular classroom settings."
> (Peterson and Treagust, 1995 p. 296)

There is ample evidence from both the literature and the data generated by this study that, in general, student teachers realise their shortcomings in subject knowledge when it comes to reflecting on their classroom practice. This is discussed in more detail in section 6.9

6.7 Local Conditions

As discussed in Chapter 3, in the framework developed by Brown and McIntyre "Conditions" was included as one of the four main parts of the framework. Brown and McIntyre found that the teachers in their study were very conscious of the circumstances in which they were working and were also conscious of the impact of these circumstances ("Conditions") on their teaching. Brown and McIntyre found that these Conditions had a marked effect on the standards that the teachers felt they could apply in maintaining their Normal Desirable State of pupil activity or promoting progress in the classroom. In some cases standards were lowered and in other cases enhanced. It was found that the Conditions could lead to a variation in the teachers' actions in the classroom to achieve his or her goals.

In a paper discussing a model of the process of curriculum development and evaluation, Millar (2002) suggests that classroom activities (what teacher and pupils actually do) and pupil performance (what pupils actually learn) are influenced by a number of factors. The three factors outlined are:

1. Teachers' and pupils' views of science.
2. Teachers' and pupils' views of learning.
3. The practical and institutional context.

The end point of the process is what the pupils actually learn from a lesson or from the programme as a whole. The same three external factors outlined above are also influential in this final stage. Millar's paper (2002) emphasised the effect of local conditions on the factors that influence decisions made in the classroom

In the present research study, it was found that the local conditions were referred to by the student teachers in the baseline questionnaire data and also in the baseline interview data. The three areas in which local conditions were mentioned may be classified under the headings of "Assessment", "Help from other teachers" and "Pupil literacy".

6.7.1 Assessment

When the student teachers in the baseline questionnaire study were asked what they thought that teachers need to do to bring about effective learning in science, a quarter of them indicated that a variety of assessment forms could enhance teaching.

In the analysis of the baseline videotape data and interview data, the teaching style adopted by all the student teachers was obviously driven by the examination system. There was considerable emphasis on learning definitions throughout lessons and on the importance of "getting through" the material during the lesson and teaching in such a way that will be of help to pupils in an exam situation. For example, Fiona went to great lengths to cover an exam strategy when teaching atomic structure.

> "Because it would be able to tell us, if you did not know the element itself you would be able to look at the Periodic Table at an exam situation and say OK sodium down 3 periods and it has got 3 shells, and its on the first row and it has got one electron and so its outer shell. It's just in years to come and certainly in their exam, this is all that they will have to help them, so that will be their only aid when they go into the exam."

When student teachers were interviewed, having reflected on their lesson, it was clear that they were focussed on the examination system in their teaching.

6.7.2 Help from other teachers

An analysis of the baseline interview data showed that only two of the twelve student teachers indicated that help from other teachers was an important element in the preparation of classes.

> "D.K. How did you decide that those were the two key ideas of the lesson?
>
> Firstly, reading up, reading through the chapter in the textbook.

> D.K. So, number one, the textbook you say guided you towards it, was there anything else?
>
> T.C. More importantly the other teachers in the school talked it through with me, about what way I was going about it.
>
> D.K. I know when they were doing the activity, we can see them here, you use petri dishes. I like the idea of you using petri dishes. What gave you that idea?
>
> T.C. One of the other teachers told me".

The fact that so few student teachers received assistance from other more experienced teachers in the school is probably due to the lack of any formal mentoring structure in Irish second-level schools. This is not the case in other research studies, e.g. Peterson and Treagust (1995) reported that "lesson planning was either guided extensively by the supervising teacher or was based on views of teaching from their own experience" (Peterson and Treagust, 1995 p. 296). Similarly, in Fischler's study (1999) he explains that the video recording of the student teachers' lessons took place in "the presence of the mentor and the coaching professor" (Fischler, 1999 p. 179). It is interesting to note that in Fischlers' paper (1999), the student teachers complained that they felt that the content of their lessons was restricted by their mentors and also by the syllabus:

> "Content was the only aspect that they perceived as restrictive as a result of both their mentor's directions and the syllabus."
>
> (Fischler, 1999 p. 186)

6.7.3 Type of pupils

In general, the student teachers did not refer to specific problems arising from the types of pupils they were teaching. For example, a problem with literacy of the pupils was only mentioned by one student teacher during the interview.

Jessica was teaching a mixed ability class of girls and made the following comments about this literacy.

> "A lot of them can't read or their reading wouldn't be great or their writing. In their science experiments they only write five or six lines, more of them could write a page and a half. I don't think a lot of them are going to go home and read the whole chapter themselves",

The problem of literacy was not referred to in any of the other research projects studied when building the theoretical framework for this study.

6.8 Examples of analysed data

One theme (***Nature of Presentation***) within the framework has been identified as an illustrative example to demonstrate the analysis of data in chapters 6 and 7.

(i) Observation Data. As described in Chapter 4, observation data were obtained by video recording each lesson and then by viewing this tape and completing the form in Appendix II (page 426). An example of one such item of data is given in Appendix XVI (page 482). Presenting the data in this form allowed the researcher to analyse the lesson in terms of the theoretical framework and to "map" the various observations on to the main categories (e.g. *View of Teaching*) and sub-categories of the framework (e.g. *Nature of Presentation*). For example, under **Nature of Presentation** it was observed that 10 of the 12 student teachers (83%) used some form of AV aid in the lesson. Hence, this information was entered in column 4 of Appendix XVII (page 484). (This Appendix is an expanded version of Appendix IV page 428). This procedure was repeated for each of the main headings and sub-headings so that the data gathered were systematically mapped on to the framework.

(ii) Interview Data. The entire interview transcript for each student was imported into Winmax and analysed under the main headings of the theoretical framework (e.g. *View of Teaching*) and sub-headings (e.g. *Nature of Presentation*). Each sub-heading was further analysed under additional individual headings identified in the analysis of the data (e.g. *audio-visual aids*, *group work*, *role play* and *projects*). An example of an extract of one item of interview data (Nature of presentation - AV aids) is given in Appendix XVIII (page 485). One of the advantages of Winmax is that it gives a "running total" of the number of entries under each category (e.g. the number of times the student teachers commented on AV aids) in addition to what each student teacher said. Thus the qualitative data could be represented in a quantitative form by counting the number of comments given by the student teachers in each section of the framework. For example, 8 of the 12 student teachers (66.7%) in the baseline study commented on the AV aids that they used in the lesson. This number was entered in the fifth column of Appendix XVII.

(iii) Questionnaire data. Questionnaires completed by the student teachers generated both quantitative and qualitative data. As described in section 4.6.2 (page 191) the quantitative data were analysed by entering the information into the spreadsheet *Excel* and then graphing it using the appropriate software tools. An example of this type of data analysis is given on pages 299 and 300. The qualitative data generated by the responses to the questionnaires were analysed in the same way as the interview data. The answers to each question were first transcribed into a master file and then imported into Winmax. The relevant sections of data were then mapped against the main heading (*View of Teaching*) and sub-headings (*Nature of Presentation* and *AV aids*) of the theoretical framework. For example, some data generated from the questionnaire issued to the baseline students (page 433) is reproduced in Appendix XIX (page 486). The analysis of these data is summarised on page 232. Note from this analysis that 50% of the student teachers referred to audio visual aids in their response. This information was entered into column 3 of Appendix XVII.

(iv) Lesson plan data. As described on page 194, each lesson plan was analysed using the headings and sub-headings in the theoretical framework. For example, under the heading of *Nature of Presentation*, evidence was looked for in the lesson plan of reference to audio visual aids used in the lesson. A note was made of the occurrence of these references in each lesson plan, e.g. it was found that 10 of the 12 student teachers (83.3%) whose lessons were observed referred to the use of AV aids in their lesson plan. Thus, this information was entered into column 6 of Appendix XVII.

6.9 Personal reflections and other feedback

The student teachers were asked to reflect on their lessons in both the interviews and also in writing at the end of each lesson plan. One of the strongest themes to emerge from this self-reflection was the fact that the student teachers realised their shortcomings in terms of their own subject knowledge and experience of teaching. For example, when the student teachers were asked in the baseline questionnaire to write down what they thought teachers need to do to bring about effective learning in science, one sixth of student teachers responded by saying that knowledge of material was portion (25%) of student teachers demonstrated inadequate subject knowledge of the topic being taught. This had the effect of introducing difficulties for pupils. For example, Stephanie was asked about a class on the particulate nature of matter that she gave to a group of twelve-year-old pupils. (In this class she had demonstrated diffusion in liquids using permanganate in water by tipping a spatula load of permanganate into a graduated cylinder filled with water). When interviewed, she realised her mistake:

> DK " I noticed that you took a fine big spoon full of permanganate and you put the whole lot into the water".
> GD "So it went very quickly then. I should only have put in a few crystals."

When Oisin was teaching the topic of chemical changes to a group of less able twelve-year-old boys, he tried to show that one characteristic of such a change was a change in mass between the reactants and products. This could have introduced difficulties for pupils.

> D.K. "Now, you did an interesting exercise of weighing the materials beforehand and weighing the material afterwards. What would you hope to get across to the students using that idea?"
>
> T.C. "Again, the whole idea that the substance at the end was totally different from the two substances at the start, that most of it was not attracted by the magnet. And to copper fasten that to show them that it was a totally different substance with a different weight".

Unfortunately, Oisin did not realise his mistake and his lack of knowledge of the Law of Conservation of Matter is quite alarming.

Another source of introducing difficulties for pupils arose from the fact that, in some cases, the student teachers used inappropriate material not directly related to a topic. For example, when Tara was teaching electrochemistry to a class of 15 year old girls, whilst explaining about the potential difference between magnesium and copper, she burned a piece of magnesium ribbon. Although her objective was clear to the researcher, it was clear from the response of the pupils that this demonstration created a diversion for the pupils and caused confusion in their minds on how this was linked to the simple cell.

> DK. "Let's play that part of the tape again. You were using a piece of magnesium and piece of copper. Were you trying to establish a link between this and the electron loss when you burned magnesium?"
>
> AB "Yes and then the electrons flowing in the circuit. I did not want to go into much detail about the electrons, because the pupils are weak - it was a tough concept for them. To be honest, I was trying to get them to understand that there was a potential difference".

As described in Chapter 4, prompts and probes were used to try to elicit more detailed responses from the student teachers. Among the strongest points to emerge from the interviews, was the clear realisation from the teachers of their own shortcomings and of their lack of confidence in dealing with various teaching topics.

Tara spoke honestly about the class she gave on electrochemistry to a group of 15-year-old girls.

> ".....I was telling them too much rather than trying to get it out of them more. But they were a weak enough class. It was hard to pitch the lesson. I felt I was going in there blind .... I found in the end when I looked back at it, I rushed in and said 'These were the electrodes' and 'This is the electrolyte' and I should have done that more slowly – the material was just landed on them."

Fiona clearly realised the problems she encountered in teaching atomic structure and the need for a more active learning environment.

> "I think I did a lot of chalk and talk. It was almost like a university lecture more than a classroom situation but in saying that maybe it was the topic that I had nothing to demonstrate with and it was

> very much of a theory class so I don't know if it was just that or maybe I am just a person that likes the blackboard and likes to talk as well."

The sense of honesty about their shortcomings was very clear to the researcher in the interviews. Oisin taught the topic of chemical change to a group of twelve-year-old boys. One of his demonstrations involved heating a mixture of iron and sulfur. When asked by the researcher if he though that the pupils understood what was happening when he heated the mixture of iron and sulfur, he gave a very honest appraisal of this part of the lesson:

> "I don't know if I explained that brilliantly well, to be honest, I was concentrating more on the results of it rather than explaining what was happening, where I probably should have talked more of what was going on but I just didn't............ I think I would spend more time at the start talking about elements again. I don't know if I spent enough time at it making sure they knew that this was an element, this was another one and you cannot break it down. I though I glanced over that point and perhaps I should have spend more time on that".

Cian realised that he had lost the class in explaining how to balance an equation. He tried to teach both chemical formulas and balancing of equations in the one lesson.

> "I think that I was trying to put three or four classes into the one double class there so I'd like to do a bit of time with atoms and just get the basics and the structure and then move onto formulas, spend one class on formulas and then equations separately".

In some cases the student teachers clearly realised the difficulties that pupils were having with certain topics. For example, Molly, having taught a class on the particulate nature of matter to a group of twelve year old pupils, realised that the pupils would have to think about the compressibility of a gas:

> "The whole particle idea, especially within a gas because they can see solids and liquids but they can't see a gas. They wouldn't have a whole lot of knowledge about gases anyway, they know the whole thing about particles and the spaces between them. 'Why do you know that a gas can be compressed?'. I think that would have been a question that they'd have had to think about, they should know now that it's by reducing the space, not the particles."

Killian taught a class on acids and bases to a group of 14 year old pupils. He realised that despite carrying out various tests, the pupils could still be lacking a fundamental understanding of the concept of an acid and a base.

> "I think the introduction to acids and bases and the pH scale is an area where I could see kids who can see what's happening, give them a solution, they test it to see whether it's an acid or a base and they understand that this is how you test it, but they're not really understanding acids and bases per se which comes on later."

It is interesting that a greater number of student teachers expressed a realisation of their shortcomings in the interviews (83.3%) than in the reflection written into their lesson plans (33.3%). This may be as a result of a fear of marks being deducted by their official supervisor or simply because in the more relaxed interview situation they were able to reflect more deeply on the lesson without their official supervisor being present.

In keeping with the findings in this baseline study where the student teachers were very much aware of their own shortcomings, much of the literature on student teachers makes reference to the limited subject knowledge and lack of experience of the student teachers. For example, one of Fischler's (1999) conclusions with regard to his research was that "only 25 per cent of the student teachers were content with their efforts".

> "Student teachers (and beginning teachers) to a large extent attribute failure to themselves. In their opinion, increased experience would improve the possibilities for the realisation of their

> intentions....The majority of student-teachers perceived the reality of physics teaching as a failure. However, they maintained their teaching principles because they attributed their failure to the specific conditions of the teaching practicum"
>
> (Fischler, 1999 p.188)

A similar finding was made by Peterson and Treagust (1995) who observed that the student teachers readily admitted their lack of subject knowledge about curriculum material:

> "Mark's comment on the need for more information on curriculum resources was typical of the responses for the seven preservice teachers interviewed: 'I would like to look at resources....I don't think many people know of all the recent scientific [curriculum] resources'."
>
> (Peterson and Treagust, 1999 p. 296)

Also, Peterson and Treagust (1995) report the problems encountered by the student teachers when explaining concepts:

> "Explaining the ideas was difficult and so was encouraging a clear understanding of the concept. Further clarification was needed than what I was able to provide" – Jane
>
> (Peterson and Treagust, 1999 p. 303)

It is worth noting that only one student teacher in this research project mentioned the fact that she tried to find out the prior knowledge of her pupils about the topic being taught. Ciara was teaching atomic structure to a group of 13-year-old pupils and obtained assistance from one of the full time teachers in the school. (This full-time teacher was a part-time student at University College Cork undertaking a masters degree in science education).

When writing about the shortcomings of student teachers Treagust and Harrison (1999) point to the fact that student teachers have a major problem with regard to expert teacher knowledge:

> "Beginning teachers often despair of achieving expert teacher knowledge and although many expert teachers cannot explain their expertise, researchers have identified and described expertise in various case studies (e.g. Shulman, 1987, Tobin and Fraser 1999).This kind of knowledge, referred to as pedagogical content knowledge (Shulman, 1986, 1987), appears to fulfil all the criteria of expert knowledge because it transcends both subject content and pedagogical knowledge and it is consistently and innovatively used to solve classroom learning problems".
>
> (Treagust and Harrison, 1999 p 36)

A similar finding was made in the research project carried out by Borko et al. (1992). In this study an analysis of patterns of science instruction by expert and student teachers was undertaken. The research was carried out by means of classroom observation and semi-structured interviews with six student teachers. Some remarkable similarities in terms of the student teachers' reflections are apparent in the Borko et al. research and the research being discussed in this thesis. For example, in the Borko et al. study, the student teachers in the interviews commented on the weaknesses in their own teaching and attributed these to a lack of knowledge and experience.

> "I'm very weak in knowing how much kids can handle, just because I don't have any experience with these kids. I mean....as far as the amount of content...how much detail to go into these things, am I going way over their head....what can you expect of them?" - Shari
>
> (Borko et al., 1992 p. 63)

The same student teacher found difficulty with pacing the lesson and anticipating how long it would take her to cover various activities in the classroom.

> "I have no idea, I've never done this at this age before...How do I know how long this is going to take them to get through this unless I've done it before?" – Shari
>
> (Borko et al.,1992 p. 63)

A similar finding was made by Russell and Bullock (1999). In an attempt to help student teachers discover their own professional craft knowledge as teachers, Russell and Bullock (1999) carried out a research study to chart the progress of Bullock who was a student teacher on Russell's course on the methodology of teaching physics. In keeping with the observations made in the study carried out with the group of student teachers involved in the baseline study, Bullock realised the importance of gaining teaching experience as he charted his own progress through the course and points to the difficulty he had with trying to identify what was good about his teaching:

> "When I return (to teaching) in January, I, like everyone else, will be learning from experience and consolidating ideas for four months. But what I find exciting is the notion that I get to go back to Waterloo and apply what I've learned about teaching to my own learning....As a student-teacher, I found positive reinforcement very beneficial to my professional development. Although I usually knew when I could have improved things in my lesson, I often found it hard to identify things that I did well"

In the exchange of e-mails between tutor and student teacher (Russell and Bullock 1999), one of the main problems encountered by the student teacher was the lack of confidence possessed by the student teacher and the need of support and encouragement from the tutor.

> "I was very apprehensive when I started teaching a general math class because I did not have any experience with classes at the general level...... My apprehension came though in my notes and Tom (the tutor) provided some words of encouragement for the route I was taking with the class. Again, it was extremely important for me to have the support both from and excellent associate teacher and from a faculty member"

One of the interesting facets of the Russell and Bullock study (1999) was the fact that the tutor provided an enormous amount of support to the individual student teacher on a one-to-one basis every day. Thus, advice and support were dispensed via e-mail, lesson by lesson, as problems were encountered by the student teacher. Whilst, this is possible for the purposes of a research study, it would be very difficult to continue this level of support to an entire class of student teachers participating in a science methodology programme. The words of encouragement from the tutor to the student teacher are most impressive.

> "You were nervous and that struck you as odd. That's what jumped off the page at me, along with the incredibly creative teaching materials you provided for the class. We so easily think that something is wrong when we are nervous. But isn't it all the anticipation of the unknown? ...Welcome to the human race! (I give you credit for recording the nervousness here..) I think being nervous in a situation like this is incredibly positive and important. There would be something wrong if you weren't nervous"

Without doubt, the realisation among the student teachers of their own shortcomings is one of the strongest themes to emerge from the analysis of the baseline data. This theme has an equally strong resonance throughout the educational literature in this area of research.

6.10 Other observations

If one takes an overall view of the data analysis, it is clear that there are some strong consistencies between what the student teachers say in the questionnaires and interviews and also carry out in the classroom. For example, when giving their opinion on their view of teaching, the use of audio-visual aids and everyday examples is consistently high in all the data analysed. Similarly, when discussing their views of science teaching, there is strong agreement on the importance of practical work in both interview data and questionnaire data. However, there are also some major inconsistencies between what the student teachers say in the questionnaires and interviews and actually carry out in the classroom. For example, in the baseline questionnaire data, almost all (92%) of the student teachers rate pupil participation as being important to bringing about effective learning in science. However, it is clear from an analysis of the classroom observation data that there is pupil involvement in only about half of the lessons. Similarly, in responses to the baseline questionnaire, 50% of the student teachers mentioned the need to encourage pupil opinion. In fact, it is clear from the baseline observation data that encouragement of pupil opinion was observed in only a minority (8.3%) of classes. This type of inconsistency is also reported by Haney and McArthur (2002) and in research carried out by Fischler (1999):

> "For many student-teachers and beginning teachers who, prior to their teaching, have stated conceptions that are closely related to learning processes, this turning to decisions stressing students' actions means a gulf between their instructional intentions and their actual behaviour."
>
> (Fischler 1999, p. 183)

Dreyfus and Dreyfus (1986) explain this inconsistency in terms of the student teacher being placed on level 1 (novice) of their five-stage model of skill acquisition. The student teacher in the Dreyfus and Dreyfus model is characterised by "rigid adherence to taught rules or plans, little situational perception and no discretionary judgement" (Eraut, 1994 p. 124). Thus, while the student teachers may say it is important to carry out activities like involving pupils in the lesson, encouraging pupils' opinions and ideas and using lots of different teaching strategies, in practice this does not happen. Dreyfus and Dreyfus (1986) explain the reason for this by saying that the student teacher is like a novice who rigidly sticks to certain rules and does not have the judgement to deviate from this course of action:

> "The beginning teacher wants to do a good job, but lacking any coherent sense of the overall task, he judges his performance

> mainly by how well he follows learned rules. After he acquires more than just a few rules, the exercise of his skill requires so much concentration that his capacity to talk or listen to advice is severely limited".
>
> (Dreyfus and Dreyfus, 1986 p. 22)

This type of inconsistency is also noted by Borko et al. (1992) when they compare the classroom practice of the student teachers with the expert teachers. They describe the meticulous detail with which one of the student teachers prepared his lessons:

> "Steve prepared detailed written plans for each lesson, usually on the night before the lesson. His plans followed a format provided in his teacher education program and included objectives, lesson outline with procedures, list of resources, assignments for students, reminders or special notes to the teacher, and sections for student evaluation and self-evaluation. Notes to himself included reminders about pedagogical strategies, diagrams to draw on the board, and subject matter content".
>
> (Borko et al., 1992 p. 65)

However, when the lessons were observed by the researchers, a very different picture emerges of a student teacher very dependant on the textbook with little or no time devoted to explaining concepts:

> "Although Steve seemed to be aware that most students [pupils] do not learn from books without the assistance of teachers, his teaching did not reflect that awareness. He relied heavily on the text during class sessions and did not seem to know how to explain concepts to others. In fact, fieldnotes for the entire observation cycle do not contain a single example of explanation of a concept, although there were several occasions on which such an explanation would have been appropriate". (p. 65).

Finally, in the study carried out by Peterson and Treagust (1995), they found that even though the student teachers recognised the importance of the pupils' views, this recognition was not always reflected in the classroom practice:

> "Five pre-service teachers were still teacher directed in their view of student learning and did not consider the prior understanding of the learner. Two preservice teachers recognised that students do have views which need to be

> identified, although one who recognised the need to assess prior knowledge was willing to accept student views at the beginning of his lesson, and then redirect the students towards the science ideas to be considered in the lesson"
>
> (Peterson and Treagust, 1995 p. 296)

6.11 Summary

This chapter has undertaken a detailed examination of the data gathered in the baseline study. In general, the picture that emerges of the student teachers in this baseline study is one in which the majority of student teachers taught their pupils with a great emphasis on learning scientific content – mainly definitions and facts. There was little attempt at enquiry-based learning. In fact, pupil involvement in the lessons (even to a small extent) was only observed in about half of the lessons. The variety of teaching methods used was limited with most of the time spent on explaining theory. There was a general belief among the student teachers that good presentation would overcome the problems that pupils had in understanding difficult ideas. Audio-visual aids (overhead projector, charts and flashcards) were commonly used by the student teachers. In addition, there was a general lack of recognition among the student teachers of problems with pupils' understanding persisting beyond the lesson.

In general, the student teachers showed in their teaching an over-emphasis on content to the detriment of understanding. The questioning of pupils in class by the student teachers mainly emphasised the recall of previously learned material – closed questions rather than open-ended questions were usually asked. The student teachers felt that terminology was a difficult area and spent a lot of time in class concentrating on this area. It was clear that the student teachers showed a great dependence on the textbook and, in general, did not deviate from the material outlined in the standard textbooks.

There are some strong consistencies between what the student teachers say in the questionnaires and interviews and carry out in the classroom, e.g. use of audio-visual aids and everyday examples. However, there are some major inconsistencies between what the student teachers say in the questionnaires and interviews and carry out in the classroom, e.g. pupil participation and encouraging pupil opinion.

It was felt by the student teachers that a good classroom climate was created by teacher enthusiasm, encouraging pupil opinion and having strict but fair discipline. Most of the student teachers felt that giving everyday examples in their teaching helped to bring about effective learning in science. Practical work was used in only about half of the lessons. The practical work consisted mainly of teacher demonstration experiments.

There was a strong sense of realisation among the student teachers of their shortcomings in terms of their own subject knowledge and experience of teaching. A lack of subject knowledge was observed among a significant number of the student teachers. Overall, the student teachers did not have views on how to teach particular science topics. Local conditions like the form of assessment, assistance obtained from other teachers and pupil literacy affected the style of teaching displayed by the student teachers.

CHAPTER 7

Assessing the Effectiveness of the Intervention Package

7.1 Introduction

The strategy for the assessment of the effectiveness of the Intervention Package was discussed in chapter 5. Arising out of this discussion, it was decided to assess the Intervention Package using the three themes common to the models for educational evaluation discussed, i.e. (i) ***awareness and provision of information and resources***, (ii) ***new teaching strategies and skills*** and (iii) ***attitudinal factors***. (There is overlap in places between some themes and these will be pointed out as they are encountered.) The post-intervention data has been analysed using the same framework used to analyse the baseline data. This data will be discussed in the context of the above three themes. Having analysed and discussed the data, it should be possible to judge how the changes observed in the post-intervention student teachers "measure up" in terms of the models of educational evaluation. It should also be possible to have a much clearer perspective on the extent to which the aims and outcomes of the Intervention Package have been achieved. Bearing in mind the aims of the Intervention Package, it would seem reasonable to expect the Intervention Package to have more impact in certain areas of the analysis framework than in other. Thus, for example, one would anticipate that student teachers' view of learning and view of science teaching (including how to teach particular topics) are more likely to alter than, for example, aspects of local conditions. The emphasis in this chapter is on those areas where change is likely to be observed. However, where changes have been observed in other areas which seem to relate to the aims of the Intervention Package, these have also been included in the analysis.

This chapter draws on evidence from:

- Questionnaires completed by the student teachers at the end of the academic year and also five months after the completion of their Higher Diploma in Education.
- The baseline and post-intervention data (drawn mainly from observations, interviews and lesson plans).
- Evidence from the Intervention Package sessions.

7.2 Awareness and provision of information and resources

In the course of introducing the Intervention Package to the student teachers, various examples of resource materials were utilised during the sessions. For example, in Session 1 the student teachers worked with diagnostic tests (student activity 1), used cartoon drawing to represent various views of teaching and learning (student activity 2) and studied paired statements about teaching and learning (student activity 3). Similarly, in session 2, the student teachers presented to their peers a summary of a research paper in the area of pupil misunderstandings that they had studied (student activity 4), build up a hierarchy of chemistry topics in order of perceived difficulty (student activity 5) and towards the end of the session participated in a discussion on some misunderstandings that pupils have and common factors relating to misunderstandings (student activity 6). In session 3, the student teachers reported on their ideas relating to the implications of pupils' misunderstandings for teaching (student activity 7), examined samples of classroom materials prepared to help overcome misunderstandings in chemistry and prepared diagnostic questions and a Concept Cartoon on a topic (student activity 8). Finally, the student teachers discussed strategies to elicit pupils' prior understanding as well as strategies to teach a particular topic (student activity 9).

In the first activity of Session 1, the student teachers discussed the results of the diagnostic tests they had carried out with their first year pupils (12 – 13). Each student teacher then completed (in writing) the sentence: "The thing that surprised me most when I read the scripts was......". Typical responses received from the student teachers were:

> "There was no one clear majority answer in any of the questions. The explanations they gave weren't very logical".

> "That there was no definite answer to any question. Every question had a good selection of pupils choosing either A to D."

> "The students have a lot of preconceived ideas on the concepts of science before they even began to study science. The students appeared to be just guessing the answers and when asked to elaborate on their answers, then the majority of them would reply 'it looks right'. No logical thinking at all."

> "That 72% of students thought that in question 2, water splits into oxygen and hydrogen when it evaporates"

> "Such a wide range of answers. Large groups of students got the same wrong answers – indicating a consistent level of group misunderstandings."

One of the planned outcomes from session 1 was that the student teachers would "appreciate that pupils' learning in science is affected by their own ideas that they bring to science lessons". It would appear from the above replies that

the student teachers' awareness of this problem was heightened by their experience of reading the pupils' answers to the diagnostic questions.
In order to gather data from the student teachers relating to their overall views on the Intervention Package, a detailed questionnaire (Appendix VIII p. 434) was issued to them towards the end of the academic year (April).

The levels of awareness of the student teachers regarding the provision of information and resources on the teaching of difficult ideas in science may be gauged from their replies to question 5. This question probed the extent to which the student teachers made use of the various resources discussed as part of the Intervention Package. The student teachers were asked to indicate the approximate extent to which they made use of various resources when teaching difficult ideas in science. The results are summarised in Table 7.1 (page 299) and displayed in Figure 7.1 (page 300).

It is interesting to note that all the student teachers reported that they had used diagnostic questions and questionnaires in their teaching practice. Only one student had not used Concept Cartoons and only two student teachers had not used the strategy of obtaining written statements from pupils or used posters in their teaching. Thus, the 5 most popular strategies reported by the student teachers were diagnostic questions, questionnaires, Concept Cartoons, obtaining written statements from pupils and posters.

	Never (No lesson)	Occasionally (1 – 3 lessons)	Frequently (4 – 6 lessons)	Often (More than 6 lessons)
Card sorting	14	6	1	1
Checklists	7	11	3	1
Concept Cartoons	1	6	8	7
Diagnostic questions	0	5	6	11
Discrepant event.	10	6	4	2
Obtaining written statements from pupils	2	11	8	1
Posters	2	2	8	10
Predict and explain	3	8	3	8
Questionnaires	0	7	8	7
Socratic questioning	3	8	8	3
Thought experiments	3	9	5	5
Other (Please specify)		1 human model	1 group work	1 getting pupils actively involved (sticking labels on posters etc.)

Table 7.1 Summary of extent to which student teachers reported that they used various resources and teaching strategies when teaching difficult ideas in science during their teaching practice.

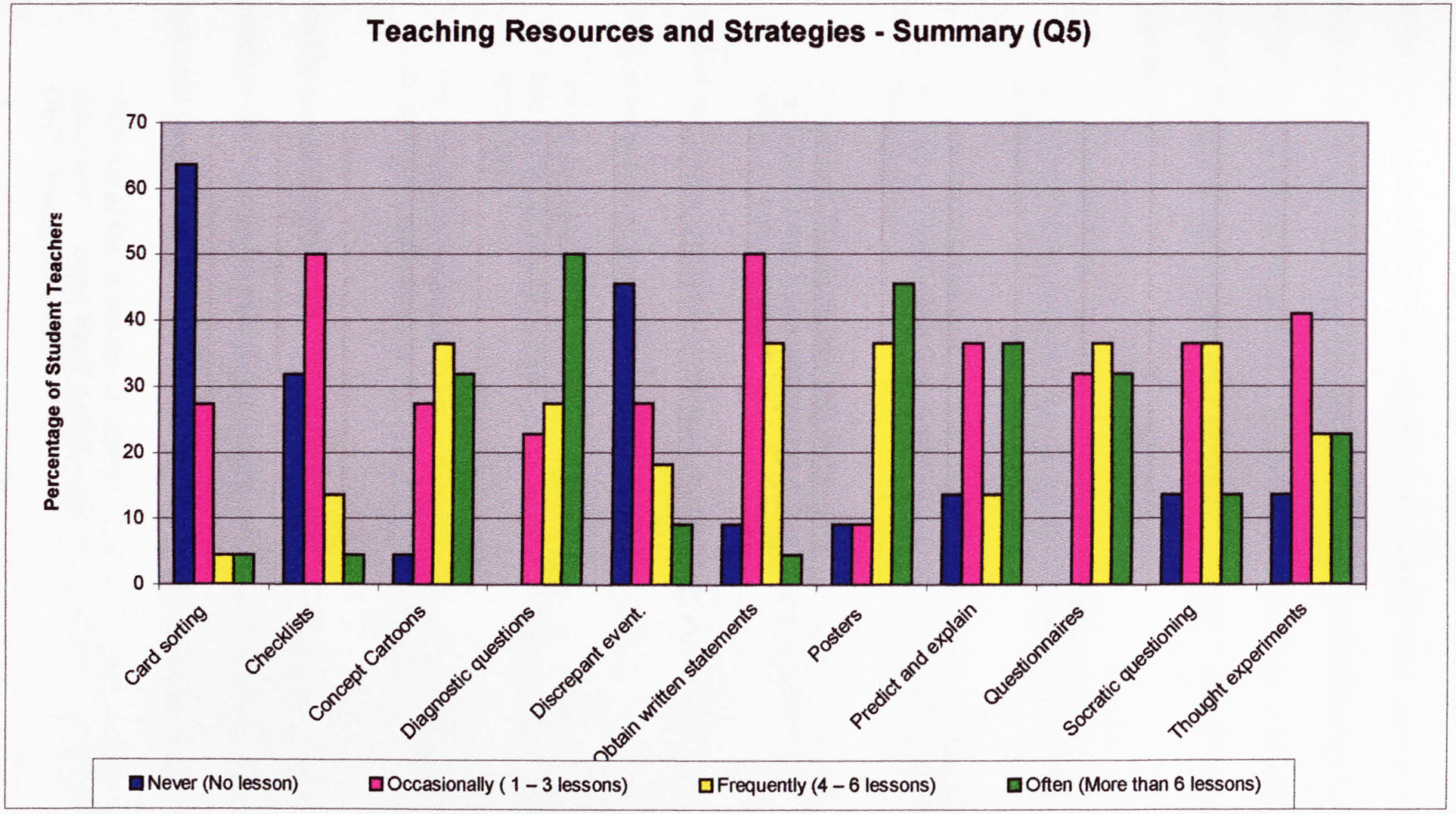


Figure 7.1 Summary of responses from student teachers when asked to indicate the extent to which they made use of various teaching strategies when teaching difficult ideas in science during their teaching practice.

In response to the final question on the questionnaire, some of the student teachers commented on the importance of being made aware of the problem of pupils' misunderstandings as well as awareness of resources available to tackle the problem. In addition, some student teachers voiced opinions on some of the specific resources introduced to them. The following are typical comments:

> "These sessions were very useful in allowing teachers to be aware of the difficult ideas in science. I feel awareness is the key for all teachers."
>
> "Very useful sessions as truly highlighted to me the importance of being aware of what the pupils are starting at in the teaching of new topics."
>
> "Concept Cartoons are the most outstanding in-road in this area and I relied on them extensively. Diagnostic questions were good with the senior cycle."

Two of the student teachers referred specifically to the impact of session 1 on their awareness of the problem of misunderstandings:

> "An awareness of common problems areas and gave the ability to see possible trouble areas in the future. Constructivist approach was very good."
>
> "This session [session 1] heightened my awareness of the existence of misunderstandings in the teaching of science."

In the same questionnaire, the student teachers were asked (question 6) to indicate the resources they used to help prepare the lesson plans. It is clear from the responses that a wide variety of resources were used:

> "The syllabus, a variety of textbooks to help research the topic. In the classroom, I used flash cards, posters, tangible objects when possible, OHP, Powerpoint etc."
>
> "Textbook, revision book, Concept Cartoons, the internet."

> "Concept Cartoons, Diagnostic questions, Resource Centre, experimental work in order for the kids to be actively engaged. Constructivism material."
>
> "Concept Cartoons, textbooks (especially), 'Pupils ideas in science' (R. Driver et al).
>
> "Ros Driver's books, any book I can find on teaching science. Teachers that are already established e.g. five years plus experience."
>
> "Questionnaires, concept maps charts, practical apparatus where possible."
>
> "All of the Junior Certificate books. Chemistry pack from the Resource Centre. Also textbook from U.K. and Internet."

In a final questionnaire issued to the student teachers in September (after they had graduated), the student teachers were asked to rank on a scale from 1 – 5 various factors to bring about effective learning in science. (Questionnaire in Appendix IX page 437). . The overall rankings are shown in Table 7.2 (page 303) and represented in chart form in Figure 7.2 (page 304). The number of students who ranked each factor as rank order 1 is shown in Figure 7.3 (page 305).

It is interesting to note from Figure 7.2 that "find pupils' knowledge at start" is the factor that received the most number of rank orderings 1.

RANK ORDER	1	2	3	4	5	Total hits
Encourage pupils' ideas	1	0	2	2	1	6
Find pupils' knowledge at start	7	1	1	0	2	11
Good presentation	1	1	1	0	1	4
Know material well yourself	2	7	0	1	0	10
Maintain pupils interest	2	4	2	0	2	10
Practical work	1	1	2	3	2	9
Project work	0	0	0	0	0	0
Pupil participation	2	2	1	4	2	11
Regular homework and worksheets	0	0	1	2	4	7
Strict but fair discipline	0	0	1	0	1	2
Teacher enthusiasm	4	2	3	1	1	11
Use audio visual aids	0	0	0	1	3	4
Use everyday examples	0	2	6	6	1	15
Vary teaching methods	1	1	1	1	1	5
Vary topics	0	0	0	0	0	0

Table 7.2 Overall ranking of factors to bring about effective learning in science chosen by student teachers (N = 21).

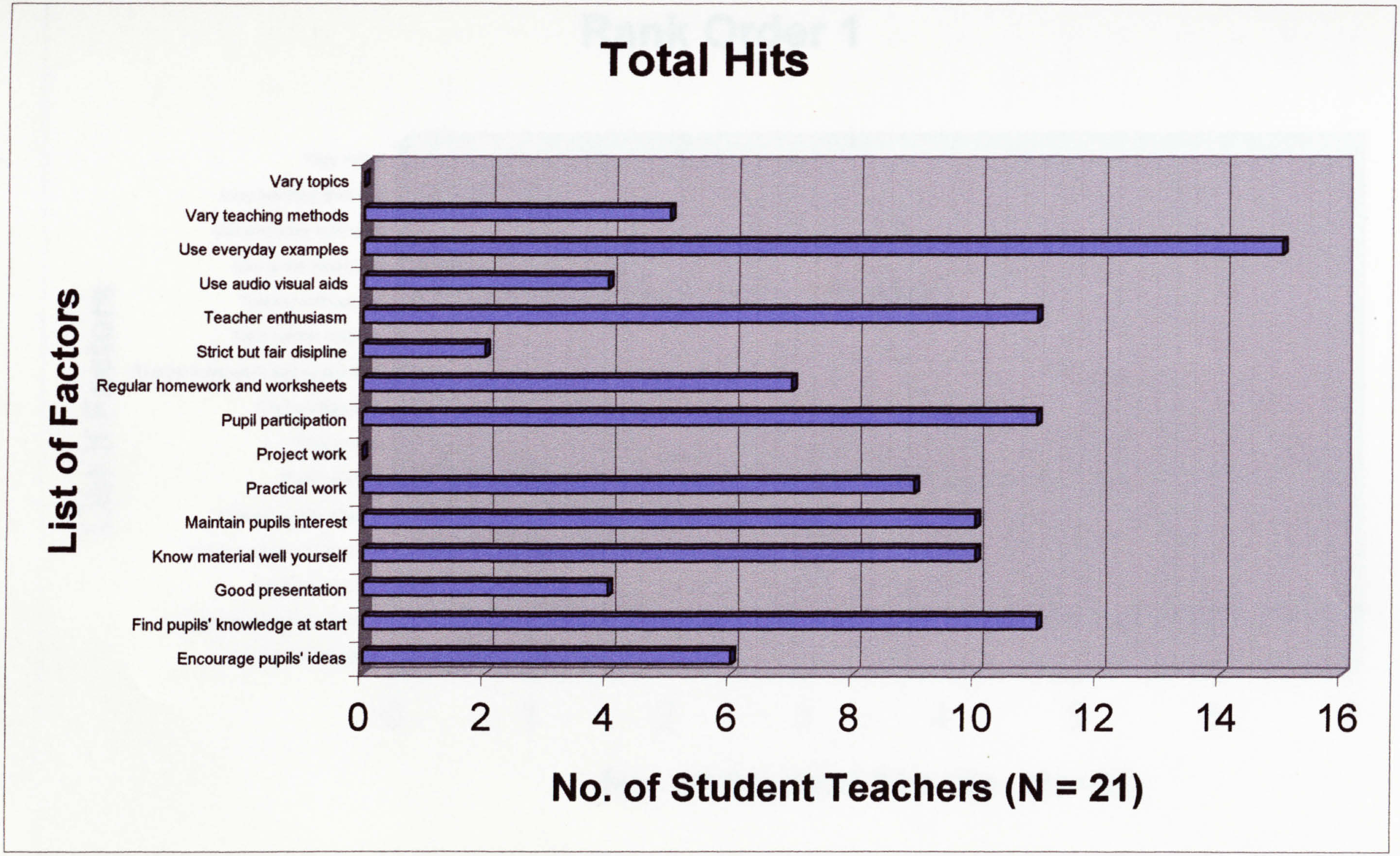


Figure 7.2 Overall ranking of factors chosen by student teachers in final questionnaire.

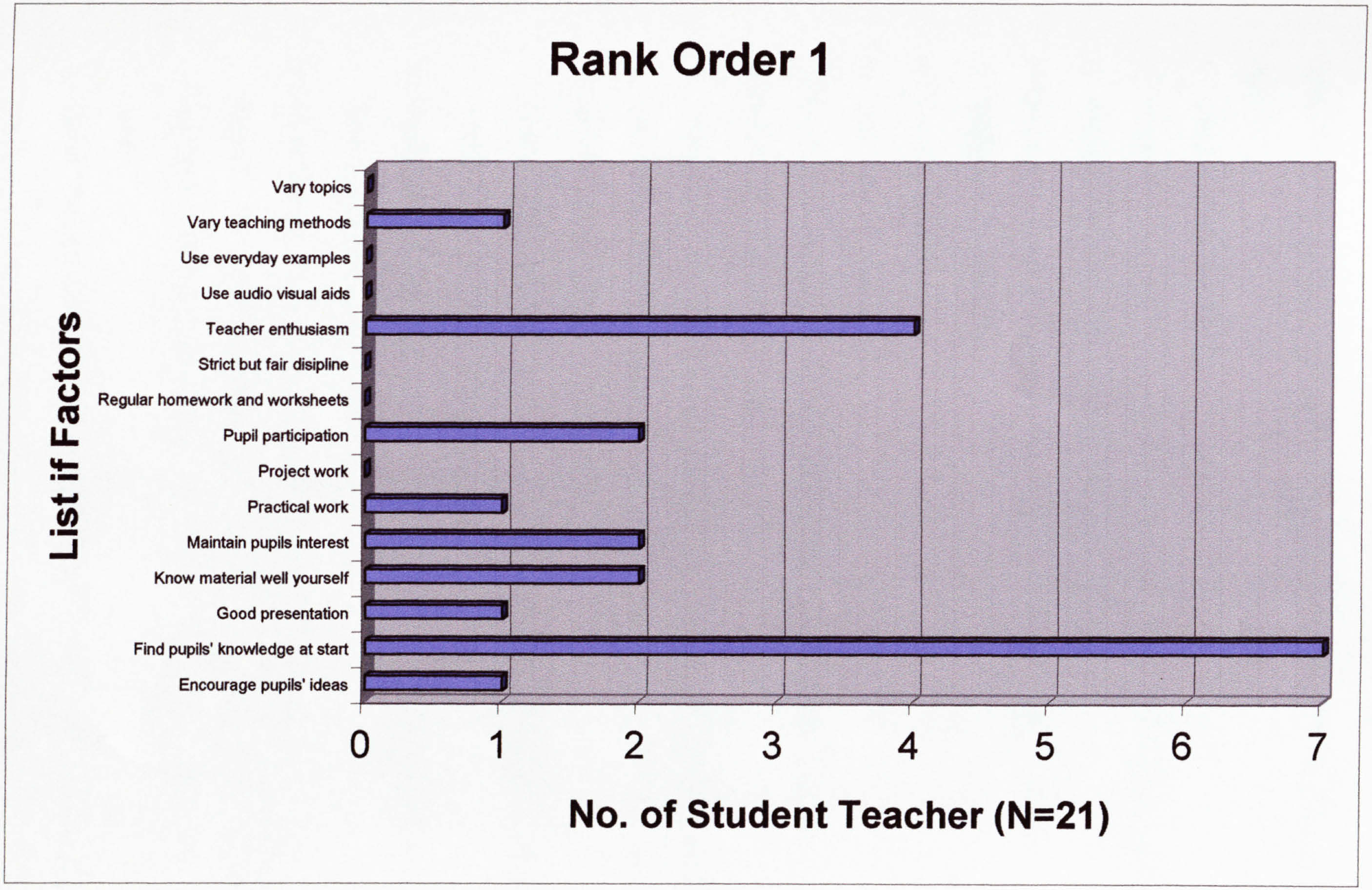


Figure 7.3 Factors chosen in rank order 1 by student teachers in final questionnaire.

Note from Figure 7.2 that the top three factors as listed by the student teachers are:

1. Use everyday examples.
2. Teacher enthusiasm / Pupil Participation / Find pupils' knowledge at start
3. Maintain pupil interest / Know material well yourself.

In the baseline data (Figure 6.2 page 232), the top three factors were:

1. Maintain pupil interest.
2. Pupil participation
3. Use everyday examples.

There are some differences between the answers of the post-intervention students and the baseline students:

- ***Find pupils' knowledge at start*** *(of lesson)* does not appear in any of the responses in the baseline data but is in joint second place in the order of priorities in the post-intervention data.
- ***Use everyday examples*** is in first place in the post-intervention data but is in third place in the baseline data.
- ***Maintain pupil interest*** is in first place in the post-intervention data but is in third place in the baseline data.
- ***Vary the topic*** and ***project work*** were not mentioned by any student teacher in the post-intervention data but were cited as important factors by a significant number (about 40%) of the student teachers in the baseline study.
- Whilst the ***use of audio-visual aids*** was rated by less than 20% of those in the post-intervention study, it was rated as an important factor by 50% in the baseline study.

- The importance of ***knowing the material well yourself*** was mentioned by about half of the student teachers in the post intervention study but not mentioned by any of the teachers in the baseline study.
- ***Regular homework and worksheets*** were cited as important factors by about a third of the student teachers in the post intervention study but no student teacher in the baseline study mentioned worksheets and only two student teachers mentioned the importance of homework.

There are also some similarities between the post-intervention data and the baseline data:

- ***Pupil participation*** is in second place in both sets of data.
- Areas like ***practical work, vary teaching methods, teacher enthusiasm*** and ***encourage pupil opinion/ideas*** were listed by significant numbers of student teachers in both sets of data.

These similarities and differences will be discussed at a later stage (chapter 8) in the context of data arising from interviews, classroom observations and lesson plans.

In general, the type of awareness shown by the student teachers is very similar to stage 2 of the Harland and Kinder (1997) model (*informational outcomes*) in that the student teachers, having been briefed about the background facts of the programme, are now knowledgeable about the materials and resources that can be used in various teaching strategies in the classroom. It is also similar to the *awareness* stage of the Joyce and Showers model in that the student teachers show a realisation of the existence of the various resources and have focussed on them.

Given the fact that the Intervention Package was implemented in November and the final questionnaire completed in the following September, it is heartening to see that a high level of awareness existed among the student teachers in terms of how much they remembered about the various teaching resources and strategies. In terms of the CBAM model, the student teachers have reached levels I (*orientation*) and II (*preparation*) of the *Levels of Use* index, i.e. they have shown an interest in the innovation (level I) and have begun to prepare to use the innovation.

But how does this level of awareness translate into practice in the classroom? In keeping with the distinction made by Harland and Kinder (1997 p. 73) between the provision of resources and their impact on practice, this question will be discussed in section 7.4. Clearly, there is some degree of overlap between sections (i) and (ii) as the levels of awareness of resources should be reflected in the teaching strategies discussed in both lesson plans and interviews and also observed in the classroom. To avoid unnecessary repetition, further discussion of levels of awareness and resources will be deferred to section 7.3. since a better position to further judge levels of awareness will be achieved when discussing teaching strategies (interview data, observational data and lesson plan data)

7.3 New teaching strategies and skills

In the light of the high level of awareness of information and resources (section 7.2), it is important to assess the level of classroom implementation of the various teaching strategies covered in the Intervention Package.

In this section, the questionnaire data are first examined to analyse the views of the student teachers on the teaching strategies and skills needed to teach difficult ideas in chemistry. Then the lesson observation data, the interview data and the lesson plan data are examined in an attempt to get a clear picture of how the views of the student teachers translated into their classroom practice. This data will be analysed under the same headings used to analyse the baseline data, i.e. **view of teaching, view of science teaching, view of how to teach particular science topics** and **local conditions.**

In questions 2, 3 and 4 of the end-of-term questionnaire (Appendix VIII page 434), the student teachers were asked to write down what aspects of the first, second and third sessions they drew on in their teaching practice. In response to the question on session 1 (dealing with pupils' learning in science), the student teachers were very positive and very clear in their responses:

> "Getting to know the students misconceptions before teaching topics is very important."
>
> "Practically, reaching the students initial level and how to move them on from this to where they understand the actual concept scientifically."
>
> "I started to incorporate diagnostic questions into my classes."
>
> "It opened up my eyes to the misunderstandings students had and the implications for me as a science teacher."

> "Need to ask students firstly about what they thought about the topic prior to teaching."
>
> "It made me appreciate that students had prior conceptions of various topics that need to be considered when planning my lesson."

Session 1 appears to have been successful in encouraging the student teachers to reflect on what is involved in learning and teaching science (session 1, aim 1)

In response to the question on session 2 (dealing with research findings and range of pupils' misunderstandings), typical comments received were:

> "The section reminded me of the common understandings that arise in the J.C. [Junior Certificate] science course. It helped me focus more on these areas".
>
> "The media and books play an awful lot of a part in misconceptions of kids. But you must build on their prior knowledge don't treat them like a 'tabulu rasa' or clean state."
>
> "Need for understanding, how to change pupils ideas"
>
> "Some of my students had difficulties not mentioned but I was aware that there could be misunderstandings".
>
> "It showed which areas were particularly misunderstood which gave direction to trying to overcome the misunderstandings".
>
> "The hierarchy [of chemistry topics] was useful in showing how difficult each subject (topic) was."
>
> "The hierarchy is important and necessary to implement"
>
> "Very useful, great insight gain. New tools to use, like questioning, starting from and getting them interested in the first place. Creating the need for understanding."
>
> "It made me aware of what students would find easy to comprehend and that which was going to be difficult so I can anticipate better where the difficulties are going to be like".

Clearly the second session appears to have some impact in making the student reflect on the fact that pupils have many misunderstandings in science (session 2, aim 2) and of the particularly acute problems with misunderstandings in chemistry (session 2, aim 3).

Finally, in response to the question on session 3 (dealing with teaching strategies to help overcome misunderstandings), the student teachers were also very positive and very clear in their responses:

> "Approaching the lesson plan with the student's misunderstandings in mind."
>
> "The use of various different teaching styles to incorporate into your everyday classroom climate, e.g., constructivism."
>
> "Constructivism – start where pupil is at (foundation)."
>
> "I'm not an original person. I don't think of innovating fresh approaches to teaching easily...... these were excellent as even I found them intriguing."
>
> "Gave me ideas for use in class e.g. diagnostic question, Concept Cartoons and posters."
>
> "The sample materials were particularly useful – as worksheets and ideas for worksheets."
>
> "The use of Concept Cartoons, discussion and experiments in the classroom."
>
> "Use of Concept Cartoons, diagnostic questioning, questionnaires etc."
>
> "Concept Cartoons, posters."
>
> "Strategies to overcome misunderstanding and put cognitive responsibility on the student to understand i.e. cartoon."
>
> "The usefulness of Concept Cartoons and diagnostic questions were two major aspects of this session that I drew upon."

> "Using Concept Cartoons and the 'what if …?' type of approach in class made both the students and I more aware of learning difficulties."
>
> "Diagnostic questions"

It is clear from these responses that the student teachers are capable of making suggestions for classroom practice which help to overcome misunderstandings (session 3, outcome 2). In the final questionnaire completed by the student teachers, in addition to ranking various items, the student teachers were also asked to comment on anything they thought was missing from the list of items needed to bring about effective learning in science. Some examples of comments made were:

> "Good preparation before each class. Check at the start of each class how well they remember material from the last lesson. Encourage pupils who have incorrect ideas to try to see where they are misinterpreting the information, instead of telling them they are wrong."
>
> "The pupil is the hub of education, they should construct their own knowledge drawing from what they already know and the experiences they had. The teacher must be enthusiastic, because there is nothing worse than having a boring teacher. All of the above are of importance and they are all interweaved."
>
> "Encourage students to be challenged (cognitive conflict), i.e. follow statements through to a conclusion. Use of analogies, prediction and explanation of why experiments did what they did. Be sensitive to boredom and confusion set the correct pace. Convey the importance of what is being taught."
>
> "Use of open-ended questions. Rewarding hard work."
>
> "Identify students' misconceptions before lesson. Evaluate the successfulness of the lesson and change the lesson to increase its effectiveness."
>
> "Encouraging pupils to think for themselves. Use of ICT (by pupils), especially regarding data manipulation and processing of practical results. Pupil use of the internet for learning support, research and project work."

The above are further examples of suggestions for classroom practice to help overcome misunderstandings in chemistry (outcome 2, session 3). In the questionnaire (Appendix VIII page 434) issued to student teachers at the end of term, they were asked (question 6) to describe the ways in which they used materials relating to teaching difficult ideas in physics and biology in their lessons. Almost all of the student teachers described some use of the materials in the physics and biology components of the syllabus:

> "In physics (mass, density and motion) I used OHP, Concept Cartoon on a poster, PowerPoint, diagnostic questions, experimental work for kids and related it to them in everyday life e.g. Cobh harbour big boats how do they float etc."
>
> "Physics-Concept Cartoons, textbooks as above."
>
> "For physics I used Concept Cartoons, discussions, diagnostic test and Socratic questioning. In biology less so, as I feel more students would have a more intuitive view of biology and biological processes."
>
> "I used Concept Cartoons, posters, experiments and Socratic questioning dealing with the topic of light."
>
> "Concept maps-asking the students opinions and in why they chose their choice of answers. Charts, flashcards. Questionnaires."
>
> "The cell analogies i.e. cell tissue organ system etc. Students write half a page on their journey through the cell. Physics- total constructivist approach, start with misconceptions, create 'acoir' (Socrates) and the need to learn then predict observe explain reinforce by teacher."
>
> "Used Concept Cartoons in teaching of measurement, energy and heat."
>
> "I used Concept Cartoons, posters, I would have like to have used card sorting where as to help my weaker students, but I was unable to due to the constraints. Perhaps in the future."

Thus, the student teachers were able to transfer some of their knowledge and skills on the teaching of difficult ideas in chemistry to the biology and physics area of the curriculum (session 2, outcome 1). It is interesting to note that none of the student teachers reported any problems with the *management concerns* (stage 3) of the CBAM model. In the research carried out that led to the development of this model, it was found that one of the most common factors leading to the failure of an innovation was the problem of implementing the innovation in a satisfactory manner in the classroom due to logistical and administrative problems. Hord (1987) summarises the problem as follows:

> "One of the most common problems afflicting school improvement efforts has been the consistent failure to recognise the existence and significance of this stage. During this period, then, teachers are typically frantic and frustrated; their connection with the innovation may be tenuous, and their use of it superficial, since most of their time and energy are taken up with basic material and logistical preparations."
>
> (Hord, 1987 p.102)

The fact that the student teachers have ongoing tutorials with their own supervisors throughout the academic year may have assisted them to overcome the problems outlined above. However, none of their supervisors reported any increased levels of help being required by the student teachers.

7.3.1 View of teaching

Whilst the views of the student teachers as expressed in the questionnaires are obviously of interest, clearly it is also of importance to investigate how these views translate into classroom practice. This area will now be studied under the same categories as used in the baseline analysis, i.e. **nature of presentation, classroom climate** and **links to everyday life.**

(i) Nature of presentation

(a) Audio-visual aids.

When the 16 student teachers involved in the post-intervention study were observed teaching difficult ideas in chemistry, all of them used some form of audio-visual aid in the classroom. In fact, all of the student teachers used at least **two** types of audio-visual aids and 15 of the 16 student teachers used at least **three** types of audio-visual aids. (In the baseline study 83% of the student teachers used audio visual aids). The most common audio-visual aids used were overhead transparencies, flash cards, posters, Powerpoint presentations, CD ROMs and the blackboard. This high use of audio-visual aids in the classroom was reflected in the lesson plans where the student teachers specified the audio-visual aids being used in the lesson and included items like overhead transparencies, flash cards and posters.

An analysis of the interview data clearly shows the great sense of reliance that the student teachers placed on audio visual aids. When asked about how they prepared the lesson dealing with a difficult idea in chemistry, the student teachers spoke at great length about the types of audio visual aid they had prepared. For example, Aoife, when speaking about the lesson on physical changes and chemical reactions, was very enthusiastic about the posters she had prepared:

> "It's very important to have a lot of colourful stuff in your lessons. Because there's some children who have a very, very short attention span and that's the only thing that'll possibly attract them into the lesson. So that would be one of the reasons I'd use them [audio visual aids]. And I just feel that it does attract the other students in general anyway. And I like to hang the posters up in the lab and leave them afterwards, so they can see them afterwards and not just on the day, so it would refresh their minds afterwards. The other teachers even said to me that they could see the other kids in their classes coming in and reading them, and it kind of revises it for them. So that's one of the reasons I like to make the posters.....It just makes the students realise that you're interested in the lesson as well, that you're doing it for them, and it's not just a case of you walking into the room, standing up there for 40 minutes and reading out of a book. Anyone can do that, but I think that if you're really, really interested, you would make the posters. Not saying that I'm a super-teacher myself." - Aoife

Similarly, Sean gave an introduction to the Periodic Table using the animation features of Powerpoint. This helped to capture the attention of his large group of 12 –13 year old pupils and settle them down. It also enabled him to highlight various areas of the Periodic Table and zoom in on some features. When asked about his use of this technology, he was clearly very enthusiastic about it:

> "PowerPoint is brilliant I think because it looks good, it's very clear, you can use it again as many times as you want, you can make adjustments. You can use Internet, you can scan, you can do so many different things."

It is interesting to note that when attempts were made to elicit responses from the student teachers about their view of teaching, they always referred to the topic being taught. For example, when Seamus was asked what he thought was good about the lesson he gave on electrochemistry, he referred to the fact that he had made good progress with the pupils by using posters and charts to explain ionic movement in the solution and the reactions occurring at the electrodes:

> "The many audio-visual aids used in it. Especially just the straightforward, schematic, simplistic manner that it was able to be taught to them in. to not confuse them and not make it look like black magic to them, I think that's the problem a lot of the time with electrochemistry".

A similar finding was made by Brown and McIntyre (1993) who found that the teachers interviewed tended to view their teaching in terms of what was being achieved in the classroom:

> "All the teachers evaluated their lessons not only in terms of maintaining particular Normal Desirable States but also in relation to promoting specific kinds of Progress. Progress goals were ...the development of pupils' knowledge, understanding, skills, confidence or other attributes......generating a product ......or completed exercise.....accomplishing a series of planned activities".
> (Brown and McIntyre 1993, p. 61)

Padraig gave a lesson on the structure of the atom to a group of 14 year-old pupils using a combination of overhead transparencies, posters and worksheets. When asked about how he prepared for teaching this difficult topic, he spoke enthusiastically about the audio-visual aids he had prepared:

> "And the poster then adds an overall picture of what we were talking about, which I hope would give them a better understanding in the end.On the poster we were talking about the atom, and I explained to them that the protons were located in the nucleus, and the electrons were located on the outside of the atom, and the protons and neutrons were in the centre, in the nucleus. So it was just to give them a better idea that I gave them that sheet of paper, and I asked them to fill in the blank spaces......"

One of the most notable features to emerge from an analysis of the post-intervention observation data and the corresponding lesson plan data was the use of Concept Cartoons by 8 of the 16 student teachers. For example, Aoife started her lesson on physical changes and chemical reactions with a "home made" Concept Cartoon showing an egg being fried. When asked about this in the interview, she was very confident of the effectiveness of Concept Cartoons with weak pupils. (The issue of the use of Concept Cartoons with weak pupils was not one that was addressed in the Intervention Package):

> "Well, I had used Concept Cartoons a few times before this, and I think they are actually very effective. Out of the whole methodology thing, I found them to be exceptional because I have a few students in my class who'd be kind of weaker than the average people, and I found it really woke them up. It was really able to give them an extra dimension to the lesson, and was an entry point to the lesson for them. But in saying that, I think it helped the other students as well, you know the students who are average ability and I suppose higher ability – if that's the word you'd use. I just felt, that it didn't make light of it, but it gave them an entry point into it, and it made it seem as if it was something relevant to them. You can bring something relevant into the lesson, and I thought something everyday like frying an egg would be something they could all relate to and all think about, you know?"

Roisin gave a lesson on solutions and started with a Concept Cartoon showing three people discussing what happens when sugar is added to water. When Roisin was asked in the interview about why she used the Concept Cartoon, she clearly felt confident of the usefulness of this type of audio-visual aid and also pointed to the advantage of getting pupils to give their own opinion about scientific ideas:

> "To be honest, I was surprised. I think it turned out to be more useful than I thought it would be, because I suppose until you mentioned them quite recently, I'd never ever thought of using a Concept Cartoon at all. I suppose it's handy for the children to see things in a picture they can represent, and then maybe see in the pictures. Because although they're cartoons, they have children around their ages, so that helps a lot rather than having older people or just having voices. The fact that they see pictures of people who are not so dissimilar from themselves. And that the cartoon people are freely giving their opinion, which mightn't automatically be right but still it's being given.

It is of considerable satisfaction that Concept Cartoons have so clearly impressed some of the student teachers to the extent that half of them have used Concept Cartoons in the classroom – the majority of them (70%) being designed by the student teachers themselves. The success of this teaching strategy is in keeping with the Harland and Kinder (1997) hierarchy of outcomes discussed in Chapter 5. The Concept Cartoons would be classified in this hierarchy as provisionary (third order) outcomes but would not have an impact on classroom practice unless higher order outcomes are present. It is clear from the questionnaire data, interview data, observation data and lesson plan data that Concept Cartoons created a certain amount of enthusiasm among the student teachers, i.e. motivational and affective outcomes (second order) in the Harland and Kinder hierarchy. Since the data clearly shows that value congruence outcomes (first order in hierarchy) also exist among the student teachers, then Concept Cartoons have a high probability of leading to a change in classroom practice.

(b) Resources and textbook reliance

In the analysis of the baseline data (section 6.4.1) it was clear that there was great reliance by all of the student teachers on the use of the textbook in the classroom. It was also clear from the baseline data analysis that the subject matter covered by the student teachers rarely strayed outside of what was covered in the textbook.

In the post-intervention analysis of interview data, when the student teachers were questioned about resources used to prepare the lesson, 8 of the 16 teachers referred exclusively to textbooks. For example, Kayleigh's lesson content was drawn exclusively from the school textbook and the corresponding revision textbook:

> "Well I suppose the first thing you look at is the textbook, and what the textbook says they should know, and then what I did was I got a

> revision book by [Name of author] for summarising the Junior Certificate syllabus. So I had a look at the questions at the end of each chapter to see what the students should be able to answer."

Similarly, Padraig saw little need to go beyond consulting the textbooks since they had all the necessary information but also admits that he consulted the internet for ideas:

> "Well in the textbook it shows what they need to know, what an atom is and the structure of an atom, and I thought I'd just pick out those two points and let them have the basics first of all. I got information from the Internet, and I got information from different textbooks".

Almost all of the student teachers showed complete faith in the school textbooks. Only one person, Amy, when questioned about the resources used in preparing the lesson, mentioned that she consulted the syllabus:

> "That would be the syllabus for the Junior Cert, their textbook, two other textbooks and the Internet for some descriptions of experiments that seem to have worked and that kids found interesting. And also that were accessible to me within what I had available to me in terms of time and locale."

Only 4 of the 16 student teachers (25%) mentioned that they consulted others to help them in the preparation of the lesson. This is some improvement on the baseline data where only 1 of the 12 student teachers (8% approx) reported asking one of the more experienced teachers in the school to help her. For example, Catherine reported in her interview that she got lots of help and ideas from the other science teachers in the school:

> "I got books out of the Resource Centre and I consulted other teachers and basically ... different resources and different books, different ideas out of books. The other teachers were very helpful as well in their ideas."

One of the student teachers, Aoife, reported that she consulted her younger brother for ideas!

> "Where? Well, my younger brother has a book at home called 'Horrible Science' and I borrowed books like that off him. He was

> always giving me ideas and saying 'Would you like to teach this tomorrow to your students?' And I suppose I got some stuff off the Internet as well, and some stuff I'd just seen myself when I was a student in college,

It was common for the student teachers who used Powerpoint in their lessons to report in the interviews that they used the internet as a source of ideas – particularly for obtaining graphics. For example, Daniel gave a lesson which was almost exclusively a Powerpoint presentation:

> "I consulted various textbooks: '[Name of textbook 1], The English and the Irish textbooks, '[Name of textbook 2]', "[Name of textbook 3], various textbooks anyway. I had a look on the web there to see if they had any graphics or anything like that. They're in short supply so most of their graphics on the Powerpoint presentation were created by myself"

One can certainly appreciate the fact that student teachers would feel very dependent on textbooks due to their own level of insecurity as they work their way through a curriculum for the first time. The subject knowledge, the depth of treatment of topics and the suggested activities contained in the textbook all combine to provide an important "crutch" to the student teachers' faltering steps! Thus, it is no surprise that the analysis of the post-intervention data shows only a small amount of progress in moving the student teachers away from the textbook towards other resources.

(c) Vary Teaching Methods

In the analysis of the baseline observation data it was found that the variety of teaching methods used was quite limited, with about 90% of class time spent explaining theory. An analysis of the post-intervention observation data shows a significant shift from an emphasis on teacher talking to activities such as discussions, pupil role play, practical work and diagnostic questions. A summary of the types of presentation used by each of the 16 student teachers and the classroom activities observed is given in Table. 7.3.

Student Number	Lesson Topic	Presentation Aids	Classroom Activities
1	**Atomic Structure**	Used flash cards, OHP, CD ROM and Powerpoint.	Class discussion, pupils used molecular models handed around, pupils used worksheet on atomic structure.
2	**Particle Theory of Matter**	Used OHP, flash cards, models, Concept Cartoon and lab apparatus.	Class discussion based on Concept Cartoon, student activity labelling solids liquids and gases, discussion on common properties, demonstration apparatus particles colliding - marbles, filling of balloon with air, bicycle pump, diagnostic questions.
3	**Solutions**	Used OHP, flash cards, posters, lab apparatus.	Closed questions, demo of solution formation and other expts, no pupil participation,
4	**Atomic Structure**	Used OHP, flash card, poster, Concept Cartoon.	Brainstorming exercise on "atom", class discussion, Concept Cartoon, cutting up carrot, class discussion, poster, class discussion.
5	**Chemical Formulas**	Used OHP, Concept Cartoon, data projector, CD ROMs, internet, apparatus, flash cards.	Classroom discussion on Concept Cartoon, molecular models used by pupils, apples and oranges and home made balance.
6	**Physical and chemical changes**	Used Concept Cartoon, flash cards, OHP, posters.	V. good discussion on Concept Cartoon, discussion on classification of examples, demonstration of chemical reactions.
7	**Physical and chemical changes**	Used Concept Cartoons, flash cards, posters, OHP.	Discussion on Concept Cartoon, lots of demonstration experiments, pupil practical work,

Table 7.3 Summary of Presentation Aids and Classroom Activities in post-intervention lessons.

8	**Solutions**	Used Concept Cartoons, flash cards, posters, OHP. demonstration expts,	Discussion on Concept Cartoon, pupils write down examples of solutions, pupil role play as particles, diagnostic questions on mass of solution, demonstration expts.
9	**Atoms and molecules**	Used Powerpoint, OHP, Periodic Table.	Closed questions, demonstration of molecular models.
10	**Electrochemistry**	Used OHP, flash cards, practical demonstrations,	Discussion, demonstration experiments,
11	**Particulate nature of matter**	Used Powerpoint, Concept Cartoon, role play, CD ROM.	Discussion on Concept Cartoon, role play of particles, demonstration experiments, used CD ROM for animation,
12	**Physical and chemical changes**	Used overhead projector, practical demonstrations, pupil practical work.	Demonstration experiments, pupil investigative practical work,
13	**Physical and chemical changes**	Used OHP, flash cards, demo expts, Concept Cartoon, worksheets.	Lots of demonstration experiments with pupil involvement as helpers, enthusiastic class – "cool" experiments, discussion on Concept Cartoon,
14	**Balancing Equations**	Used Powerpoint and blackboard	Closed questions.
15	**Atomic Structure and Per Table**	Used Powerpoint, Concept Cartoon, flash cards, diagnostic question, blackboard, role play.	Discussion on Concept Cartoon, role play, pupils fill out worksheets,
16	**Electrochemistry**	Used charts, blackboard, practical work, handout.	Demonstration experiments, pupil practical work, discussions, work sheet.

Table 7.3 (continued) Summary of Presentation Aids and Classroom Activities in post-intervention lessons.

The Concept Cartoons and diagnostic questions were mainly responsible for initiating classroom discussion. This strategy of using classroom discussion was a new feature that emerged from an analysis of the post-intervention data. Other new areas to emerge in the post-intervention lessons were brainstorming exercises, model building and role play. All of these areas were covered in Session 3 of the Intervention Package and linked to the following outcomes:

- Be capable of making suggestions for classroom practice which help to overcome these misunderstandings in chemistry.
- Be capable of developing teaching strategies to help overcome children's misunderstandings of ideas in chemistry.

For example, Kayleigh started her lesson on atomic structure with a brainstorming exercise dealing with the meaning of the term "atom". When asked about the reason for including this in the lesson, she was clearly convinced that it was a worthwhile exercise:

> "...I wanted to see if they knew the meaning of the word "atom" because there's a few of them who are very into science and watch the *Discovery Channel*......so that's why I asked them what's the smallest thing they could think of....what I was trying to do was get the students' own opinions, to make them think for themselves....I wanted them to come up with it themselves, to think of it themselves"

An example of the use of models in teaching was observed in a lesson given by Mary on chemical formulas. In this lesson, she used various items like apples, oranges, and spheres of different colours to show bonding occurring. When asked about this teaching strategy, she was very enthusiastic about its usefulness:

> "When I inter-linked the ionic bonding with the chemical formula they were just mesmerised. They could actually see the bonding occurring rather than just thinking it in their head. I can draw as much as I want on a poster or flashcard, one they see it for themselves, they can just consume it, they can really come to grips with it ...."

These new outcomes are explained by Harland and Kinder (1997) in terms of the ***impact on practice*** stage of their framework, i.e. the innovation has brought about changes in practice either directly by "the transfer of new skills to the teacher's repertoire in the classroom" (Harland and Kinder, 1997 p. 76) or indirectly via other outcomes. It is also similar to the second dimension of Fullan's (2001) model of educational evaluation "the possible use of new teaching approaches, i.e. new teaching strategies or activities" (Fullan, 2001 p. 39).

(d) Simulations and models

The only type of simulation used by the student teachers in the post-intervention study was role play. This type of activity was observed in only two lessons in the baseline study and in only three lessons in the post-intervention study. For example, in the post-intervention study, Sean used a group of pupils to act out the building up of the Periodic Table. Each pupil held a card giving information about a particular element and pupils were divided into groups according to these properties. Sean was asked where he got this idea from and described how he got the idea from a cartoon in a textbook:

> "Well, there was a cartoon I showed in the Powerpoint presentation and I got that in the book I got in the Resource Centre. And I thought that I could do that with them, I could give them the cards and they'll be doing that themselves. So they'll be able to see how it's arranged. I just came up with it myself really........I thought it worked well enough, yeah. I thought it was good."

Catherine was observed teaching a lesson on the particulate nature of matter in which she used the pupils to represent particles in the various states. When asked what gave her the idea of including this in the lesson, she referred to "active learning" in her reply:

> "I actually thought of it myself......It's just something I think from all this active learning and everything it must be rubbing off on me. It was the first thing that I thought of when I knew I was going to be teaching states of matter, it was the first thing I thought of was actually that they get up, it's such an easy thing to represent themselves, they all group together and form a solid and you know the way the classroom was laid out, I pretended that was the beaker in the middle, so for the liquid then they had to fill up the beaker and then the gas then I got a few of them up on the tables just to show. I thought it was very good and they really enjoyed it, they loved it."

Roisin gave a lesson on solutions and used role play in which the pupils represented particles before and after dissolving. When questioned about this in the interview, she referred to the material covered in the subject methodology course (Intervention Package):

> DK: "I noticed that you used role-playing in the class with the students. Could you tell me about the thinking behind that?"
>
> Roisin: "I think yet again that came from the methodologies that we had before Christmas. Remember when you were talking about the macroscopic and the microscopic? And I actually just thought with melting that what you can actually see is something changing from a solid to a liquid, but they'd never actually see it in smaller terms of what's going on. So therefore I thought if I used the children to re-enact what actually happens to a solid when it melts, that it might help their understanding."

This strategy is in keeping with the first aim of session 3 of the Intervention Package: to encourage the student teachers to reflect on the types of teaching strategies that are of assistance in overcoming children's misunderstandings of ideas in science.

However, the Intervention Package appears to have had little effect on most of the student teachers in terms of encouraging them to try out an active-learning methodology like role play. In the baseline group of student teachers, only 2 out of 12 students (16%) used role play in their teaching. In the post-intervention group of student teachers, only 3 out of 16 student teachers (19%) used role play as one of their teaching strategies. In terms of the CBAM levels of use model, most of the student teachers have not made the transition from the **orientation level** (stage I) (where they have received information about the innovation) to the preparation level (stage 2) where they are making preparations to use the innovation.

(e) Analogy

In the analysis of the baseline observation data (section 6.4.1) it was found that 2 of the student teachers (17%) used analogies to assist them with their teaching. However, the analysis of the post-intervention observation data shows that 8 of the student teachers (50%) used some form of analogy in their teaching. For example, Fiachra was observed giving a lesson on solutions to a group of 12-13 year old pupils. To explain about the mixing of the solute and solvent particles, she used the analogy of marbles being mixed with oranges and had an accompanying poster to help the pupils visualise the situation. When questioned about where she got this idea, she was obviously convinced of its effectiveness as a teaching strategy:

> "I just thought of it. You see, because their chapters are laid out by another teacher, they haven't done the particulate nature of matter, and I couldn't go into a lot of detail so that was the best way I could think of. Because they can all visualise a crate of oranges and marbles, and they can see the oranges and marbles and the spaces in between them. So it was just something I could relate it to. I had the poster done, and I thought that it might be the easiest thing to relate it back to."

In another example, Kayleigh passed around lengths of polystyrene packing (aeroboard) to help the pupils visualise the packing of particles in a solid element. In the interview she pointed out that the packing of the spheres in the aeroboard is analogous to the packing of particles in a solid. She clearly felt that the use of this analogy was an effective teaching strategy:

> "My reason for using the aero board, which I got off my nephew – he's 3 and he loves breaking it up and throwing it around the place – was, if you look at it, it's small little balls all packed in together. That was my representation of the element, which is made up of all the little atoms clung together

Mary gave a lesson on chemical formulae to a group of 14 year-old pupils. She introduced the concept of chemical formula in terms of a discussion on Formula One racing. When asked why she used this analogy, she explained at considerable length in the interview about trying to avoid just giving to the class a definition of chemical formula in terms of ratios of symbols and instead using an analogy with which the pupils would be familiar:

> "To understand first of all what a formula was before understanding what chemical formulas. I wanted their feedback on it ....well the guys would probably definitely say, thinking on their level, "Formula One car racing" whereas girls would have a different aspect to it.......and I asked them did anyone know what a formula was first of all before we start. Some guy said "Formula One", exactly what I was thinking and some of the girls said something that may be very specific or to something which is getting along the lines of very precise ....Formula One racing because the height, the engine, everything has to be perfect or they can't run out.....After they knew what formula was I introduced what a symbol was as well because I didn't want to give them a definition of ratio, symbols and something very precise all together, I wanted to take them aside first, we'll see what formula is, what a ratio is, what a symbol is and then combine it all to have chemical formula ......I didn't want to be the one telling them everything. I wanted them to try to answer it from their ideas".

One interesting use of analogies was observed in a lesson given by Seamus on electrochemistry to a group of 14 year-old pupils. In this lesson he compared the voltameter to a swimming pool and the electrodes to ladders at opposite ends of the pool. He explained the results of the electrolysis experiment carried out by the pupils in terms of ions "swimming" across to the ladders and either losing or gaining electrons. His lesson plan showed a simplified diagram with electrons on a conveyor being put into the swimming pool at one end and taken out of the swimming pool at the other end. This diagram was used in poster form in the lesson. In addition, in the lesson, one of the pupils questioned him about why some ions were discharged in preference to others. The sport of greyhound racing is popular in the area in which the school is located and he used the analogy of a race between a greyhound and a terrier to indicate that some ions are more easily discharged than others. When questioned about the use of these analogies in the interview, he clearly felt that they worked well:

> "......we were thinking all the time of that poster and the middle of the swimming pool, because we could relate back the whole time, that had the exact same thing as the poster of the beaker. Because the showed the exact same thing, in layman's terms, of someone taking electrons out and putting them in, and it was set up to look the same way as the beaker beside it. So they're to understand that this is just electrons going out one side and coming back in the other. And I used an analogy of dogs going for a competition between ions, which was at the end what they all started saying back to me again".

Thus, it is clear that since 8 of the 16 student teachers involved in the post-intervention data phase of this research project used analogies in their teaching, this area of the Intervention Package (session 2 on research findings and session 3 on developing specific teaching strategies) appears to have had some definite impact in this area relative to the baseline cohort of student teachers. The situation is similar to that described by Brown and McIntyre (1993) when devising a framework to explain the actions of experienced teachers when making progress in the classroom. The use of analogies by the student teachers can be considered to be similar to the *repertoire of actions* described by Brown and McIntyre (1993):

> "We are suggesting that experienced and expert teachers arrive at the class with clear goals for the pattern of activity (Normal Desirable State) and for the Progress to be made by the pupils, make rapid initial judgements about the Conditions impinging on the teaching........and select from their repertoire of actions those which their experience tell them are best suited to achieve their goals in the given Conditions".
>
> (Brown and McIntyre, 1993 p. 83)

Whilst Brown and McIntyre describe the increased use of analogies in terms of an addition to the repertoire of actions of the student teachers, Shulman (1986) describes the situation in terms of an improvement in their *pedagogical content knowledge*:

> "Within the category of pedagogical content knowledge, I include for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations – in a word, the ways of representing and formulating the subject that makes it comprehensible to others...... the teacher must have at hand a veritable armamentarium of alternative forms of representation, some of which derive from research whereas others originate in the wisdom of practice. "
>
> (Shulman, 1986 p. 9)

Thus, both perspectives underline the importance of the teacher having various teaching strategies to enable progress to be made in the classroom and to facilitate understanding among their pupils.

(f) Terminology

In the analysis of the baseline interview data, 8 of the 12 student teachers (67%) indicated that terminology was a problem area in teaching the particular topic. In the analysis of the post-intervention observation data, it was clear that these student teachers also considered terminology to be a problem as 10 of the 16 student teachers (63%) used flash cards when explaining scientific terminology. When the latter group of student teachers were questioned about this teaching strategy, some interesting comments emerged. For example, Fiachra gave a class on solutions in which she used flash cards extensively whenever a new term was encountered. When questioned about this teaching strategy, she spoke at some length about the problem she perceived pupils would have with terminology:

> "Basically I think that the chapter has a lot of terminology, and there is an awful lot of theory to go with the topic. And it goes from one term to another the whole way down ...But I don't think they'd know about solvent, solution, as well - the terms they wouldn't know. They may have an understanding themselves of what the things are, but not the actual scientific terms.... As I say, they have an everyday understanding or a basic knowledge of solvents - like paint on your hands - so I think a lot of it is terminology... Probably the most difficult bit would be the 'saturated' bit and the copper sulphate, and heating it..... Generally, I knew that certain aspects of it would be easy, leading to the terminology, which would be more difficult and that would be where they'd have the problem with remembering the different terms."

When discussing the lesson given by Padraig on atomic structure to a group of 14-15 year old pupils, he referred to the problem caused for the pupils by the term "nucleus". He found that the pupils in their homework copybooks were drawing the nucleus of the atom as if it were the same as the nucleus of the cell:

> "But I was trying to explain to them that it wasn't a circle, in the centre, it was just protons and neutrons. I think they were kind of mixing it up with the nucleus in the cell, which we had already covered, and they knew that was a round or spherical structure. So I was trying to explain to them that that was made up of genetic material, whereas this is made up of protons and neutrons, and that it didn't have to be a perfect circle. As I said, the difficulties were the mixing-up of the words and terms, and the mixing-up of the structure, making the protons and neutrons a circular or spherical shape. They were mixing it up with the nucleus of the cell. When I mentioned the nucleus of the atom, they automatically thought it was the nucleus of the cell, so they were making it a more circular shape."

This problem about the use of terminology, specifically the use of the term *nucleus* in this context (Harrison and Treagust, 1996) has already been discussed in Chapter 2.

Mary gave a lesson on chemical formulas and bonding. She made extensive use of flash cards in the lesson. When asked about this in the interview, she showed great sense of confidence in their usefulness as a teaching strategy:

> "In my lesson plan I always before I introduce a new term I would maybe put up a flashcard and ask an individual student, I would name them out and ask them 'do you know what, say, a bond is first of all' before we go onto ionic bonding before I launch into it and they might say adhesive bonds they might go on to something completely off the wall but just bring it to the scientific term again and explain it for them and I always have a lot of student activity throughout my lesson plan, a lot of questions I would gear towards the students, I would find their input is their knowledge, I only can teach them what I think they don't know."

In Hannah's lesson on electrochemistry to a group of 14-15 year old pupils, she made a clear decision in her lesson plan to tackle the problem of terminology "head on" from the very beginning of the lesson:

> "Introduction to the area of electrochemistry. Introduce the term electrochemistry to the students.
>
> - Write the word ELECTROCHEMISTRY on the board.
> - Ask question – what do you think the area of electrochemistry involves?
> - Electrochemistry is a branch of chemistry which involves the two areas of electricity and chemistry working together".

When questioned in the interview as to why she took this particular approach, she emphasised the importance of the terminology in this topic:

> " .... why I approached it that way.....I just wanted to introduce the basic terminology. This was all new, they'd never, well they had an idea what electrochemistry was just from the word but I wanted to introduce the terminology and focus on relating terminology to a particular system, and that hopefully afterwards if I showed them the system again that they'd be able to say well that part is the

> electrode, this is the electrolyte and define them and have an idea. Not even learn it off but have an idea what was going on in the different parts of the system and to be able to use the terminology, I felt, because it's a new area and when they'd go into it deeper, it's all that terminology; electrode, electrolyte and all of that, so that was my main aim really. And just to give a brief introduction to what it was all about, kind of an overview...."

It was interesting to see the same topic being taught using a completely different approach by Seamus who started the class with pupil practical work in which each group of pupils carried out their own electrolysis experiments using home-made electrolysis kits in which paper clips were used as electrodes. Having done the experiment and explained what was happening in terms of an analogy with a swimming pool (as described previously), it was only in the last 15 minutes or so that the terminology was introduced. When questioned about this strategy in the interview, he was quite clear on the importance of not getting "bogged down" with terminology at the beginning of the lesson but rather to avoid introducing the terminology until the pupils had a clear understanding of what was happening in the electrolysis experiment:

> "I think just because there was a swimming pool, and everything is as it would be in a swimming pool. So that's why the ladder was there. And I didn't introduce the word 'electrodes' until a long way into it, and then I just used it in simple language as a bit sticking into the beaker, and I kept it at that, because I didn't want to make it any more complicated."

The efforts of the student teachers to tackle the problems of terminology appears to be related to Session 2 of the Intervention Package where each of the student teachers studied a research paper and made presentations to each other on the paper that they had studied. Some of these papers (Briggs and Holding, 1986; Harrison and Treagust, 1996; Solomon, 1983) dealt with the area of terminology and the confusion caused in the minds of pupils by the use of various scientific terms in our teaching. This was in keeping with one of the aims of session 2 of the Intervention Package: *To encourage student teachers to reflect on some misunderstandings in science that they have studied in the research literature* and the second outcome of session 2*: Be able to describe some of the misunderstandings children have.*

The type of picture painted by the analysis of data in this particular section is similar to the description of a level III user (mechanical use) found in the CBAM model. The student teachers are obviously aware of the problems caused by terminology among their pupils and are trying out various strategies in the classroom to try to tackle the problem:

> "At this level [stage III] the person is inexperienced and is still experimenting with the innovation trying to make it work.....At this point the person simply lacks the experience and the practical and emotional resources to look much beyond the next day's preparations. The principal interest of level III users is in seeking out ways to make use of the innovation easier for themselves".
> (Hord, 1987 p. 112)

An interesting incident relating to the use of terminology took place during a lesson given by Amy on physical and chemical changes. She was carrying out a variety of demonstration experiments one of which involved putting some magnesium ribbon into a test tube of hydrochloric acid. She asked the class what did they observe and one pupil said it was "dissolving" in the acid. The student teacher immediately picked up on this and discussed it with the class as a group. When questioned about this in the interview, Amy clearly remembered what went through her mind when the pupil used the wrong terminology:

> "I think one of the disappointments that I remember was when I did the magnesium ribbon and the acid, and I still heard the word 'dissolving' coming from the crowd. And I actually noted who said that and it would have been from what I would have considered some of the students faster to pick up sometimes on certain

> concepts. And we still kind of fall back into the language that we're most familiar with, and I think one girl started to say 'dissolving' and either she recognised that it was wrong or she saw the look on my face and she started to backtrack, but even the fact that she was backtracking meant that she was still on the edge of not being 100% sure of what she was looking at."

It would appear that the discussion on the research findings in the various articles read by the student teachers (Session 2 of the Intervention Package) helped Amy to identify this incorrect use of terminology.

(ii) Classroom Climate

Analysis of the post-intervention lesson plan data, observation data and interview data shows a general sense of satisfaction among the student teachers of the classroom climate in terms of pupil behaviour. Typical comments were:

> "I thought the class were very well behaved, most of the class were interested in participating...." - Daniel:
>
> "I had no class management problems" – Daithi
>
> "Well I thought the class were very well behaved anyway, they were fairly enthusiastic and whenever I asked a question there was always one or two people who were able to put up their hands" - Padraig

Whilst the analysis of the post-intervention interview data shows that most of the student teachers expressed satisfaction simply with the behaviour of the pupils, four of the student teachers showed a deeper understanding of the concept of classroom climate. For example, Kayleigh spoke about trying to foster a climate of independent thinking in her classroom:

> "What I was trying to do was get the students' own opinions, to make them think for themselves rather than just reading a statement and going, 'Yeah, I agree with that' or 'I don't agree with it'. But I wanted them to come up with it themselves, to think of it themselves."

Daniel's reply to the question on classroom climate showed that his priority was to foster a climate of understanding of the topic being taught and he regularly checked on this understanding as the lesson proceeded:

> " ...other times I got them answering one at a time or just put their hands up and constantly through the lesson there, there was a lot of class interaction so I was asking questions all the way through so if they had any problems I was able to look into them during the lesson and again at the end of the lesson."

Also, the student teachers in the post-intervention study were more forthcoming than those in the baseline study in terms of their own sense of satisfaction at how the lesson went. For example, Padraig was very pleased with the high response rate to the questions he asked in the class and spoke enthusiastically about this in the interview:

> "Whenever I asked a question there was always one or two people who were able to put up their hands and even the ones who didn't put up their hands, most of them had a fairly good idea and even there was one student there I thought he was fairly weak and he was able to answer all the questions I asked him, so I was happy enough with that."

A similar comment was made by Catherine who used role play in teaching the particulate nature of matter to a group of 12-13 year old pupils. Various groups of pupils were used to represent particles in the solid, liquid and gas phase. This teaching strategy worked very well and, in the interview, Catherine spoke about it in a very animated fashion:

> "I really thought the role play was a brilliant way of showing it and the kids really enjoyed it as well and I actually enjoyed doing it as well, so I think that was the best part of it."

When Roisin was asked what she felt was good about the lesson that she gave to a group of 12 – 13 year old pupils on solutions, she immediately referred to the atmosphere created in the lesson. (In the lesson she used a Concept

Cartoon, flash cards, posters, overhead transparencies, demonstration experiments and diagnostic questions.) It is interesting to note that she measured the success of the lesson in terms of the enjoyment that the pupils derived from it:

> "I think the children enjoyed the lesson and seemed to like being in the classroom. I think that was good about it."

When Hannah was asked what she would change in the lesson if she were repeating it, she spoke about her realisation that the classroom atmosphere was close to that of a lecture hall at times and made a conscious effort to set up a more interactive climate:

> "I felt I was talking an awful lot, I felt I was bordering on a lecture at times... I'm not saying now I wouldn't have changed, I would've but I felt I was talking a bit too much and that's why I questioned them so much because I was talking so much and I wanted to gauge what they were learning. I would've tried to increase interaction with them or get more feedback from them if I could at all......"

In addition, the student teachers in the post intervention study appeared to be more conscious of the need to create a good atmosphere in the classroom by involving the pupils. When Hannah was asked about the reason for including a practical activity in her lesson on electrochemistry, she obviously felt that this generated more interest among the pupils and thus contributed to a better classroom atmosphere:

> "Carrying out the practical work that maybe it would interest them more and just make it more their class instead of me just lecturing away to them. That hopefully if I involved them a little bit that it would help the class, and it would help the flow and the atmosphere of the class and they might be a bit more open to listening and learning what it was all about."

Similarly, Amy gave a lesson on balancing chemical equations to a group of pupils who were clearly struggling. The fact that she was a mature student reflects her view of the classroom climate as one in which she emphasised the importance of building up of an atmosphere of confidence and understanding among the pupils:

> " ......but generally I suppose what I would have to say, is it does take time to get to know a class and it takes time to build up this kind of confidence and understanding"

Clearly, the student teachers in the post-intervention study display a more mature and a more reflective attitude towards the importance of creating a classroom climate characterised by items like independent thinking, understanding of concepts, pupil involvement and a sense of confidence. The data analysis suggests some resonance with stage 7 (knowledge and skills) of the Harland and Kinder typology (1997):

> "Knowledge and skills [stage 7] suggests the development of deeper levels of understanding, critical reflexivity and theoretical rationales, with regard to both curriculum content (e.g. enhanced understanding of scientific concepts) and pedagogy (e.g. the management of investigations). It could also signal developments in teachers' self-knowledge and awareness."
>
> (Harland and Kinder, 1997 p. 75)

The data analysis is also in keeping with the second stage of Fullan's model of educational evaluation (new teaching strategies or activities) in that the student teachers are attempting to implement new teaching strategies in the hope that these will have an impact on the classroom atmosphere.

(iii) Links to everyday life

In the baseline study, analysis of the data showed that the majority of student teachers felt that giving everyday examples was important in bringing about effective learning in science. This was evidenced in the baseline lesson observation data where 8 of the student teachers (67%) used everyday applications in their teaching. Similarly, in the post-intervention study there is a consensus among the student teachers of the importance of integrating everyday examples into their teaching. Analysis of the post-intervention lesson plan data and observation data showed that 14 of the 16 student teachers (88%) used some everyday example in the lesson. For example, in teaching a lesson on *Solutions* to a group of 12-year-old pupils, Fiachra brought several examples of everyday solutions into the classroom to show the pupils:

> "I suppose again from where they are, everyday, is where they need to be able to understand.... there's so many everyday examples really of things dissolving - suspensions, even Milk of Magnesia and things like that. And I just used those to bring it back to a scientific level. I think looking at all the different examples - like marshmallows, perfumes, nail varnish removers, so many different solvents, and then when you bring that back to the scientific level - the solutes, the solvents, giving the solutions, soluble, insoluble. I kind of brought it back as opposed to started at that."

David looked at the problem of making the science in school relevant to their everyday lives and talked about the need to bridge this gap:

> "I suppose it [using everyday examples] can bridge the gap between the lab and every day life quite well. Bridging them across and bringing every day life into the lab, as well as that I mean there's always so much talk that will register with them and if they have that there and it wasn't really an easy question and it developed curiosity as well."

Padraig taught a lesson on atomic structure and introduced it in an unusual fashion - by cutting up a carrot into smaller and smaller pieces! When asked about this in the interview, it was clear that he looked on the use of everyday example simply as an aid to increasing understanding:

> "......and then using the concrete examples they would then get a better understanding of what we were talking about."

Seamus used a very clever strategy to get the pupils to try to figure out what was happening when sodium chloride was electrolysed. He asked the pupils to smell a small sample of the gas being given off and asked them to relate it to something that they meet in their everyday lives. Most of the pupils recognised the smell of chlorine from the swimming pool:

> ". A swimming pool has chlorine in it so they got that around I ......they could smell the chlorine and recognise what chlorine is."

Aoife gave a lesson on physical and chemical changes to a group of 12 – 13 year old pupils. She used a piece of burnt toast as an example of a chemical change and compared this to an ordinary slice of bread. She also showed how milk went sour if you added vinegar to it, as well as demonstrating that baking soda and vinegar reacted to form a gas that extinguished a lighted candle. She did succeed in getting the point across very clearly and when asked about this teaching strategy in the interview, was convinced of the usefulness of using everyday examples:

> "I had a piece of burnt toast and a lot of them could see that it was different to a slice of white bread .... they just didn't know what the name for what had happened was. I kind of facilitated them and gave them what the term was that we'd use for what had happened.......Adding the vinegar to the milk actually shows them what happens when milk goes sour. It's something for them to relate to that they'd see happening at home.......It was one of my older brothers who told me the thing about the candle because he remembered seeing it at school, you know the candle being surrounded by the baking soda. And if you add the vinegar when the candle is lighting, you can see the candle going out. But I think it really put them thinking, you could see the baking soda had gone all fizzy and didn't feel the same when they touched it, and they could see the candle going out. So it kind of gave them an idea that a new substance had been formed and something had happened to make the candle actually go out."

Overall, there appeared to be a definite conscious effort among the post-intervention student teachers to include links to everyday life in their lessons. This was obvious not only in the demonstration experiments, examples of which are outlined above, but also when teaching theoretical concepts, e.g. electroplating knives and spoons, burning of petrol in car as examples of chemical change, melting of ice cream as an example of change of state, smell from frying steak as an example of diffusion and using different bottles of Coke to show that liquids take up the shape of the container.

The use of everyday examples by so many of the student teachers is similar to the description of teachers at level IVB (*Refinement*) in the CBAM model. Teachers at this level show "typical behaviour" of "actively seeking ways to change it [the innovation] that will improve pupil outcomes. The changes may be targeted at a particular subgroup at a particular subgroup of pupils, fast or slow learners, for instance, or at the group as a whole" (Hord, 1987 p. 113). The increased use of everyday examples by the post intervention student teachers (relative to the baseline student teachers) appears to suggest an increased effort to make the science being taught more interesting and more relevant to their pupils.

7.3.2 View of science teaching. View of how to teach particular science topics.

The previous section discussed how the view of teaching of the student teachers affected their classroom practice. This section considers how the view of science teaching possessed by the student teachers influenced the strategies and skills displayed by them in the classroom.

A "snapshot" of the views of the student teachers about teaching and learning in science was obtained in activity 3 of session 1 of the Intervention Package. In this session, the student teachers were asked to look at paired statements about teaching and learning and pick out the ones with which they agreed. The paired statements are reproduced in Table 7.4 and the results of the group discussions are shown in Figure 7.4 (page 344).

1A. Before starting a new topic, it is worth spending some time finding out what the pupils already know.	1B It is best to assume that the pupils know nothing about a topic before you start to teach it. Some may know a little, and some may have some mixed-up ideas. It's better to start with a clean sheet.
2A. Science has established a large body of useful knowledge about the world. Teaching science is mainly a matter of communicating this knowledge clearly and effectively to pupils.	2B Pupils have to be allowed time to discover and find things out for themselves, otherwise they won't understand them. Rather than telling them, we need to give them opportunities to find out for themselves.
3A. At the end of the lesson, I always get them to copy down the key points of the lesson from the blackboard. That way what they have in their notebooks is correct.	3B Trying to express your ideas in your own words is an important part of learning. So it is important to make pupils write their own summaries of what they have learned.
4A. Giving pupils opportunities to talk to each other about science in their lessons helps them to understand new ideas.	4B Letting pupils get into groups to talk about their ideas is largely a waste of time. Many of their ideas are incorrect. The teacher has to stay involved in discussions to keep them on the right track.
5A. If the class hasn't understood something I've tried to explain to them, it means that my explanation has not been clear enough. So I should try to explain it again, in a different way.	5B Children's ability to think and reason develops as they grow up. A child cannot understand an idea until they have developed to the level where they are ready for it.
6A. Pupils need an ordered and quiet environment in which to learn.	6B Learning requires activity. More learning is going on when pupils are actively engaged in doing things and talking to each other about them.
7A. We all learn better if we have done something for ourselves. That's why practical work is an essential part of science teaching.	7B After the pupils have done a practical, the teacher still has to explain what the results mean and how they can be explained.

Table 7.4 Statements about teaching and learning in science

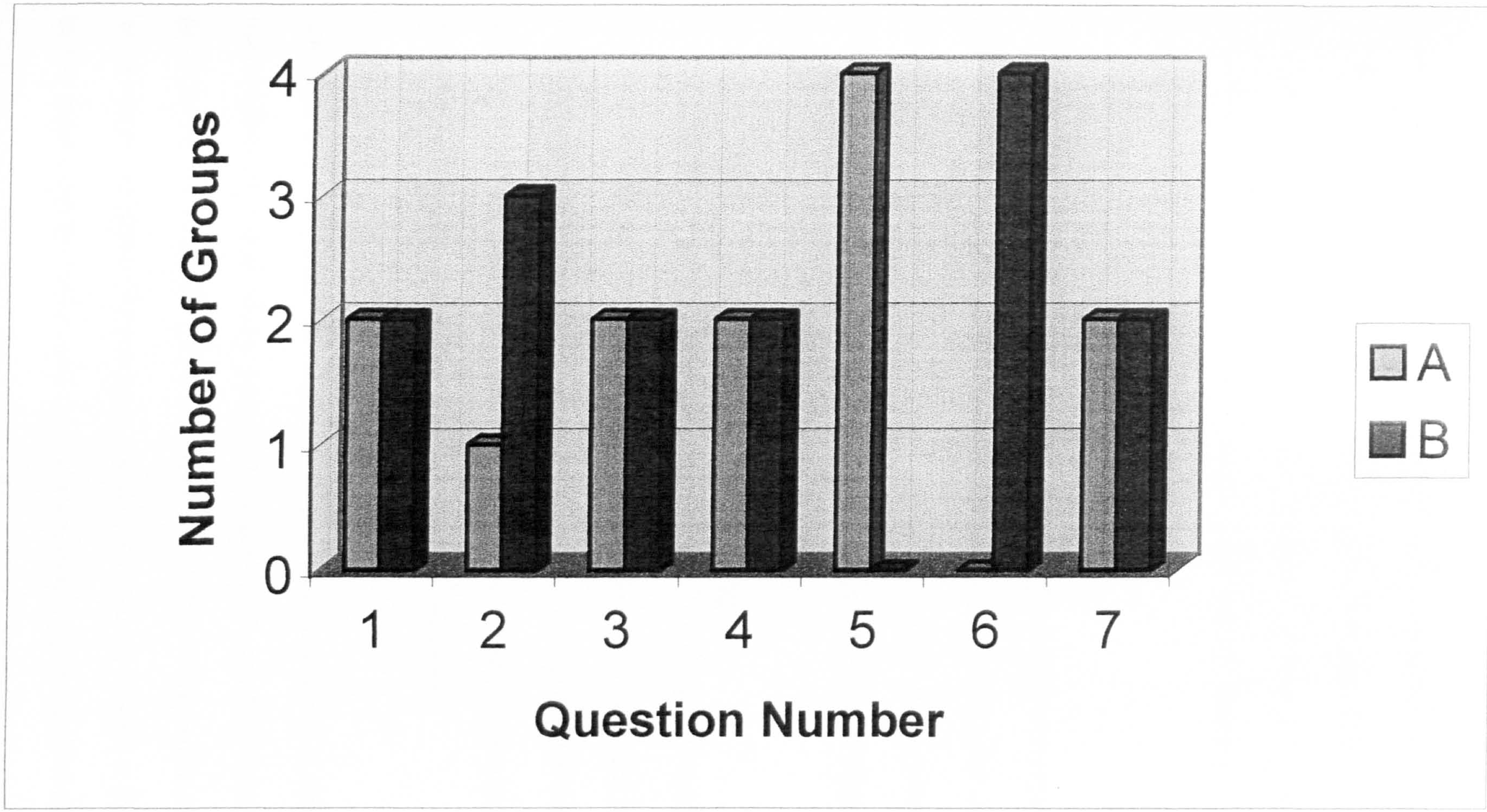


Figure 7.4 Choices of statements of groups about teaching and learning in science.

It is interesting to note that in the case of 4 of the 7 statements (statements 1,3,4 and 7) the groups of student teachers were evenly split in their choices. In the case of statement 5, all groups chose option A and in the case of statement 6, all groups chose option B. In the case of the second statement, three of the four groups chose option B.

In order to study the views of the student teachers in this area after the Intervention Package, the post-intervention data were analysed using the same framework that was used to analyse the baseline data, i.e. **exploring pupils' ideas and understanding** and **relevant strategies for teaching particular topics or sub-topics.**

(i) Exploring Pupils' Ideas and Understanding.

In the analysis of the baseline observation data, it was found that there was a poor level of questioning of the pupils by the student teachers to ascertain their level of understanding of the topic. In general, it was found that the type of questioning in the baseline study emphasised the recall of previously learned material that required short, closed and factual answers.

One of the most striking items that emerged as the analysis of the lesson observation data and lesson plan data progressed, was the more prominent role given to exploring pupils' ideas. A total of 10 of the 16 student teachers (63%) were observed using this teaching strategy at various stages in the lessons. One of the most popular items used by the post-intervention student teachers was Concept Cartoons. As stated previously, 8 of the 16 student teachers used Concept Cartoon in their teaching. Invariably, the Concept Cartoons led on to group discussions and whole class discussions. When asked in the interview about the reason for using Concept Cartoons, David's answer was fairly typical of the answers from the group in that he wanted to explore what ideas (about chemical reactions) existed among the pupils and he wanted to investigate what misunderstandings the pupils had about this topic:

> "They have thirteen years or fourteen years of existing on this planet, and from that alone they have thousands of misconceptions or correct conceptions. I suppose I assessed what they understood by using the Concept Cartoon .... I made them assess themselves as it were. You know that I didn't ask for a straight answer after showing them the Concept Cartoon but I did at the end, and I had a majority decision, well everybody actually picked the correct option on the cartoon. But they wouldn't have thought in depth about a chemical reaction before this"

Similarly, Seamus spoke enthusiastically about a lesson he gave on electrochemistry to a group of 14-15 year old pupils. He used diagnostic questions and a Concept Cartoon near the beginning of the lesson. When asked for his views on the value of the diagnostic questions, his response indicated the value he placed on this teaching strategy:

> "The diagnostic questioning was very, very helpful ......because electrochemistry is just wires sticking into something and you couldn't bring it down to everyday life in that sense. But the questioning that they had these things like, you know, if you break a wire no electricity flows, or if the electricity is earthed. So all those questions were... you know, if you break the wire and put it into a solution then electricity should not flow. Again they had all these ideas."

When asked what he hoped this teaching strategy would achieve, he immediately referred to understanding of the concept among the pupils:

> "I wouldn't say a better understanding, but a proper understanding. Because they'd have carried ideas through the class that would be all wrong until they'd actually see it going right, for example when you break the wire no electricity flows. I'm sure a lot of them had that idea, most of them thought that was right when I put up the questions. But obviously when you do the experiments, they can see that that has to be wrong, but you

> didn't tell them the answer then. You told it after the class. So they didn't achieve a better understanding, they achieved a proper understanding."

Another strategy used by 4 of the 16 student teachers was brainstorming. Padraig used this tactic to begin a lesson on atomic structure. He asked the class what they thought the word "atom" meant and wrote the various responses on the blackboard. He was very clear in his mind that a constructivist approach to teaching was the way forward:

> "First of all I was thinking 'How was I going to show them this concept, or explain to them what the concept was'. First of all, I started off with what they covered before, matter, so they knew that, so I said we'd start off with that, and we'd say then that matter was made up of some other particles .... And I asked them then what an atom was, what was their impression of what that word was. And then I built on that. Most classes I start from what they might have known before, and then I always just try to see where they're at, so that gave me an idea that some of them actually already knew what an atom was, ands more of them didn't really know anything about it."

A third strategy that the data analysis showed being used by three of the 16 teachers was diagnostic questions. For example, Roisin was teaching the concept of solution formation to a class of 13 – 14 year old pupils. She placed a beaker of water and 45 grams of sugar on an electronic balance. She then asked the class to predict what change, if any, there would be to the total mass if she tipped the sugar into the water. This generated great discussion among the pupils and Roisin used the results of the experiment as evidence for the existence of particles in solution. When questioned about this in the interview about the reason for using this teaching approach, she appeared happy that she had helped the pupils to come to an understanding of the concept of a solution:

> "The reason why I picked it was I think it was just to show the children physically a solution being formed. They had covered mass before so it wasn't like I had to explain anything like that, just that

> the sugar did dissolve and because they could no longer see the sugar, the sugar was still there with its full mass. Because I think a lot of them, when I asked that question, seemed to think that the sugar would add to the mass of the water only a little bit, but that it wouldn't add its full mass of 45 grams. So that's why I did it, just so they could see physically."

The lesson plan data clearly show that the above teaching strategies were not spontaneous actions but were planned carefully with all the relevant questions written into the lesson plan notes. In general, the standard of questioning of pupils among the post-intervention student teachers was of a more probing and testing nature than that found in the baseline study. Harland and Kinder (1997) describe this type of outcome (stage 9 of their typology *impact on practice*) as a change in "the nature of the interactions between teacher and pupils". (Harland and Kinder, 1997 p. 76). It is similar to the second stage of Fullan's model "the use of new teaching approaches (i.e. new teaching strategies or activities)" (Fullan, 2001 p. 39). Clearly, items like Concept Cartoons, brainstorming and diagnostic questions that were introduced to the student teachers as part of the Intervention Package appear to have had an impact on the classroom practice of the student teachers and helped to move them from their initial views reflected in the 50 : 50 split in questions 1 and 4 (Table 7.3).

(ii) Relevant strategies for teaching particular topics

As discussed in section 6.5.2, the analysis of the baseline data showed that the teaching strategies used by the student teachers were confined to those found in the textbooks. Analysis of the post intervention data was carried out in order to investigate if evidence of innovation is present in the strategies of the post-intervention student teachers when teaching particular science topics involving difficult ideas. These strategies are now considered under the same headings used in the analysis of the baseline data, i.e. (a) everyday examples, (b) practical work, (c) recognition of pupil difficulties, (d) content vs understanding (e) analogies and (f) view of how to teach particular science topics.

The results of the data analysis (a) – (f) are first presented and this is then followed by a brief discussion of these results.

(a) Everyday examples

When Siobhan was teaching about balancing equations, she began by talking about apples and oranges being put into a scale. She asked the pupils to imagine that you could only buy oranges and apples in pairs. (These pairs were used to represent hydrogen and oxygen molecules.) She then went on to ask the pupils to imagine on the other side of the balance a situation where one orange was joined to two apples ("for every two apples you bought you got a free orange"). This represented a molecule of water. From then on, pupils were engaged in trying to figure out the ratio of apples (hydrogen) and oranges (oxygen) to give a fixed number of H_2O molecules.

This was a very interesting and a successful strategy as it started with everyday objects and taught the pupils the idea of ratio before introducing the more difficult concepts of atoms and molecules. When asked in the interview about why she introduced the apples and oranges, she felt that these everyday objects would help the pupils to understand better the concept of balancing an equation:

> "I did the kind of apples and oranges thing and kind of said if I have two oranges here can I have an apple and an orange here, you can't, why, tell me............And just trying to balance it in so I tried to bring it to that level because I though to myself that might be one of the hardest parts."

Her final statement clearly shows that she recognised the potential difficulties that the pupils would have with balancing equations. The strategy was certainly an innovative one and had not been covered specifically in the Intervention Package.

(b) Practical Work

An example of an innovative practical demonstration was observed in a lesson on the particulate nature of matter. Daithi was teaching the particulate nature of matter and, after discussion about the various possibilities, showed a discrepant event to emphasise that there were gaps between the particles of gas. He used a bicycle pump filled with air and asked one of the pupils to push down on the handle of the bicycle pump. When asked in the interview about this, he referred to the fact that discrepant events were covered in the Intervention Package:

> "Well exactly, I told them at the start I wanted them to know what matter was, I wanted them to know any different states of matter and the properties of each of them, which I think I went through and at the end then, I wanted them to know the particle theory and I put up the constructivism that you went through, you gave me a handout of it, we all had it but I used a half empty-half full gas idea, and I said lads if you can answer that, you understand the particle nature of gases anyway, that's what I wanted them to do, I think they understood it."

This innovative approach to teaching the particulate nature of matter was devised by the student teacher himself.

(c) Recognition of pupil difficulties

One of the strongest themes to emerge from the post-intervention interview data analysis was the fact that the student teachers recognised that pupils had difficulties with certain area of chemistry. In some cases, the student teachers had read up on some of the recommended literature and some referred to the literature papers discussed as part of the Intervention Package. Typical comment were:

> "I went through some of the literature references that you gave us, and there were the difficulties that they [the pupils] would have encountered in understanding particle theory" Daithi
>
> It goes back to that thing again .... about how they thought things just disappeared when dissolved in water. So I thought I'd plan it around that more so than the other way." - Roisin
>
> Students had a bit of difficulty with the terminology. I noticed one student who answered a question confused the word 'electrode' with 'electrons' - Eoin
>
> "I read that Rosalind Driver article on children's misconceptions in science and then the other resources would have been the handout that you gave to us ..... The children didn't realise that mass was still there". - Maire

Analysis of the post-intervention observation data shows some interesting strategies adopted by the student teachers to teach specific topics. For example, Elizabeth was teaching the topic of chemical reactions to a group of 12-13 year old pupils. In order to emphasise the idea of conservation of mass, she used a very clever teaching strategy. She mixed some baking soda and hydrochloric acid in a bottle with a balloon over the mouth. The pupils could see the gas being given off and trapped in the balloon. When asked about this particular experiment, she spoke about the fact that she wanted to show the gas being given off and to link this in with a topic in biology that had already been covered:

> "With the baking soda and the vinegar, carbon dioxide gas being given off........Now in that class before, we had just started talking about micro-organisms and yeast and whatever, and that linked in with using carbon dioxide production for raising dough and bread making". – Anne Marie

The cross-linking of topics in chemistry and biology by the student teacher appears to have worked well. The innovative strategy of trapping the gas given off using a balloon was devised by the student teacher herself.

(d) Content versus understanding

In section 7.4.1 evidence from the post-intervention data of a move towards exploring pupils' ideas and understanding will be discussed. This manifested itself in the use of Concept Cartoons, brainstorming and diagnostic questions. In specific cases of teaching particular topics, it was observed that other strategies were used to help the understanding of the pupils. For example, Daniel gave a lesson on atomic structure to a group of 13 – 14 year old pupils. In his lesson, he kept emphasising to the pupils the three-dimensional nature of the atom and warned them about the diagrams in the books being only two-dimensional. To emphasise this point, he incorporated into his Powerpoint presentation some very good three- dimensional animation effects. Whilst the observer of the lesson was very impressed by the animation effects, Daniel was very modest about his efforts:

> "Well basically something like atomic structure is very hard to explain, so I feel if it was put up in front of them there and they could see, they could actually see if it was some animation, that it would be easier to visualise .... some of the effects weren't brilliant. It was PowerPoint 97 anyway so I prepared it on PowerPoint 2000 so some of the effects weren't carried through, but I feel once they see it it's easier to understand it."

Elizabeth also gave a lesson on atomic structure to a similar age group. She was also concerned about the static, two-dimensional representations in text books. One of the strategies used in her lesson was the introduction of a CD-ROM (science encyclopaedia) from which she played an extract showing atomic structure in an animated and colourful fashion. When asked about the reason for including this in the lesson, she was confident that it was a good teaching strategy and pointed out that the pupils would understand it better if they saw the electrons spinning:

> "The CD-Rom, I used because it actually had the electrons spinning around the atom. It's easy enough for me to say they spin around, but they might actually remember it and understand it better if they see it spinning around, rather than just believing everything I say."

Once again, the innovation of bringing in three dimensional animation effects was entirely the work of the student teachers themselves.

(e) Analogies

The use of analogies in the baseline study has already been discussed in some detail in Chapter 6 (section 6.4.1). In the analysis of the baseline data, it was found that only 2 of the 12 student teachers (17%) used analogies in their teaching. Analysis of the post-intervention data showed that 8 of the 16 student teachers (50%) use some form of analogy in their teaching. Some examples of these analogies have already been discussed in section 7.3.1 of this chapter, e.g. the use of a swimming pool to represent the electrolyte in an electrolytic cell, the use of polystyrene foam to represent the packing of atoms in a solid and the mixing of oranges and marbles to explain the concept of solutions. Whilst the intervention Package did not deal with specific strategies for teaching particular topics, it is interesting to note that a significant number of the student teachers were able to apply the general guidelines discussed in the Intervention Package to devise specific strategies for teaching particular topics. This is in keeping with outcome 3 of the third session of the Intervention Package: *Be capable of developing teaching strategies to help overcome children's misunderstandings of ideas in chemistry.*

The student teachers responsible for the above examples of innovative practice show all the characteristics of level IVB (*refinement*) users in the CBAM model in that they are introducing new ideas into the innovation in order to improve the level of understanding among their pupils:

> "Beyond IVA [Routine], the user's relationship with the innovation changes yet again. Instead of struggling merely to survive with it, or being content to adhere to an established pattern of its use, at the highest three levels the person begins actively seeking ways to change it that will improve student outcomes. The first of these is Level IVB, **refinement**........The key fact is that the user's activity is now **outwardly directed**; instead of making changes to help themselves use the programme, Level IVB people are experimenting with ways to help students use it more fruitfully. These changes....are based on a viable level of understanding of the innovation.."
>
> (Hord, 1987 p. 114).

Although the number of innovative teaching strategies among the student teachers is limited, nevertheless it is satisfying to see that student teachers in their first few months of teaching practice have the ability to introduce such innovation into their classroom practice.

(f) View of how to teach particular science topics

In the analysis of the baseline data (section 6.6) it was found that very little emerged to indicate that the student teachers had views on how to teach particular science topics. In fact, only one of the 12 student teachers gave a lesson in which she demonstrated her own way of approaching a particular topic.

In the analysis of the post-intervention data, a similar finding was made. The only lesson of the 16 which demonstrated a unique approach to teaching a particular science topic was that given by Seamus. Aspects of this lesson on electrochemistry have already been outlined. Whilst the other student teachers used the Hofmann voltameter to demonstrate electrolysis, Seamus used non-conventional "home made" apparatus from a DIY store. He had no choice since his lab was so poorly equipped. His style of teaching the topic was unique in that he avoided the use of terminology until towards the end of class - the textbook had all the terms clearly defined at the beginning of the chapter. Whilst other student teachers simply electrolysed acidified water, Seamus began by electrolysing sodium chloride solution. As already described, he carried out this electrolysis to enable the pupils to smell the chlorine coming off and hence satisfy themselves that a chemical reaction was taking place.

When Seamus was interviewed about the lesson, some interesting points emerged with regard to this teaching strategy. One of his first statements set the scene in terms of his own interest in electrochemistry:

> "When I was going through college myself, the one bit of chemistry I loved myself was electrochemistry".

His focus on what he wanted his pupils to be knowledgeable about was made very clear by him in the interview: the idea of loss and gain of electrons at the electrodes.

> "What I wanted them to be knowledgeable about, was that there are all these different types - electroplating, electrolysis, they all go back to the one basic thing that one gains electrons, another one loses electrons. Some of the posters I used were the same for every single thing, I just changed the flash card so they could see that no matter what you did, no matter how complicated the ions got, it was still one simple little idea: gaining and losing electrons."

Another interesting item that arose in the interview was the fact that Seamus was in one of the working groups in session 3 of the Intervention Package that had to devise a Concept Cartoon to explain electrochemistry.

> "There was also a discussion in your methodology session where we were all split up into groups, and I was actually in the electrochemistry group, and one idea we came up with was the Concept Cartoon to show the actual workings of electricity. I used that. And that was really it. The resources for electrochemistry tend to make it harder rather than easier, I found – they are too complicated".

When asked about his particular teaching strategy, he drew on his own experience of studying electrochemistry when a pupil at school:

> "Basically, my own experiences through school of electrochemistry. Which I think is nearly everyone else's experience of electrochemistry as well - all the things that could go wrong and do go wrong. As they say, you start thinking of electrochemistry being so difficult, with electricity flowing around, with loads of ions, and you don't know what's happening - *that*. That's why. So it's my own experiences, and suddenly someone here making it very simple for me, and me realising that. Just telling them what's wrong, what they don't need to know and shouldn't know, then makes it a lot easier."

Thus, apart from Seamus, little has emerged from the data in terms of views on how to teach particular science topics. However, overall it appears that the Intervention Package has had some effect on the student teachers in using relevant strategies in the classroom, e.g. Concept Cartoons, diagnostic questions, discrepant events and analogies.

7.3.3 Local conditions

Two of the intended outcomes of session 3 of the Intervention Package are:

- Be capable of making suggestions for classroom practice which help to overcome these misunderstandings in chemistry.
- Be capable of developing teaching strategies to help overcome children's misunderstandings of ideas in chemistry.

Clearly, the extent to which the student teachers are in a position to implement suggestions for classroom practice and changes in teaching strategies will be affected by the conditions in which they find themselves teaching. Are the conditions in the school conducive to innovation? Are the permanent science teachers on the staff willing to assist the student teachers? Do the student teachers have adequate access to physical resources like laboratories and equipment? Are the pupils co-operative when introducing innovation? Questions like these will be considered as the data are analysed under the same headings as in the baseline data, i.e. **assessment of course, backup help from school** and **types of pupils.** These three areas have the potential to facilitate or to hinder the introduction of innovation into the classroom practice of the student teachers.

(i) Assessment

In the analysis of the baseline observation data and interview data, it was clear that the teaching style adopted by the majority of student teachers was driven by the examination system. Similarly, in the post-intervention phase, it is clear from the lesson plans, observations and interview data that the examination system was still very influential in determining the content of the lessons. For example, Amy referred specifically to the terminal examination when asked about the difficulties the students would encounter in her lesson on balancing chemical equations:

> "Well I suppose the main difficulties would be that some of them could balance just a few of the equations but I think it's more with we'll say the average group that balancing equations that they would be able to do this in their exam I just did a few for their exam – just enough to get them through because a lot of it would be a little over their head."

Similarly, when Mary was asked about the resources she used when preparing the lesson on chemical formulae, it was interesting that she pointed out that as well as the textbook she also consulted a "rapid revision" textbook and a pocket dictionary of key terms. These exam aids are popular among exam pupils in Ireland and are normally purchased by the pupils in their examination (third) year. Mary was teaching a second year class but obviously wanted to ensure that she included all the key points in her lesson:

> "I looked up first of all, The [name of textbook] also Junior Certificate [name of textbook] revision book and also a small handbook dictionary, it was [name of publisher] with very simplistic definitions".

In terms of the subject content of the lessons, in the baseline study all of the student teachers stuck rigidly to the syllabus. In the post-intervention study, 15 of the 16 student teachers in the post-intervention study also stuck rigidly to the syllabus. The only exception was Seamus who introduced the electrolysis of salt solution to the pupils. This experiment is not part of the Junior Certificate course but Seamus included it as he wanted to demonstrate that a chemical reaction was occurring by allowing the pupils to smell the chlorine gas being evolved. However, given that Seamus was a fairly exceptional teacher anyway, it is fair to say that the Intervention Package appears to have had little effect in terms of the subject content of the lessons.

Overall, in terms of the influence of assessment on the implementation of the Intervention Package, the student teachers display all the characteristics of teachers at level IVA(routine) in the CBAM model. At this stage, the student teachers have reached the "comfortable plateau" (Hord, 1987 p. 113) and have settled down to a "pattern of innovation use "(Hord, 1987 p. 113). Hord points out that the users on this level need the feeling of stability associated with it regardless of whether or not they move on to the next stage. As would be expected of inexperienced student teachers, they feel most comfortable teaching closely to the syllabus until they have sufficient experience to move beyond the constraints of assessment and experiment with other material beyond the syllabus.

(ii) Backup help from school

In the analysis of the baseline interview data, only 2 of the 12 student teachers (17%) indicated that they had received help from other teachers in the school. In the post-intervention interview analysis, it was found that 6 of the 16 teachers (38%) had sought assistance of some form from other teachers in the school. This assistance took various forms – bearing in mind that the level of laboratory equipment in schools in Ireland varies widely and laboratory technicians in schools do not exist in Ireland!

In some cases, the help received from other teachers was very basic. For example, Kayleigh gave a lesson on atomic structure and needed help setting up some molecular model kits:

> "And I asked one of the science teachers in the school, Ms E. who has been there 15 or 16 years, she helped me with the atomic models." - Kayleigh

Similarly, David used a good home-made Concept Cartoon poster in his lesson and reported that he received help from the other teachers in the school in designing the poster.

> I asked some of the chemistry teachers in the school and they were able to give me a lot of help with the poster." - David

Catherine gave a lesson on the particulate nature of matter and consulted another teacher in the school to try to devise an experiment to demonstrate that there were gaps between the particles in a solid:

> I consulted other people about it as well, yes and that's one that I didn't really understand at first and then he explained what it was, but it's a good way of showing, just to see the bubbles forming around the chalk are the spaces between the particles in the solid." – Catherine

In another case, the student teachers reported a good level of assistance in the actual preparation of the lesson. For example, Fiachra reported that she received help in obtaining resource material and some hints on methodology to use for her lesson on solutions:

> The school is very good, one teacher has a lot of other books like [name of textbook] and [name of textbook] and a couple of others. So I just looked at the one I have that they would have to use - [name of textbook] - did basic notes on that, and then brought in information from wherever else I could get it. All the other books, and wherever else I could think of myself. I asked a few other teachers too of what they thought would be good methods to use." - Fiachra

Similarly, Hannah, who taught in a large girls secondary school with very well equipped laboratories consulted the various textbooks in the school laboratory and obtained help from some of the teachers when preparing the lesson:

> "Well I had a look through a few textbooks, a few different textbooks just to get an idea of the material covered in the different textbooks and I spoke to a few of the teachers in the school and asked them when they were introducing electrochemistry, what did they think would be the main points to get across ...... I felt myself the important part was the terminology really and to try and explain that to them." - Hannah

Likewise, Seamus reported that he received help from the chemistry teacher in the school when planning out his approach to teaching the topic. Seamus taught in a boys secondary school with a small student population of about 200 and a very run-down chemistry laboratory. It was obvious that practical work was not a regular activity in this laboratory. Seamus had to get the various items of equipment in a local DIY store.

> "Planning the lesson? Oh, obviously I talked with Mr. X, the chemistry teacher at the time, because he always has good ideas. The planning of it came about that it was such a hard topic that it would be better off taking as direct a route to it as possible. So we didn't want the students getting confused about molecules and stuff along the route, because at the end of the day the topic itself we based on one very simple idea. So if you got them straight into the very simple idea, you could build all the hard stuff around it and not get them confused. So that was my planning around it."

It is interesting to note the increased willingness among the post intervention student teachers (relative to the baseline student teachers) to seek help from more experienced teachers when preparing their lessons. It is possible that the student teachers, having been alerted by the Intervention Package to the problems associated with teaching difficult ideas, were more likely than the baseline teachers to seek help from experienced teachers. This spirit of collaboration was found by Harland and Kinder (1997) to be one of the outcomes of the INSET course that they studied and refer to the fact that "collaboration and mutual support when attempting curriculum innovation in the classroom are fairly well established in the research literature" (Harland and Kinder, 1997 p. 76). They refer to these types of outcomes arising from teachers helping each other as **institutional outcomes.**

(iii) Types of pupils

In the baseline study, only one student teacher commented about a problem (literacy) associated with the particular pupils being taught. In the post-intervention study, about half the student teachers referred to problems with weak pupils in their classes. For example, Amy spoke enthusiastically about the benefit of Concept Cartoon for weaker pupils who had difficulty in articulating an answer to a scientific question posed in the traditional manner:

> "It got them all into their own way of thinking and it got them really involved and interacted then with the actual lesson – especially the weaker ones participated a bit more than usual, I found that was definitely a good aid to start with and to see where they're coming from. We don't want to treat students as empty vessels coming into a classroom. A lot of them actually do have a good knowledge, more then we think sometimes, just get the basis on that. I think more so for weaker students it was a good idea .....because of their poor reading and writing skills they don't participate ....don't respond so well to normal questions ......the cartoon encouraged them to answer"

A number of other student teachers in the post-intervention study did refer to the fact that the weaker pupils were encouraged to participate more in the class because of the use of Concept Cartoons in the lesson. For example, Mary taught a large mixed ability class and normally found it difficult to get some of the weaker pupils to participate in the lesson but this lesson was different:

> "For my second years because they are very much a mixed-ability class I have some and they are always A's and some they're so weak considered remedial and when I showed the cartoon, one particular guy that sits in the front always, I have him in the front because he's a very weak student. He asked the majority of the questions throughout that class which I could not believe because he just doesn't participate at all in class just to see him. He was one of the guys that would never even dream about answering a question ....but the fact I probably say "Give your view on it...give your ideas on it". So he participated well in class.

Aoife had a similar experience in dealing with weak pupils. She found that the Concept Cartoons helped to increase the level of participation of these pupils in the lesson:

> "Well, I had used them a few times before this, and I think they are actually very effective. Out of the whole methodology thing [the series of lectures on science methodology given by the researcher!], I found them to be exceptional because I have a few students in my class who'd be kind of weaker than the average people, and I found it really woke them up. It was really able to give them an extra dimension to the lesson, and was an entry point to the lesson for them".

Thus, overall the introduction of Concept Cartoons to the student teachers in the Intervention Package appears to have had some effect in sensitising them to the particular problems of the weaker pupils. In addition, the Concept Cartoons appear to have had a positive influence on the pupils, especially the weaker pupils, in terms of their level of participation in the lesson. The student teachers whose teaching strategies target the weak pupils show the characteristics of level IVB (refinement) teachers in the CBAM model:

> "Level IVB, refinement, in which changes may be targeted at a particular subgroup of students, fast or slow learners, for instance, or at the group as a whole.....The user's activity is now **outwardly directed**....Level IVB people are experimenting with ways to help **students** use it more fruitfully".
>
> (Hord, 1987 p. 113)

In short, the Concept Cartoons appear to be the catalyst for increasing the level of awareness of the student teachers to the needs of the weaker pupils.

7.4 Attitudinal factors

As already discussed in Chapter 5, attitudinal factors are harder to evidence as they have to be inferred. In this section attitudes are inferred from elements of the questionnaire, the interviews, lesson plans and the classroom observations. In the end-of-year questionnaire (Appendix VIII page 434), the student teachers were asked for their opinion on the usefulness of each of the three sessions of the Intervention Package. The results are summarised in Figure 7.5 page 365. Overall the attitudes of the student teachers to the three session was very positive with all student teachers describing the first session and third session as either "very useful" or "fairly useful" and all student teachers except one describing the second session as either "very useful" or "fairly useful". The one exception described the second session as "not very useful".

Some of the student teachers gave additional comments in this area on the final question:

> "I found the three sessions very helpful. They helped to remind me of the difficult concepts in J.C. [Junior Certificate] Science and gave very good ideas on how to teach them."
>
> "The sessions were most beneficial to me in my teaching. I have learned an incredible amount."
>
> "I really found them of extreme help on helping me prepare my students for better understanding in science."

The student teachers were clearly very positively disposed towards the materials of the Intervention Package.

In stage 2 of the CBAM model (*personal concerns*), the personal attitudes of the teachers to the innovation are linked to the success of the innovation (Hord, 1987 p. 100). This stage is explained in terms of the teacher being faced with new sets of demands and new ways of thinking along with the subsequent anxiety of having to cope with these. In the case of the student teachers, their **view of science** and their **view of learning** could be expected to have some influence on their attitude towards an innovation. Hence, analysis of these two factors in the post-intervention data (as was carried out in the baseline data) should assist the assessment of the effectiveness of the Intervention Package.

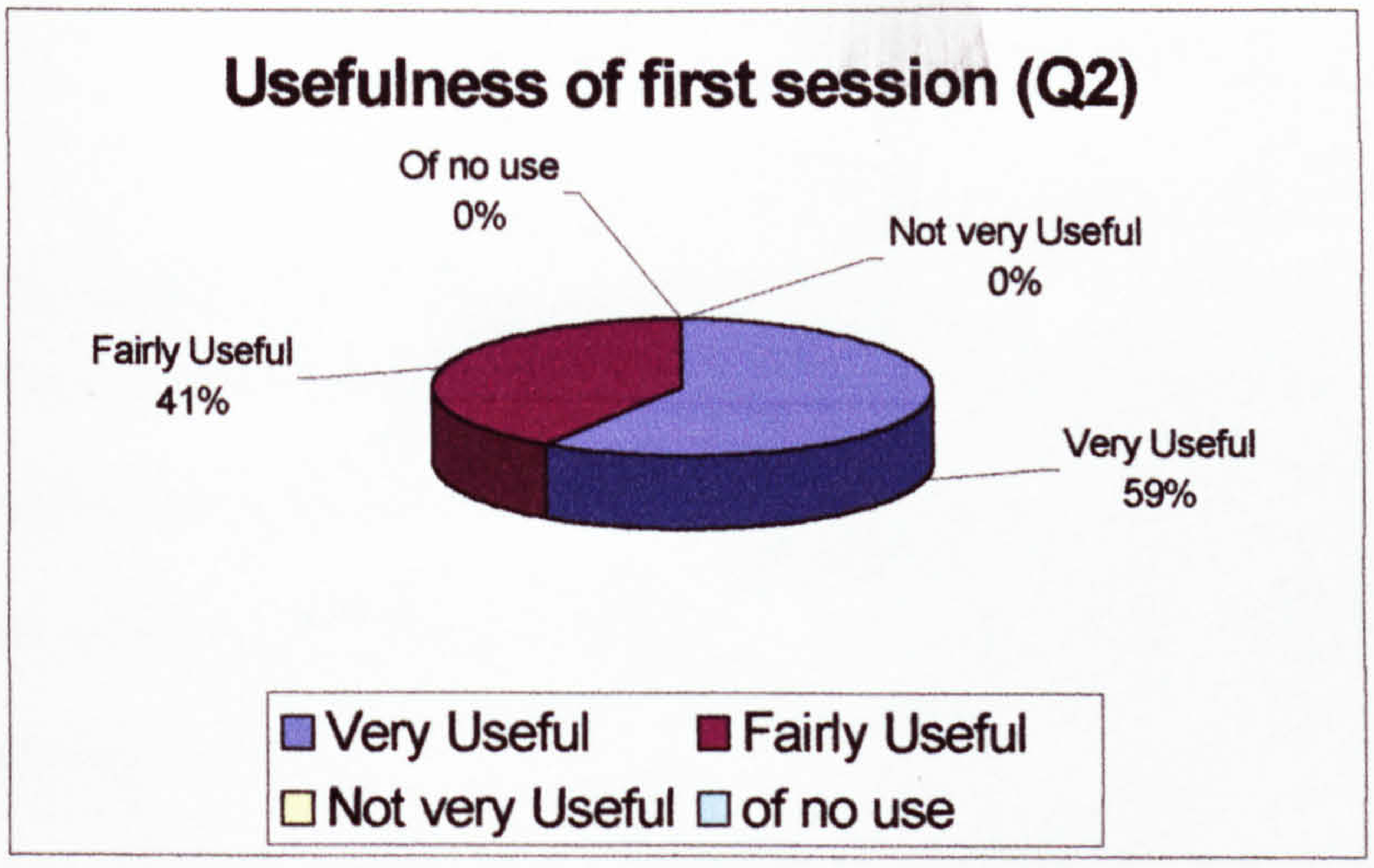


Figure 7.5 (a) Response of student teachers when asked to describe the usefulness of session 1 of Intervention Package to their teaching practice.

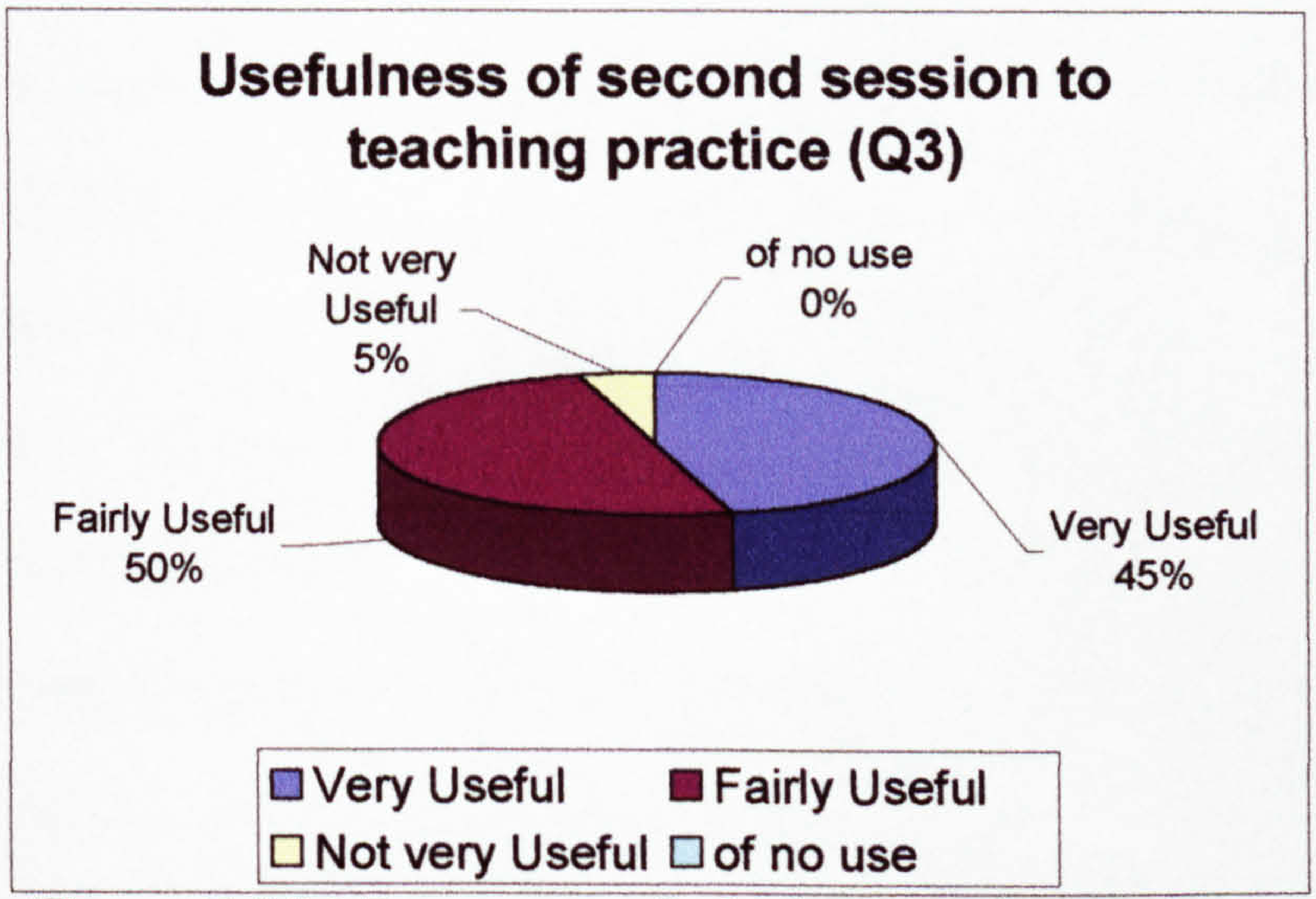


Figure 7.5(b) Response of student teachers when asked to describe the usefulness of session 2 of Intervention Package to their teaching practice.

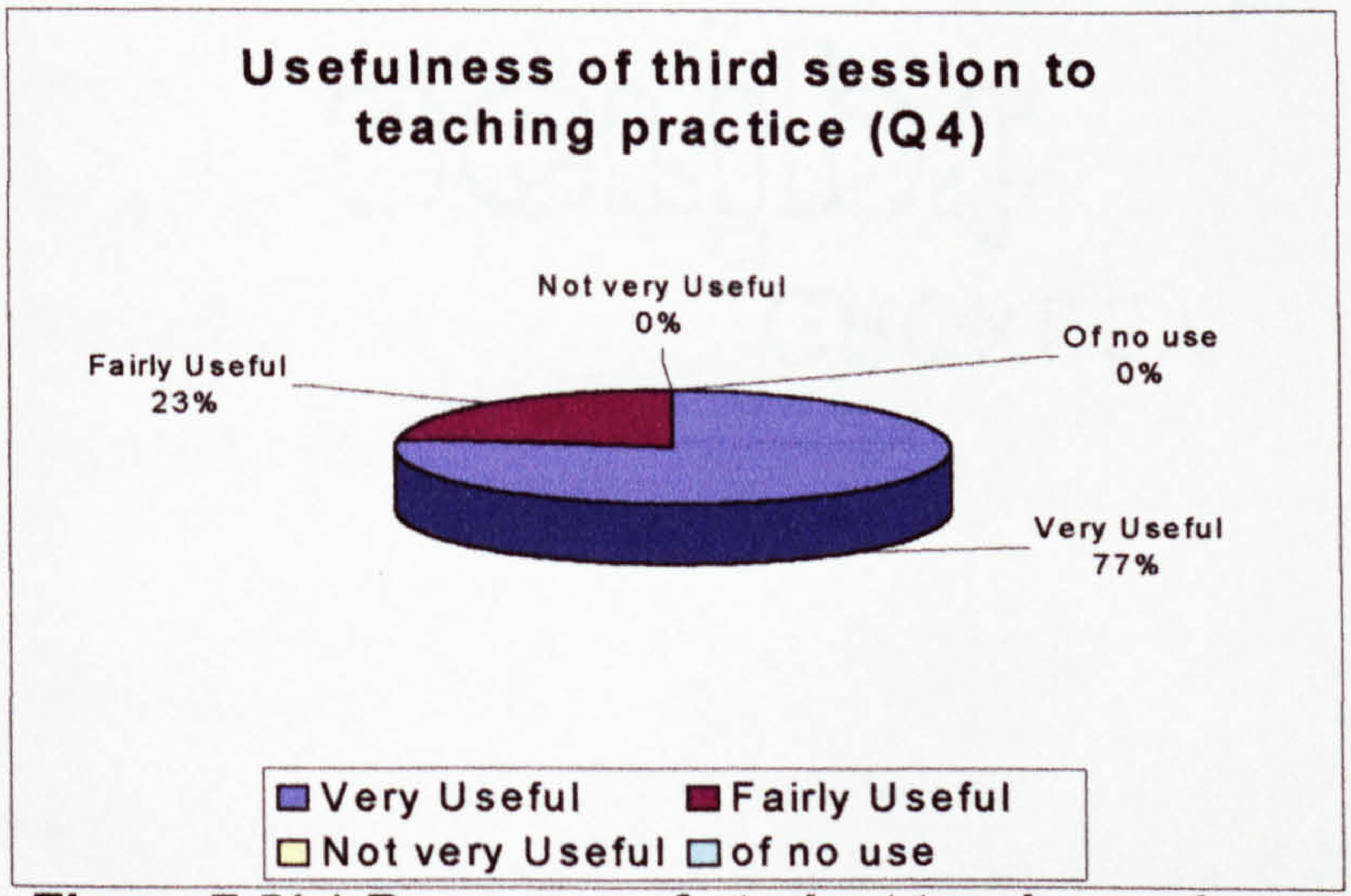


Figure 7.5(c) Response of student teachers when asked to describe the usefulness of session 3 of Intervention Package to their teaching practice.

7.4.1 View of science

The view of learning as exemplified by the student teachers will be discussed under the same categories that were used in the analysis of the baseline data, i.e. body of principles, method of enquiry, a practical subject and an important social institution.

(i) Body of principles

The analysis of the videotaped lessons clearly shows that 10 of the 16 student teachers (62%) in the post-intervention study taught their lessons with considerable emphasis on learning definitions and facts. A study of the lesson plans prepared by these 10 student teachers also shows that their lesson plans were very much driven by factual information. However, it is interesting to note that there is evidence of some degree of a shift from this high emphasis on scientific content in the case of the other 6 student teachers. For example, Seamus gave an example of an investigative-type approach in teaching the topic of electrochemistry where pupils constructed their own simple electrolysis kits to investigate the electrolysis of dilute sulfuric acid. Similarly, Anne taught a class on physical and chemical changes in which the distinction between the two types of changes was built up by careful questioning and practical investigations rather than presented in a table as a *fait accompli* - the method used by the majority of her fellow student teachers.

In the analysis of the interview data, there is still a strong emphasis among the majority of the student teachers on learning definitions and facts. For example, when the student teachers were questioned about the emphasis on covering scientific content in their lessons, it was clear that this was seen by the majority of them (63%) as the main aim of the lesson. To illustrate this, when Kayleigh was asked about the aim of the lesson that she gave on atomic structure, she replied:

> "Well, at the end of the lesson, I wanted the students to know that elements were composed of atoms, and the structure of an atom. To know the three components – the proton, neutron and electron – where they were found, what charge each of the particles had, and then to know from the periodic table that could get the number of protons, neutrons and electrons in an atom of any element."

Similarly, when Hannah was asked about what she had hoped the pupils would have learned from her lesson on electrochemistry, she concentrated very much on the terminology covered in the lesson:

> "I just wanted to introduce the basic terminology... I wanted to introduce the terminology and focus on relating terminology to a particular system, and that hopefully afterwards if I showed them the system again that they'd be able to say well that part is the electrode, this is the electrolyte and define them and have an idea. Not even learn it off but have an idea what was going on in the different parts of the system and to be able to use the terminology, I felt, because it's a new area and when they'd go into it deeper, it's all that terminology; electrode, electrolyte and all of that, so that was my main aim really.

However, on analysing the interview data for references to the importance of fostering understanding among the pupils, it was found that there was definite evidence in the case of 11 of the student teachers (69%) who spoke about the importance of ensuring that the pupils understood the concepts being taught.

For example, when Fiachra was asked about what he hoped pupils would learn from the class she gave on solutions, her answer did not simply focus on the terminology (as was observed in the baseline study of a lesson on the same topic) but dealt with a more general understanding of solutions:

> "Basically, to be able themselves to identify that, simply, a cup of coffee is a solution. That there's coffee in there, that the coffee doesn't disappear, it's still present, but it's dissolved. And if they could identify that, especially in their everyday going around the place, know that that's a solution of salt and water, and know whether something is soluble or insoluble"

Similarly, Padraig was more interested in generating an understanding of the concept of the atom among the pupils than simply dealing with the terminology:

> "Well, I wanted them to understand the concept of what an atom was, that it was a small object, really tiny. And I also wanted them to know the structure in that there was an outer layer where the electrons were located, and in the centre there were protons and neutrons."

In one case there was evidence of the student teacher trying to get the pupils to extend their understanding of chemical reactions from the specific example covered in class to other examples. This student teacher also referred to some background reading he had done in the area of problems that pupils have when understanding atomic structure:

> "I wanted my pupils to be familiar with what a chemical change was, what a chemical reaction was but I didn't want them to learn it in context if you know what I mean. I wanted them to be able to take what I told them and apply it to a totally new system, so it was more of an understanding really, than just to learn it in context, and I suppose having read some of the problem articles about chemical changes is that you know disappearance and all this sort of thing transmutation, displacement, all of that are big issues and the little part with the sod of turf and the ashes, when they were able to see that, that meant that they do believe that the matter is transformed into a new substance, because a lot of the time what they perceive is what goes rather than the microscopic world, or whatever they're looking at from the macro the whole time."

It is worth noting that whilst 11 of the 16 student teachers spoke in the interviews about the importance of emphasising understanding rather than concentrating simply on factual information, this did not translate into practice in the classroom. Analysis of the observation data clearly shows that only 6 of the 16 student teachers (38%) demonstrated this shift in emphasis.

(ii) Method of enquiry

In the analysis of the baseline observation data, only 1 of the 12 student teachers demonstrated any form of enquiry in their teaching. This form of enquiry was limited to a "predict-and-explain" type activity. Analysis of the post-intervention observation data shows no evidence of the student teachers attempting to give the pupils an understanding of the scientific approach to enquiry or the limitations of different kinds of scientific knowledge claims or the difficulties of obtaining reliable and valid data. This would appear to suggest that, in terms of an enquiry approach to teaching, the student teachers are still at the **management** stage (stage 3) of the CBAM model, i.e. their main concerns are items like preparing resource materials, organising their time and teaching their classes rather than taking a broader perspective of teaching.

(iii) A practical subject

Of the 16 lessons observed in the post-intervention phase of this study, 13 lessons (81%) involved some form of laboratory practical work. This compares favourably with the fact that 58% of student teachers in the baseline study performed practical work. The practical work in the post-intervention study was either demonstrated by the teacher or carried out by the pupils themselves. This higher level of practical work was also reflected in the lesson plans of the student teachers. Typical practicals carried out involved test-tube experiments to investigate chemical reactions, making iron sulphide, diffusion of hydrogen chloride and ammonia, making carbon dioxide, showing that air has mass and electrolysis of acidified water.

Most of the practicals observed involved typical "recipe type" experiments found in the textbook. In the interviews, the student teachers tended to speak in a very animated fashion about the practical work they had carried out. For example, Eoin set up a series of test-tube experiments to introduce the idea of chemical reactions. When asked about this in the interview, he clearly showed that he was very pleased with his results:

> "Because the kids can refer to it while we're doing the experiment and I'm going through it bit by bit while the kids are sitting down there so it's not me handing out test tubes, saying put this into this so they can see it beforehand, it's all labelled as well, they can see sulfuric acid was added to the barium chloride and the sulfuric acid was added to the magnesium."

Even in lessons that did not lend themselves easily to practical work, the student teachers tried to have some form of practical activity. For example, Daniel used molecular models when explaining about covalent bonding. Also, Mary used the balancing of apples and oranges on a home-made balance to illustrate the balancing of chemical equations. When questioned about this in the interview, Mary was clearly happy about the success of this type of strategy:

> " ...and then I did the kind of apples and oranges and kind of said if I have two oranges here can I have an apple and an orange here, you can't, why, tell me, we can see it and I try to bring it into an apple can represent aluminium and an orange can represent an oxygen. And just trying to balance it in so I tried to bring it to that level because I though to myself that might be one of the hardest parts."

The importance of practical work was summarised by Aoife who gave a very interesting lesson on physical changes and chemical reactions. She had the pupils enthralled by a simple experiment of a candle standing in a beaker containing some baking soda. She added vinegar to the baking soda and asked the class to explain why the candle went out. This generated great discussion in the class and created a great "buzz" of activity:

> "....you know the candle being surrounded by the baking soda. And if you add the vinegar when the candle is lighting, you can see the candle going out......But I think it really put them thinking, you could see the baking soda had gone all fizzy and didn't feel the same when they touched it, and they could see the candle going out. So it kind of gave them an idea that a new substance had been formed and something had happened to make the candle actually go out. I suppose science is a practical subject and if you want to make it interesting for your students, you have to have some little experiment every day. You don't have to have something fantastic, but you have to have something small every day or else you are going to lose interest straight away, no matter what you're teaching. So I would always have some small experiment every day, no matter how silly it was or if it only lasted for two or three minutes. Something that would really make them interested in the subject."

However, there was little evidence of practical work that was specifically aimed at challenging misunderstandings with a view of developing thinking along scientifically accepted lines. The only example of this was in a class dealing with chemical changes. David was trying to get across the idea that a new substance was always formed and that mass is conserved when a chemical reaction takes place. He used the volcano experiment to challenge the pupils' conclusions when they saw a small amount of yellow crystals being burned in the fume hood to generate a large volume of green powder. When asked about this in the interview, he was quite excited about it and felt that the experiment had been successful in achieving its aims:

> "Being a Dip [H.Dip.Ed student teacher] and not having taught the Junior Cert. course before, I mean I was given a scheme by another science teacher in a school. Chemical change came up for teaching and I didn't feel that [name of textbook] covered it well at all you know. The book seems to be very vague... but the way I taught it was I looked at the different problems with the concept of what I would've perceived to be the different problems and the idea of totally new substances - that's one that gets the kids going. They see the new substances as being transformed, the same substance which just looks different, it's still paper rather than ash. In the second one then there were new substances. I showed them that clearly, in the volcano experiment because I had the chromium

> oxide that was green in colour and started with a bright orange colour."

The increased level of practical work by the majority (81%) of the post-intervention student teachers is in contrast to the smaller number of student teachers (58%) who were observed using practical work in the baseline study indicates a greater willingness among the post-intervention student teachers to include practical work in their lessons.

The higher level of practical work among the post-intervention student teachers may be evidence of *new awareness* as discussed by Harland and Kinder, i.e. "a perceptual or conceptual shift from previous assumptions" (Harland and Kinder, 1987, p.73). However, the fact that there is little evidence of an attempt by the student teachers to use practical work to challenge the misunderstandings of the pupils could suggest that the level of use on the CBAM scale is IVA (Routine), i.e. the student teachers have settled down into an established pattern of use of practical work and have not attempted to go beyond this in order to produce more beneficial effects. (Hord, 1987 p. 111)

(iv) Important social institution

In session 1 of the Intervention Package, reference was made by the tutor to the aims of science teaching. In the 15-minute presentation given by the tutor (interspersed with some discussion) reference was made to the following areas:

- An awareness of how the applications of science affect our lives and the society in which we live.
- Interest and curiosity about science.

- Some appreciation of the nature and limitations of science.

One of the intended outcomes of this session was that the student teachers would "be able to describe some of the aims of science teaching". However, of the 16 student teachers observed teaching in the post-intervention part of this study, only 4 of them (25%) displayed any awareness of the social or historical aspects of science. These examples included Padraig talking about the work of the ancient Greeks when explaining the meaning of the term "atom"; Hannah spoke about the work of Humphry Davy when she demonstrated some of the properties of the alkali metals; Eoin told the class the story of the Hindenberg airship when talking about the properties of hydrogen gas; Sean talked about the efforts of Mendeleeve to arrange the elements in order in the Periodic Table.

When Padraig was questioned about why he told the story of the ancient Greeks to the class, he clearly felt that the background information fitted in well with the topic he was teaching:

> "Well, I just wanted to bring them back to where the word originally came from, and I got that from the Internet. I got this little paragraph on it, and I just gave them a basis of why we were studying it, and this Greek philosopher came up with the idea, and the definition and who came up with the word, and it kind of worked from that."

Similarly, when Sean was asked about his approach to teaching the Periodic Table, he spoke about the importance of putting the lesson in its historical context in order to give pupils an appreciation of how the structure of the Table evolved:

> "Well, it was an introduction to the Periodic Table. So basically what I wanted them to know was a bit about the history behind it – how it was developed – and just a general idea of how it worked. Why it was shaped like it was, and why the elements were arranged the

> way they were in the periodic table. Now I didn't want them to know much more specifically than that, because I felt if I tried to go into that in one lesson, it would be too much for them to take in. Because it was very much a theoretical lesson ...just a lot of explaining and stuff, there wasn't much practical things I could do with it. So I wanted to keep it quite general – just how the Periodic Table works, the groups and periods. Don't go into it much more than that so I can develop it more in further lessons."

In the baseline data analysis, only 2 of the 12 student teachers (16%) made any effort to put science in its social or historical context. Whilst this percentage of student teachers in the post-intervention study has increased (25%), nevertheless it is clear that the majority of student teachers still do not see this area as being an important factor in bringing about effective learning in science.

7.4.2 View of learning

The view of learning as exemplified by the student teachers will be discussed under the same categories as used in the baseline data analysis, i.e.
(i) *Transmission versus active learning* and (ii) *Control and choice offered to pupils over activities* and (iii) *personal reflection.*

(i) Transmission versus active learning

This section discusses the active learning strategies used in the classroom by the post-intervention student teachers. In particular, it examines the active learning strategies that focus on challenging ideas and developing understanding of difficult ideas in chemistry. Analysis of the post intervention observation data shows that 13 of the 16 student teachers (81%) used some form of active learning in their teaching. This is an increase from the baseline data where only half of the student teachers adopted some form of active learning. The active learning observed took a number of forms, e.g. classroom activities like discussions (usually generated by Concept Cartoons), pupil worksheets on difficult ideas, word searches and crosswords, role play of pupils to build up the Periodic Table, pupil practical work in experimenting with "home made" electrolysis apparatus, groups of pupils assisting the teacher in setting up and carrying out demonstration experiments, group work in which pupils tried to figure out chemical formulas, practical worksheets to distinguish between physical and chemical changes, use of diagnostic questions, etc. A study of the lesson plans of the student teachers shows that these "active learning" type activities were not spontaneous occurrences but were incorporated into the planning of the lessons.

Some interesting comments arose in the interviews when the student teachers were questioned about some of the active learning strategies they were using. For example, Sean used a Concept Cartoon in his lesson to elicit views from the pupils as to their understanding of the term "periodic" as it applied to the Periodic Table. When Sean was asked about the fact that he had a lot of discussion going on in his lesson about the Periodic Table, he acknowledged the beneficial effects of Concept Cartoons in promoting this discussion:

> "As for Concept Cartoons, the one thing I noticed about the chemistry book is that it's limited materials and stuff, so to try and think of them yourself then is a bit tougher, from a point of view of even drawing them up. But I do think they are a very good idea and I would use them wherever I can, because it's something different, and also make for good discussion."

Anne Marie gave a lesson on chemical reactions and used a Concept Cartoon to generate a lively discussion about why a yellow substance was formed when two colourless solutions were mixed:

> "The reason I used it was because I had used a Concept Cartoon before with a previous class, and I was amazed at the response of

> the students. It would never have occurred to me that something would get the students interested, not just in a funny humorous way but in that they see it as a puzzle that they have to solve .....And as for why I chose that particular one, looking through some of the material on misconceptions, it was obvious that where the new product comes from at the end seemed to be a major stumbling block for students. And so they would seem to think that it was some modification or change that occurred to one of the things you mixed, that would bring about this new colour or new substance that you saw. So it was a pretty simple one. My idea then was to take that and take three different kids with three different opinions about where this substance came from. And seeing as the misconception would generally be 'That must mean A turns B yellow' or 'B turns A yellow', because sometimes the way you mix them, they think that actually matters if you put B in first or A in first".

Clearly, Anne Marie set out to challenge the pupils' ideas about chemical reactions and she appeared very pleased with the results.

Eoin gave a lesson on physical changes and chemical reactions in which pupils worked in groups and carried out a series of test-tube experiments. He obviously felt that this was a very beneficial strategy:

> "I thought if they saw for themselves, what a chemical reaction does, especially that a new product is being made, so the clear sulphuric acid and the clear barium chloride added together will give a precipitate. First of all they didn't know what a precipitate was, I don't think I actually used the precipitate because I think it's a bit complicated for them so we just said it went white and then we linked it to suspensions and the fact that there was all little particles going around, the fact that the new product was white, the old products were clear and clear, so it was just for them to do it themselves, if I'm up on the blackboard doing it so it wasn't even too difficult to set up, all I had to do was set up solutions and pour them into the test tubes......"I thought the kids were quite interested in it, they actually got stuff to do and stuff to see and they all got hands-on, they all put one chemical into another chemical and saw a chemical reaction, so that was the best part of the lesson I think from their point of view."

He followed up the lesson with a worksheet in which pupils had to classify each of their observations and explain why some were physical changes and others were chemical changes. He asked some of the pupils to call out their answers and this led to some discussion – though not as lively as in the case of Anne Maire's class.

Mary was teaching the topic of chemical formulas to a group of 14-year-old pupils. She had lots of artefacts (apples, oranges, home made balances, worksheets, molecular models, etc) incorporated into her lesson. It was obvious from the lesson that she had a great rapport with the pupils. When questioned about this, she clearly recognised the importance of getting the pupils involved in the lesson:

> "I myself like the idea of teaching science because I like the idea of interaction with the students, to get them involved in experiments that's how I think I used to learn the work, rather than reading and learning and I thought of chemical formulas... it's the tough one because there isn't much student interaction there..." - Mary

However, at no stage did she try to challenge their understanding of what was happening in the chemical reactions to give rise to these chemical formulae. Thus, whilst the majority of the student teachers made a definite effort to incorporate some form of active learning into their teaching, not all of it was aimed at challenging pupils' ideas and misunderstandings. Some of the interview data (like Mary's above) suggest a belief among the student teachers that active learning *per se* would help to overcome misunderstandings without the need to challenge the ideas of the pupils.

The use of active learning strategies that challenge the misunderstandings among the pupils is directly related to two of the outcomes of the third session of the Intervention Package:

- Be capable of making suggestions for classroom practice which help to overcome these misunderstandings in chemistry.
- Be capable of developing teaching strategies to help overcome children's misunderstandings of ideas in chemistry.

It would appear from the lesson observation data and the interview data that these outcomes have only been achieved to a limited extent by the active learning strategies adopted by the student teachers. In the CBAM model, these student teachers would be described as having reached level IVB (*Refinement*) on the index of use, i.e. they see some potential in the innovation and are seeking ways of using the innovation "to improve pupil outcomes" (Hord, 1987 p. 113).

It is interesting to note that of the three student teachers who had no form of active learning incorporated into their lessons, two of them used Powerpoint presentations in their lessons. Obviously, given the small number of student teachers involved in this study one cannot draw conclusions but this observation does raise the question: "Is there a possibility that Powerpoint has the tendency to turn teachers into lecturers?"

(ii) Control and choice offered to pupils over activities

In the analysis of the baseline data there was no evidence of the student teachers deviating from any of the activities outlined in the standard textbooks (section 6.3.2). In the analysis of the post-intervention observation data and lesson plan data, a similar finding was made. In no case was a choice offered to pupils over the activities – in all cases, the work was prescribed by the teacher and the instructions followed by the pupils.

In the analysis of the interview data, there is some evidence of recognition among the student teachers that more freedom of choice should be given to pupils. For example, when Daniel was questioned about his use of ready-made molecular models in teaching chemical bonding, he realised that the class would have been more effective if the pupils had to make their own models of molecules:

> "....... I think the only way you could have involved pupil activity there was maybe making models or alternatively one of the things I probably should have done was given them out a question each just on the atomic number and the mass number, given them out an element with the atomic number, the mass number and got them to calculate the number of protons, the number of neutrons, the number of electrons, I possibly should have done that, and possibly given them balls of plasticine or something to make the molecules, with the atomic structure I don't know could I have done much with them.".

Only one other teacher, Kate, realised that the lesson could have been improved if she had encouraged more of the pupils to become involved in the demonstration experiments:

> The other kids love watching other kids taking part, much better than just watching me doing it, so it increases their concentration as well. And the other thing is, looking back on it, one of the ways you gain confidence in life is just getting up in front and doing something, even if it goes wrong. And it's easier doing it when they're 12 rather than when they're 15 or 16 and much more self-conscious..... give them more freedom to participate and try getting them up then in order to come up and participate."

The fact that so little control and choice was offered to pupils over the activities is not surprising given that the Junior Certificate science course in Ireland has a very detailed national syllabus. Teachers tend to stick closely to the syllabus to get it finished over the three-year period in order to maximise the examination results of their pupils.

(iii) Personal reflection

Among the aims of the Intervention Package were:

- To encourage student teachers to reflect on some misunderstandings in science that they have studied in the research literature. (Session 2).
- To encourage the student teachers to reflect on the types of teaching strategies that are of assistance in overcoming children's misunderstandings of ideas in science. (Session 3)

In addition, one of the intended outcomes of Session 3 was:

- Be aware of the fact that the misunderstandings may still persist after the lesson and know that further developmental work may be required.

In the course of session 2 of the Intervention Package, the student teachers made a short presentation to the class on a research paper that he/she had studied. By encouraging the student teachers to reflect on some misunderstandings in science, it was hoped to make them aware of the implications for teachers. Each student teacher completed a summary sheet for the research paper (Appendix XI, page 439). The final question on this summary sheet was: "What are the implications for teachers?". Typical answers given by the student teachers were:

> "Development of conceptual change – teaching techniques need to promote understanding of topics like chemical changes."
>
> "Students' ideas about science, such as dissolving, are heavily influenced by the fact that the substance that dissolves disappears. Teachers need to be aware of this problem and how to address it."
>
> "Teachers must challenge the firmly entrenched ideas that students have and maybe even used these notions to change the alternative conceptual ideas that students possess by confronting them directly."

> "Teachers should be aware that children's preconceptions may be very resistant to change and therefore must spend time addressing a new topic."
>
> "Everyday language must be looked at in teaching to thwart the misconceptions in 'people speak'. "
>
> "Teachers can put students into groups and discuss their answers and can examine each other's reasoning. This would reduce misconceptions on scientific topics".
>
> "If science teaching is to be more successful in the many areas where everyday meanings are different from the scientific ones that they learn at school, then it must address the issue of everyday language directly in the students' lesson."
>
> "Teachers shouldn't assume as much as they do when it comes to teaching the 'Transmission of Light'. It was clearly evident in the paper that student with/without tuition in light still had misconceptions."
>
> "Students have many ideas about science before ever being taught the topics in particular."
>
> "Overall, teachers should develop teaching methods based on these misconceptions, because if prior knowledge is ignored, pupils view science as difficult."

Clearly session 2 of the Intervention Package has achieved the aim of encouraging the student teachers to reflect on some misunderstandings in science that they have studied. How does this reflection influence the classroom practice of the student teachers when teaching difficult ideas? As in the baseline study, the post-intervention student teachers were asked to reflect on their lessons in both the interviews and in writing at the end of each lesson plan. In the reflections of the student teachers, a strong theme to emerge from this self-reflection was the fact that they realised their shortcomings in terms of their experience of teaching and, in some cases, their own subject knowledge. For example, in her reflection written into her lesson plan, Elizabeth was happy that in the lesson she gave on physical and chemical changes, she succeeded in encouraging lots of questions from her pupils. However, she was rather self-critical that she did not control the questioning a bit more as some of the questions were not directly related to the topic being discussed:

> "The lesson went more or less along the lines I had planned. I've encouraged these first years to ask many questions and this has the unpredictable result that their questions tended to dominate and direct the lesson. This I greatly welcome as long as the questions are somehow connected to the topic under discussion."

In another part of her reflection she was clearly aware that some of the misunderstandings that the pupils had about the magnesium simply dissolving in hydrochloric acid still remained:

> "I am glad that the students seemed happy about the differences between physical and chemical changes but I still feel some pupils are unwilling to give up the whole idea of the metal dissolving in the acid"

This particular problem of pupils being confused between melting and dissolving had been discussed in sessions 2 and 3 of the Intervention Package. In fact, one of the intended outcomes of session 3 was that the student teachers "be aware of the fact that the misunderstandings may still persist after the lesson and know that further developmental work may be required".

Daniel gave a lesson on atoms and molecules (through the medium of Gaelic) but was extremely self critical in his own evaluation in his lesson plan. (He is the holder of a BSc honours in chemistry and exhibited no problems with his subject knowledge):

> "Class very well behaved but very dead.....too much material covered, should have had review of each section of the lesson at different stages during the lesson, possibly using a test, my Irish needs to be improved, talking too fast, should have used labels on the overhead projector for the final review, used bigger balls of plasticine...the Powerpoint effects were not great".

Without doubt, Daniel is being too critical of himself as he does not refer to any of the positive points observed in the lesson, e.g. his good use of questioning, his use of models and the good graphics and summary diagrams used in his Powerpoint presentation.

Bearing in mind that the student teachers were teaching these topics on difficult ideas for the first time, some of the student teachers clearly felt that the topic should be done at a later stage. For example, Padraig gave an introductory lesson on atomic structure to a group of 12 – 13 year old pupils. However, it is clear from the reflection in his lesson plan that the experience made him realise that this topic would be better treated when the pupils were older. In fact, based on the feedback from the pupils during the lesson, he left out some of the more difficult material in his lesson plan:

> "This chapter is a very difficult one.....However, allowing the children to come up with THEIR definition of the atom was a great idea. The cutting up of the carrot and the 10^{16} carbon atoms in a full stop really made this concept more concrete and real....Handing out the sheets and asking the students to place the neutrons, protons and electrons in the atoms allowed me to check to see if they understood what was going on. I didn't show the 30 diagrams of the atoms [in the Periodic Table].... This might have confused the situation. Overall, I firmly believe I would not introduce this topic again until second year".

Some really good, honest reflections on the lessons took place in the interviews. For example, when discussing the lesson she gave on the particulate nature of matter, Catherine felt that she was doing too much of the talking and not asking enough questions:

> "First of all I would probably again maybe do a little more with them, maybe on the changes of state just a little bit more, just to stretch them because they are such a good class. I think at stages there I was doing a lot of the talking, I think I might get more out of them themselves and ask more and more questions to them, I think I did a lot of talking throughout the class."

In the interview, Daithi felt that his lesson on the particulate nature of matter highlighted a similar problem with his teaching:

> "I wouldn't be as didactic if I could, I thought it was too much of me talking, there should be a bit more discussion"

In the interview following his lesson, Pat, on viewing a section of the videotaped lesson, felt he had covered too much subject matter and needed to improve his body language:

> "Well I kind of covered an awful lot...I think it highlighted a lot of problems with my teaching that we'll have to sort it out, I think my body language too, I looked very aggressive there at stages and other times I looked too relaxed so I'll have to try to sort that out."

Thus, whilst the student teachers were very forthcoming when asked to reflect on the teaching strategies used to overcome difficult ideas, their own level of self-criticism almost blind them to the successful aspects of these teaching strategies.

One of the most enthusiastic teachers in the post-intervention group was Aoife who gave a lesson on physical and chemical changes. At the end of the lesson, she handed out worksheets for the pupils. In the interview, she clearly was not satisfied that the worksheet was up to standard and regretted that she had not put more time into its design:

> Aoife "Well I had this little handout at the end, I got it out of a book just to see if they knew the difference between physical and chemical changes, so they could decide what were the differences between them."

> DK: "Is that the table, where you ask which of the following is a physical or chemical change and you had to put a tick next to each one?"
>
> Aoife: "Yeah, that's right."
>
> DK: "And do you feel that that it worked?"
>
> Aoife: "I thought some of them were a bit hard, because while I was able to see why some of them weren't a chemical change, the students couldn't. I thought some of them were a small bit too difficult."
>
> DK: "What ones would you think would be too difficult?"
>
> Aoife: "Well I thought that one was too hard, because they wouldn't understand the concept of how beer is brewed... And I think a few of them got tricked on the one too, about making the French dressing with the oil and the vinegar. They thought that was hard. They knew of course that the paint dry was a tricky one. I think they were the hardest ones. And I think a few of the weaker students found other ones hard too, and I kind of regret it now. I think I maybe should have put a bit more time into it, but I was kind of stuck for time. I probably should have made up one myself, looked at it more closely and thought about it, but I didn't, and I'd say that was the worst part of the lesson. If I were to say there was a very bad part, I'd say that was a very thoughtless part really. It was nearly just to have something for them to do at the end, but if I was to do it again I definitely wouldn't do that, because it was a bit over the top for a few of them."

The level of maturity of reflection found in many of the above reflections is not found in the baseline data.

However, in keeping with what was observed in the baseline data, a greater proportion of the student teachers expressed a realisation of their shortcomings in the interviews (10 of the 16 student teachers i.e. 63%) than in the reflection written into their lesson plans (3 of the 16 student teachers i.e. 19%). This may be as a result of the more relaxed environment of the interview in which they could reflect more deeply on the lesson in respond to the various prompts and probes in the absence of their official supervisor. In the reflection written into their lesson plans, there may be the fear of marks being deducted by the official supervisor if the impression is given that the lesson did not go according to plan.

There is a clear link between value congruence outcomes and teachers being comfortable both with new areas of teaching methods and the accompanying subject knowledge (Harland and Kinder, 1997 p. 73). These authors make the point that whilst some teachers embrace an innovation, other teachers stay with "the approach they remain comfortable with" (Harland and Kinder, p. 73). For student teachers, this latter response may be what they experienced themselves as pupils. To what extent does a problem with lack of subject knowledge among the student teachers have a bearing on the extent to which they embrace the Intervention Package? In the analysis of the baseline observation data, it was found that of the twelve lessons observed, three of them (25%) indicated a lack of subject knowledge on the part of the student teachers presenting the lesson. Analysis of the post-intervention observation data showed a lack of subject knowledge in the case of 4 of the 16 student teachers whose lessons were observed (25%). Unlike formal supervisions carried out by the university tutor, the lack of subject knowledge was not pointed out to the student teacher in the interview that took place after the observation of the lesson. The situation needed careful handling by the researcher lest it might impact on the willingness of other student teachers to participate in the research study or could cause some student teachers to become demoralised after the interview.

Some of the student teachers felt uncomfortable teaching certain topics in chemistry. For example, when Hannah was observed teaching a class on electrochemistry, she used the wrong colour coding for the electrodes and gave an incorrect explanation in answer to a question asked by a pupil regarding the reason why the hydrogen ion was discharged at the electrode rather than the sodium ion. In the interview, when Hannah was asked about problems the pupils had with this area, her response reflected her own feeling of discomfort when dealing with this area:

> "I think the whole area is difficult, I think it's really hard area for them to understand........it's difficult for fourteen, fifteen year old students to understand, to grasp that concept. And also I suppose, the combination of electricity and chemistry, that's a bit unusual for them to grasp. It's hard for them to imagine ....you know they've always kept electricity separate, that's in physics and chemistry is chemistry and there's no link, so that's hard enough I suppose. If I was really to think about it yes, that's hard enough, even the definition."

Even the final interview question ("Before we finish, is there anything that you would like to say about the lesson that hasn't come up in our conversation?") elicited a response in which the same student teacher referred back to the difficulty she had with the subject and appeared to find comfort in the fact that some other teachers in the school had similar difficulty:

> "Well I think it's a very hard topic I really do, I think it's almost above their understanding to be perfectly honest. When talking to the other teachers about how they would approach Electrochemistry, teaching it to the class, it did come across to me that no matter what pedigree of teacher you are or how long or how experienced you are that they're like, 'O Electrochemistry that's terrible' and one of the other teachers I spoke to, she just covered it before Christmas with her third years, so it's left to the very end to do because it is very difficult and I was happy enough with what they gathered because to be honest I just think it's ridiculously hard topic for them to understand. I really do. But I've never been a lover of Electrochemistry myself, that particular area."

The other areas in which lack of subject knowledge was apparent was in the case of Fiachra giving an incorrect explanation of the effect of heat on solubility, Catherine giving a wrong explanation and incorrect demonstration of the process of diffusion and Elizabeth using the wrong terminology ("physical reaction") when teaching about the topic of physical changes and chemical reactions. This terminology even caused confusion for the researcher!

One of the main factors contributing to the problem of subject knowledge is the fact that, in many cases, the student teachers are teaching outside of their own subject specialist area. In Ireland, applicants for the Higher Diploma in Education are selected on the basis of examination results in their degree courses. There is no quota for science graduates nor it there any mechanism to select student teachers from different science disciplines. Since all student teachers teach a broad science course to the 12 – 15 year age group, it is not surprising that problems with subject content knowledge arise. In addition, the introduction of modularised degree courses and direct-entry degree courses into Irish universities has had the effect that one can no longer assume that the student teachers have a common foundation of physics, chemistry and biology in first year. The Intervention Package did not specifically aim to improve the subject knowledge of the student teachers. However, some aspects of subject knowledge were covered when discussing the research papers in session 2. Some of the student teachers used their own strategies to deal with difficult questions from pupils. In two cases the student teachers did not "pick up" on questions asked by pupils in the course of the lesson and diverted the question with a response like "we will cover that in another lesson". An example of this was in a lesson on the Periodic Table given to a group of 12 —13 year old pupils by Sean. One of the pupils asked the reason why hydrogen was "out on its own from the rest of the table". Sean gave the unsatisfactory response "because hydrogen is totally different, we'll cover that later on" and carried on with the lesson. When asked about pupil questioning in the interview, he referred to this incident and acknowledged his own sense of inadequacy:

> "It was a very good question. It caught me a little bit, I must say, and I probably should have been prepared with an answer for that. They are very quick that way, in that if they see something they'll ask it. Yeah, it was a very good question, and I suppose I'll redress it again when I'm going into the specific properties of each group in the periodic table. I'm not surprised – they're always asking me questions like that, they are very good and very quick."

In some cases it was apparent to the researcher that, whilst the lesson itself seemed to proceed without any problem, the student teachers lacked a sense of confidence in teaching topics involving difficult ideas. For example, Eoin gave a lesson on chemical reactions in which he made extensive use of pupil practical work. However, once he began to draw the various points together towards the end of the lesson, his notes never left his hand and the balanced chemical equations were transcribed verbatim from his notes to the blackboard. He reminded the class what happened when the magnesium ribbon was added to dilute sulphuric acid and used the phrase "the magnesium disappearing". When asked if he felt that the pupils thought the magnesium had, in fact, disappeared, he was quick to realise his poor choice of language:

> "No, when I say it 'disappeared' it's kind of common language more than kind of scientific language, so I put it up on the board, we had our magnesium, our sulphur dioxide, our sulphuric acid, magnesium joined with the sulphate so we had magnesium sulphate and the hydrogen went off. So from that point of view, I don't think they think the magnesium disappeared completely as in The Law Of Conservation Of Matter, just because we put the equation up on the board and I just circled the magnesium and sulphate part of the

> sulphuric acid, we saw that hydrogen was on its own and it could just go off as a gas."

On analysing the observation data for other examples of this lack of confidence in teaching, three further examples were found: Fiachra clearly showed she was not at ease teaching the pupils how to deduce atomic structure from nuclear formulae. She carried out the procedure like a mathematical exercise, spent little time in explaining the reason behind the procedure and carried on to the next topic. Similarly, while Roisin gave a good lesson on solutions, she stuck rigidly to the textbook, all her examples were taken from this textbook and all the questions she asked were based on the same textbook material. Finally, Ann taught a lesson on balancing equations. The lesson was satisfactory in every sense but never strayed from the steps outlined in the textbook. All examples were taken from the textbook and all questions based on material in the textbook. Her lesson was delivered via Powerpoint and, at times, it appeared as if this medium was being used as a "crutch" to help her get through the various points.

The lesson observations data shows that the remaining 12 student teachers were reasonably confident when giving the lesson. Aoife showed a maturity beyond her age in giving a lesson on physical and chemical changes and, when asked in the interview about the fact that he hardly consulted her lesson plan, she pointed out the need for being confident in the lesson:

> Maybe it wasn't exactly as I had written in the lesson plan, but I think ultimately I did try and cover most of what I had written. I just don't think it's great to be walking around with the sheets in your hand, reading them and trying to remember what's going on. Students would lose confidence in you..... if you're reading out a load of lesson notes they think she needs to be reminded constantly of what she's doing. And I think if you can do it without the notes, you're much better off. I know it wasn't exactly as it was in the notes, but I think I tried to cover as much of it as I could remember."

In summary, it is clear that problems like lack of subject knowledge, inability to handle questions, and lack of confidence in teaching that were found in some student teachers in the baseline study are also found to a similar extent in the student teachers in the post-intervention study. This is entirely to be expected at this early stage of development of teaching skills. What is also to be expected is that, despite the problems outlined above, the student teachers have such a positive attitude towards the Intervention Package as evidenced by the end-of-year questionnaire data. The situation may be explained in terms of Harland and Kinder's *value congruence outcomes*, i.e. the "individuated codes of practice" of student teachers is very likely "to coincide with the INSET providers' message about good practice" (Harland and Kinder, 1997 p. 73). In view of the fact that the INSET provider is their own tutor, that the student teachers are people of high academic ability who aspire to be good teachers, it is not surprising that they would embrace the Intervention Package in such a positive manner.

7.5 Examples of analysed data

As described in Chapter 4, all data (observation, interview, questionnaire and lesson plan) were mapped on to the theoretical framework in exactly the same way as the baseline data. For example, Appendix XX (page 488) shows how a comparison was made between the stated intentions of the post-intervention student teachers as expressed in the lesson plan data with what was actually observed in the classroom. In addition, by comparing this chart with the corresponding chart in the baseline data, it was possible to identify changes between the two sets of data.

As discussed in Chapter 5, the effectiveness of the Intervention Package was assessed using the three themes common to the models for educational evaluation: (i) awareness and provision of information and resources, (ii) new teaching strategies and skills and (iii) attitudinal factors. For example, if one considers the *View of Teaching* category for the post-intervention data, as explained in section 5.3 (pages 219 – 223), this category is analysed under the heading of *New teaching strategies and skills.* New teaching strategies like the use of diagnostic questions and the use of Concept Cartoons emerged from this analysis as described on pages 315 – 319. These new teaching strategies were then analysed in terms of the hierarchy of outcomes in the Harland and Kinder typology of outcomes as discussed on pages 319 and 320.

7.6 Other observations

In the analysis of the baseline data, it was clear that there was a high level of consistency between what the student teachers said in the questionnaires and interviews and carried out in the classroom. For example, their opinion on the need to use strategies like using audio-visual aids, giving everyday examples and making use of practical work were all reflected in the classroom (section 6.10). In addition, it was found that there were some inconsistencies between what the student teachers expressed in the questionnaire and interviews in regard to items like pupil involvement and encouraging pupil opinion, etc. and carried out in the classroom. Are these consistencies and inconsistencies found in the post-intervention data?

In the post-intervention study, high rates of utilisation of audio-visual aids (100%), reference to everyday examples (88%) and practical work (81%) were all observed in the classroom. In addition, areas like pupil involvement in some form of active learning (81%) and encouraging pupil opinion (63%) appear to suggest that the Intervention Package had some effect in these areas relative to the baseline study.

7.7 Summary

This chapter has assessed the Intervention Package using the three themes (i) awareness and provision of information and resources, (ii) new teaching strategies and skills and (iii) attitudinal factors.

Compared to the student teachers in the baseline study, the level of awareness of the post-intervention student teachers about the problem of teaching difficult ideas was heightened by some of the activities in the Intervention Package and reflected in the resources used by them in the classroom. In addition, the post-intervention student teachers used a wider variety of resources in their classroom teaching.

In terms of new teaching strategies and skills, the post-intervention student teachers reported on the usefulness of some of the activities discussed in the Intervention Package and on their application in the biology and physics components of the course. Audio visual aids and Concept Cartoons were widely used by the post-intervention student teachers but little progress appears to have been made in moving them away from over-dependence on the textbook. Relative to the baseline study, there was a significant shift towards more pupil activities like classroom discussions and brainstorming. The Intervention Package appears to have had little effect in encouraging strategies like role play but does appear to have had a definite impact on the use of analogies as a teaching strategy. The post-intervention student teachers placed a lot of emphasis in their teaching on tackling what they perceived as a problem among their pupils of understanding terminology. The activity of discussing research papers in the Intervention Package appears to have influenced them in this area.

In terms of classroom climate, the student teachers appeared to be more conscious of the need to create a good atmosphere in the classroom by involving the pupils and displayed a reflective attitude to this area. There appears to be a definite conscious effort among the post-intervention student teachers to include links to everyday life in their lessons. Relative to the baseline data, a far more prominent role was given to exploring pupils' ideas by the post-intervention student teachers. Concept Cartoons and diagnostic questions were frequently used for this purpose. The use of everyday examples and practical work by the student teachers were very common but the practical work did not tend to challenge the misunderstandings of the pupils. As in the baseline data, little emerged to indicate that the student teachers had views on how to teach particular topics in science.

In terms of the effects of local conditions, it was the examination system rather than the Intervention Package that was still very influential in determining the content of the lessons. Relative to the baseline student teachers, the post-intervention student teachers were more willing to seek help from more experienced teachers. Some student teachers saw Concept Cartoons being useful to help involve the weaker pupils to a greater extent in the classroom activities.

The attitude of the student teachers to the materials covered in the three sessions of the Intervention Package was very positive. There is evidence of some degree of a shift from the high emphasis on scientific content in the baseline study towards a realisation of the importance of ensuring that the pupils understood the concepts being taught. As in the baseline data, there is no evidence of an enquiry approach to teaching among the post-intervention student teachers. There is a higher level of practical work in the post-intervention lessons but little evidence of practical work that was specifically aimed at challenging misunderstandings with a view of developing thinking along scientifically accepted lines.

The post-intervention student teachers showed little awareness of the wider role that science plays in society. There is a definite increase in the use of active learning strategies in the classroom relative to the baseline study. However, whilst the majority of the student teachers made a definite effort to incorporate some form of active learning into their teaching, not all of it was aimed at challenging pupils' ideas and misunderstandings. As in the baseline data, there was no evidence of a choice being offered to pupils over activities in the classroom. The quality of reflection on their teaching strategies was far higher among the post-intervention student teachers compared to those involved in the baseline study. As in the baseline study, the student teachers in the post-intervention study were very aware of shortcomings in their own subject knowledge – an area not specifically addressed by the Intervention Package.

CHAPTER 8

CONCLUSIONS

8.1 Introduction

This study set out to answer the research question: ***How do student teachers draw on the guidance they are given in their training course about dealing with pupils' misunderstandings in chemistry?*** In an attempt to answer this question, data were gathered from a first cohort of student teachers prior to the development of the Intervention Package (baseline data) and from a second cohort of students who participated in the Intervention Package (post-intervention data). By studying various relevant frameworks in the literature, a new framework was developed to assist in the analysis of both the baseline data and the post-intervention data. In addition, a second framework (referred to as a "strategy" in Chapter 5) for assessing the effectiveness of the Intervention Package was devised using the findings from a number of key research projects in the area of curriculum evaluation.

This chapter considers the contributions that the study has made to knowledge by means of the development of the above frameworks. It also discusses the empirical evidence that, in the context of models such as that developed by Harland and Kinder (1997), beginning teachers can improved their expertise as a result of the type of short intervention package described in this study. Finally, this chapter provides a methodological critique of the overall research study.

8.2 Contribution to knowledge

The study has contributed to knowledge in two ways. The first is the development of two structures for providing a comprehensive method of analysing data. The first of these structures takes the form of a framework which enables student teachers' actions in the classroom to be mapped against seven key themes which influence the way in which they approach their teaching (see Chapter 3). In addition, the framework has potential uses in other areas for studying the classroom actions of both student teachers and experienced teachers, for studying the teaching of disciplines other than science and for studying the introduction of teaching innovations in the classroom like role play, discussions, discrepant events and brainstorming (Chapter 3) The second structure provides a model for identifying the effects of the Intervention Package in three key areas (see Chapter 7).

The second contribution to knowledge is to provide empirical evidence that a short intervention package can lead to an improvement in student teachers' abilities to teach difficult ideas in chemistry.

8.2.1 Frameworks developed

As discussed in Chapter 2, very little research has been carried out in the area of how student teachers teach difficult ideas in chemistry. As part of this research study, an Intervention Package to assist student teachers to tackle this problem area has been devised, implemented and its effectiveness analysed. As part of this analysis, a theoretical framework has been developed in order to provide a comprehensive means of capturing the full spectrum of activities and thought processes of student teachers in the classroom. The crafting of this theoretical framework has involved synthesising a range of existing frameworks that have been developed in related areas. Seven main themes emerged from the process of developing the framework: *view of science, view of learning, view of teaching, view of science teaching and teaching of particular science topics, subject knowledge, local conditions* and *personal reflection.* These seven main themes were used to characterise and interpret the variables which influenced the thought processes and actions of the student teachers in the classroom as well as reflecting how the student teachers construed their own teaching. In other words, the seven themes served as the key components of the framework against which the data gathered were mapped as part of the process of analysing the baseline and post-intervention data.

Whilst the above framework was developed for student science teachers, the seven themes are of a generic nature and could readily be adapted to study the teaching of experienced teachers as well as teachers of other subjects.

In developing the framework to assess the effectiveness of the Intervention Package, various models of professional development were studied to assist in devising a strategy to try to measure its level of effectiveness in three key areas (*awareness and provision of information and resources, new teaching strategies and skills, attitudinal factors*) identified in the literature. The models of professional development (Hord,1987; Fullan, 2001; Joyce and Showers,1980; Harland and Kinder,1997) were chosen as these models were based on empirical data gathered from full-time practising teachers. The factors in inservice training courses that are likely to influence the classroom practice of full-time teachers may also be likely to have a similar impact on student teachers. In addition, as discussed in Chapter 5, the models from which the three key areas were synthesised had in-built flexibility, i.e. they can be applied to innovations of different types and scales and tailored to fit varying needs.

8.2.2 Empirical evidence

This research study has gathered a wide range of empirical data on how student teachers teach difficult ideas in chemistry to pupils in the 12 – 15 age range. The most significant aspect of this data is the evidence it yields on the progress student teachers make in their teaching as a result of an intervention package. It could be argued that student teachers are likely to be disposed to use the ideas they encounter in their science methodology courses when preparing their lessons, and this study certainly provides a range of examples of this occurring. However, the study also provides good evidence that many of the student teachers have moved well beyond this point, as can be demonstrated when their progress is mapped against the above four models used to assess the effectiveness of interventions – with particular reference to the typology developed by Harland and Kinder.

This section summarises the evidence which demonstrates the effectiveness of the Intervention Package. It shows that student teachers are quite clearly aware of the problems associated with the teaching of difficult ideas and that they are willing to try out some new teaching strategies and skills in their lessons. Most crucially, it presents evidence to demonstrate that the student teachers have reached the higher orders of Harland and Kinder's typology (*affective outcomes, motivational and attitudinal outcomes* and *new knowledge and skills*), i.e. the conditions which need to be present for an intervention to be most effective and to become embedded in practise. In the following discussion, evidence is presented with particular reference to Harland and Kinder's typology as this is the most comprehensive of the four models considered in chapter 5.

The following sections synthesise the evidence which illustrates the areas in which the Intervention Package was effective. This is done under the three headings outlined in Chapter 5, i.e. (i) *awareness and provision of information and resources*, (ii) *new teaching strategies and skills* and (iii) *attitudinal factors*.

(i) Awareness and provision of information and resources

As discussed in section 7.2, the diagnostic questions of session 1 of the Intervention Package appear to have been successful in achieving their aim. It is clear from the surprise expressed in the responses of the student teachers (page 297) that they were made aware of the fact that their pupils' learning in science is affected by the ideas that the pupils bring to science lessons (session 1 outcome 3). This heightening of awareness is similar to the description of new awareness outlined by Harland and Kinder in level 3 of their typology of INSET outcomes (Table 5.4 page 216). In addition, as also discussed in section 7.2, the end-of-year questionnaire completed by the student teachers clearly showed the extent to which they made use of the various teaching resources to overcome pupils' misunderstandings as introduced to them in the course of the Intervention Package. It is clear from the analysis of the questionnaires (Table 7.1, page 299 and Figure 7.1, page 300) that certain resources were frequently used by the student teachers, e.g. Concept Cartoons, diagnostic questions, obtaining written statements, "predict and explain" resources and questionnaires / worksheets. Whilst many of the student teachers used the "ready made" Concept Cartoons in the commercial publication available, some of the student teachers went a stage further and made their own Concept Cartoon posters. This may be interpreted in terms of a movement by these student teachers from level 3 (new awareness) of the Harland and Kinder typology to level 4 (value congruence), i.e. the student teachers' own beliefs about the benefits of using this innovation coincided with the tutor's message about good practice, thus making it more likely that the innovation would have an impact on practice.

It is interesting to note that the impact of the Intervention Package was also evident in the questionnaire issued in the month of September following the student teachers' completion of the Higher Diploma in Education course. In this questionnaire, the newly qualified teachers beginning their first year of full-time teaching, gave *find pupils' knowledge at start* the most number 1 rankings in the questionnaire completed by them. In addition, whilst the baseline student teachers placed a high emphasis in the questionnaire on items like *use of audio-visual aids*, *varying the topic* and *project work*, the post-intervention students rated these items quite low in favour of other areas like *maintaining pupil interest* and *using everyday examples*. This is good evidence for a movement away from the materials and provisionary outcomes stage (level 1) of the Harland and Kinder typology where the main concern is with the physical resources used for teaching towards the new awareness stage (level 3) where there is a definite conceptual shift from previous assumptions about appropriate content and delivery towards a deeper understanding of good practice.

(ii) New teaching strategies and skills

Analysis of the end-of-term questionnaire (Appendix VIII page 434) shows that Session 1 of the Intervention Package appears to have been successful in encouraging the student teachers to reflect on what is involved in learning and teaching science (session 1, aim 1). In addition, this questionnaire analysis also shows that the second session appears to have some impact in making the student reflect on the fact that pupils have many misunderstandings in science (session 2, aim 2) and of the particular problems with misunderstandings in chemistry (session 2, aim 3). Also, it is clear from the responses to the questionnaire that the student teachers are capable of making suggestions for classroom practice which help to overcome misunderstandings in chemistry (session 3, outcome 2). This deeper and more critical understanding of teaching approaches is described as new knowledge and skills in the Harland and Kinder typology (level 7). At this stage it is possible to identify deeper levels of understanding with regard to curriculum content and pedagogy. The attainment of these deeper levels of understanding in level 7 of the Harland and Kinder model is also evidenced by the fact that when asked in the end-of-year questionnaire to describe the ways in which they used materials relating to teaching difficult ideas in physics and biology in their lessons, almost all of the student teachers were able to describe some of the strategies they had used in teaching the physics and biology components of the syllabus. Harland and Kinder describe this type of observation in terms of deepening levels of understanding with regard to curriculum content and pedagogy being more likely to have a definite impact on practice.

Analysis of the post-intervention interview data shows a slight increase (relative to the baseline data) in the number of student teachers seeking help from their more experienced colleagues. However, in view of the emphasis placed on the teaching of difficult ideas, one would expect a greater increase than that observed (from 8% in the baseline data to 25% in the post-intervention data). Given the fact that the student teachers had been alerted to the problem of teaching difficult ideas, the level of increase is disappointing but understandable in the light of the fact that there is no formal mentoring system for student teachers in operation in most of the schools in Ireland and none in operation in any of the schools in which the student teachers worked. In their typology of INSET outcomes Harland and Kinder describe this type of occurrence in terms of institutional outcomes (level 8), i.e. the benefits of collaboration and mutual support of teachers within the school can contribute to the successful implementation of the innovation.

In prioritising the order of the nine INSET outcomes in their typology, Harland and Kinder placed impact on practice on level 9 of the typology since the ultimate aim of INSET is to bring about change in practice in the classroom in terms of new strategies and activities. The evidence to demonstrate the impact on practice of the Intervention Package may be summarised as follows:

- **Greater use of pupil-based activities.** The analysis of the post-intervention observation data shows a significant shift from the emphasis on teacher talking in the baseline study to activities such the use of diagnostic questions, brainstorming exercises, model building and role play. All of these areas were covered in Session 3 of the Intervention Package and linked to the intended outcome: "Be capable of developing teaching strategies to help overcome children's misunderstandings of ideas in chemistry" (Session 3, outcome 3).

- **Increased level of classroom discussion.** One of the interesting features that emerged from an analysis of the post-intervention lesson observation data that were not observed in the baseline lesson observation data was in relation to the use of Concept Cartoons. These cartoons were used in half of the 16 lessons observed and this teaching strategy had the effect of initiating class discussion on the misunderstandings involved in the particular topic.
- **Greater use of analogies.** Another area in which the Intervention Package appears to have had some impact is in the use of analogies as part of the teaching strategies used by the student teachers. Analysis of the post-intervention observation data shows that half of the student teachers used some form of analogy in their teaching compared to less than one fifth of the student teachers in the baseline study. The discussion in session 2 dealing with research papers and the development of specific teaching strategies in session 3 could possibly have succeeded in sensitising the student teachers to the advantages of using analogies in helping the pupils to move from the macroscopic to the microscopic (session 2, outcome 2 and session 3, outcome 2).
- **Classroom climate.** Analysis of the interview data showed that a further area in which there was a marked difference between the two groups of

student teachers was that of classroom climate. There was evidence in the case of four of the teachers that their priority was to foster a climate of understanding, to create a good atmosphere in the classroom by involving the pupils and to foster independent thinking among the pupils. This enhanced level of of reflection was not observed in the baseline data where the main concern of the student teachers was in the area of classroom management (section 6.4.2).

- **Use of everyday examples.** Analysis of the lesson observation data of both cohorts of student teachers shows a definite effort among the student teachers to use everyday examples in their teaching. The slight increase of use of everyday examples by the post-intervention student teachers (from 77% to 88%) could not be said to be significant. However, the views expressed by the student teachers in the interview show that that the Intervention Package was not detrimental to the focus they had on the use of everyday examples as part of their teaching strategy.
- **Exploring pupils' ideas.** A "before and after" perspective of the student teachers with regard to their own view of science teaching was obtained by means of the paired statements activity in the introductory session of the Intervention Package. For example, the paired statements showed the groups of student teachers to be equally split between (a) assuming that pupils know nothing about a topic before you start teaching it and (b) spending some time finding out what the pupils already know about the topic. Analysis of the post-intervention observation data shows that the majority of the student teachers devoted time in their lessons to exploring pupils' ideas. Various strategies were used to achieve this, e.g. Concept

Cartoons, diagnostic questions, brainstorming and group discussions. This was in contrast to the baseline student teachers whose questioning techniques consisted mainly of questions that required short, closed and factual answers.

- **Innovative teaching strategies.** There was definite evidence of innovation among the post-intervention student teachers in terms of the strategies used to teach difficult ideas. As discussed in Chapter 7, examples of discrepant events, "home-made" electrolysis kits, three-dimensional animation effects on Powerpoint and the high use of analogies helped to add a sense of freshness to the lessons. When asked about the source of these ideas, some of the student teachers mentioned that, when preparing the lesson, they had consulted some of the reading material referred to in the Intervention Package. The inclusion of innovative teaching strategies in the lessons could be interpreted in terms of the student teachers moving away from the option chosen by all the groups in the introductory Intervention Package session: "If the class hasn't understood something I've tried to explain to them, it means that my explanation has not been clear enough. So I should try to explain it again, in a different way". There appears to be a realisation among the student teachers that the pupils' ability to think and reason are developing and the use of innovative teaching strategies like three-dimensional models will help them to understand ideas more clearly. This was not observed in the baseline cohort of student teachers where there was a firm belief that a clear explanation, repeated if necessary, helps overcome misunderstandings among the pupils.

- **Academically weaker pupils.** One unexpected effect of the Intervention Package was highlighted by the interview data. This effect was in the area of increasing participation of the academically weaker pupils in the lesson. A number of the student teachers commented that the use of teaching strategies involving Concept Cartoons helped to encourage the weaker pupils to become more involved in the lesson. The particular problems associated with teaching difficult ideas to weaker pupils was not addressed in the Intervention Package itself or in any of the intended outcomes. However, it is of some satisfaction to note the apparent positive outcomes of the Intervention Package when dealing with this type of pupil.

Thus, there is definite evidence that the Intervention Package has had some success in having an impact on the classroom practise of the student teachers and thus moving the student teachers towards level 9 (*Impact on practice*) of the Harland and Kinder typology.

(iii) Attitudinal factors

As discussed in Chapter 5, Harland and Kinder established that affective outcomes were important precursors for impact on practice. In their typology of INSET outcomes they describe the important attitudinal factors in terms of value congruence outcomes (level 4), affective outcomes (level 5) and motivational and attitudinal outcomes (level 6).

Attitudinal factors are inferred from the interview data, lesson plan data, questionnaires and lesson observation data. For example, there is definite evidence of value congruence and positive affective outcomes among the student teachers when their views regarding the three sessions of the

Intervention Package were sought in the end-of-year questionnaire completed by them (Appendix VIII page 434). It was clear from the analysis of the responses (section 7.4) that the student teachers were extremely positive in their responses to all three sessions and expressed views that were shared by the tutor when presenting the Intervention Package.

Further evidence of value congruence leading to an impact on classroom practice may be obtained from the analysis of the lesson plans and lesson observation data. This analysis shows that, in the case of six student teachers, there is evidence of a move from high emphasis on lesson content to a more investigative approach. This was also apparent in the interview data where eleven of the student teachers spoke about the importance of ensuring that the pupils understood the concepts being taught but this was only evidenced in the classroom in the case of six student teachers.

There is also definite evidence of the student teachers attaining the positive **affective outcomes** stage (level 5) as well as aspects of the **motivational and attitudinal outcomes** (level 6) of the Harland and Kinder typology in the analysis of their views regarding active learning. For example, in student activity 3 of session 1 of the Intervention Package, all of the groups agreed with the statement "Learning requires activity. More learning is going on when pupils are actively engaged in doing things and talking to each other about them". It is no surprise to learn that the post-intervention observation data shows that 81% of the student teachers used some form of active learning in their teaching. This is higher than that observed in the baseline lessons where only about half of the lessons contained active learning strategies and these were limited to questioning, practical work and worksheets. There was a far richer variety of active learning strategies observed in the post-intervention lessons, e.g. group discussions, word searches, crosswords, practical worksheets, diagnostic questions and practical work. Strategies like class discussions, often initiated by Concept Cartoons, challenged pupils' thinking in a very direct and positive way. Other strategies like worksheets that accompanied pupil practical work did not challenge the pupils to the same extent. Whilst one could not attribute all of the emphasis on active learning to the influence of the Intervention Package, nevertheless it is clear that the student teachers' positive attitude towards some of the generic strategies discussed in session 3 of the Intervention Package was reflected in their classroom practice.

Whilst Harland and Kinder's research found that if the challenges associated with the innovation were too formidable for the teachers, the innovation is unlikely to be successful, there is no evidence to suggest that this was found to be a problem in this research project. For example, the self-reflections contained in the lesson plans of the student teachers showed a high level of self criticism. Whilst a lot of this self criticism dealt with the way in which the lesson was taught, some of the reflections show greater depth in that they discussed areas like the mismatch between the age of the pupils and the difficulty of the topic being taught and also the realisation that misunderstandings still persist after the lesson. This depth of reflection was not found in the analysis of the baseline data where the self-reflections were confined to aspects of the classroom presentation of the lesson and the lack of subject knowledge (section

6.8). The Intervention Package appears to have had a definite effect in giving rise to a greater depth of reflection among the student teachers and this allied with value congruence appears to have enhanced the affective outcomes.

Similarly, in the analysis of the interview data, a greater proportion of the student teachers expressed views about their own shortcomings than they expressed in their lesson plans. The fact that the student teachers were more vocal in the interviews when discussing their shortcomings may be due to the fact that the interviews took place shortly after they had conducted the lesson and hence their recall of the lesson was still very fresh in their minds. In addition, the fact that their written accounts of their own shortcomings would have been read by their tutor, may have inhibited them from giving detailed accounts of these shortcomings for fear of being penalised in their teaching practice grade. The most common shortcoming referred to by the student teachers was in the area of their own subject knowledge. As in the baseline study, 25% of the lessons observed indicated a lack of subject knowledge on the part of the student teachers. The subsequent lack of confidence of the student teachers was very obvious in the analysis of the interview data but the existence of high *value congruence outcomes* (level 4 Harland and Kinder typology) and high *affective outcomes* (level 5 Harland and Kinder typology) in the questionnaire data appears to have overcome any negative impact that lack of confidence may have had on impact on practice.

There is no doubt but that there is persuasive evidence to suggest that the Intervention Package was effective in certain areas. Also, it is heartening to note that despite the problems that some student teachers had with subject knowledge and lack of confidence, the end-of-year questionnaire still showed a positive attitude existed among the student teachers towards the materials of the Intervention Package.

8.3 Reflections on strategies to make the Intervention Package more effective

This research has shown that creating an Intervention Package that is totally effective in a range of areas of teaching difficult ideas is a challenging, if not impossible, task. A retrospective examination of the aims of the Intervention Package shows that of the seven aims, three of them use the phrase "encourage student teachers to reflect on..". Creating an environment that helps student teachers to become more reflective and more analytical about their teaching of difficult ideas in chemistry is challenging. However, the positive results of some aspects of the Intervention Package in this area are cause for optimism.

As discussed in chapter 4, whilst this project is a case study of practice in one institution it also has aspects of an action research project. Therefore, in the light of the research findings, the following are the planned changes to be incorporated into the Intervention Package:

1. To make the Intervention Package a more effective one in terms of its impact in the classroom, it would need to be extended from the present three sessions (1.5 hours each) to at least four sessions of the same duration. A priority area for improvement would be the devotion of more time to paint a clearer picture of the constructivist view of learning. In session 1

only 10 minutes were devoted to discussing why constructivism is the dominant view of learning among science educators. Additional materials could be produced to assist the student teachers to develop a more holistic view of constructivism and more time allowed for discussion at the beginning of session 2.

2. In session 3, it would be helpful to display a greater number of "ready made" resources like packs of cards for sorting, completion card games/checklists, role play scripts and discrepant events. Hopefully, involving the student teachers in the use of these resources would ensure that they have a greater impact on classroom practice.
3. A major topic in the new session 4 would have to tackle the problem of subject knowledge. In section 7.4.2 the analysis of the baseline data and post-intervention data shows that in both cases about 25% of the student teachers displayed a lack of subject knowledge. This is in keeping with the findings of Lenton and Turner (1999) who found that the PGCE course undertaken by the student teachers had little effect on improving their subject knowledge. In the interviews, the student teachers acknowledged the lack of subject knowledge as a problem and, in the lesson observations, it was clear that some of the student teachers had developed strategies to avoid answering awkward questions from the pupils and getting involved in discussion around the questions raised. Harland and Kinder (1997) point out the definite link between teachers' own classroom practice and value congruence outcomes in that teachers whose own subject knowledge is lacking, feel uncomfortable with a practice that might expose it and take an "approach they remain comfortable with" (Harland and Kinder, 1997 p. 73).

In short, the problem of subject knowledge among the student teachers may serve as an impediment to the extent to which they embrace the Intervention Package. Hence, in a revision of the Intervention Package, the problem of subject knowledge would have to be addressed in terms of providing signposts for the student teachers to help them tackle this problem. One possibility would be to produce sets of "Key Facts" cards for various topics on the Junior Certificate science syllabus. Some templates could be produced and the student teachers given assignments to produce cards for areas in which their own subject knowledge is strong. The student teachers could make a presentation to their peers about each card and circulate them to each member of the group. Alternatively, consideration could be given to adopting an initiative similar to that of the Teacher Training Agency recently introduced in the UK (Ireson and Twidle, 2004) where subject knowledge booster courses have been introduced.

Session 4 could also address the problem of terminology that was encountered by so many of the student teachers. In addition to dealing with strategies for overcoming the problem of terminology, strategies for teaching particular topics could also be covered.

8.4 Reflections on significance of this work for practice

Learning to teach places many heavy demands on student teachers – demands in the areas of classroom performance and skills, demands in the area of the cognitive domain and also demands of an affective nature. Also, the student teachers have to come to terms with the teaching environment in the school and settle into a good working relationship with their colleagues. In addition to all of this, they are asked to reflect on their actions in the classroom, on their role as teachers and on the effectiveness of the lessons given by them. This type of learning is very different from the learning that the student teachers in this study would have experienced as undergraduate students. Learning to become a teacher of science is very different from learning science. The situation is summarised well by Calderhead and Shorrock (1997) as follows:

> "Learning to be a teacher requires multiple forms of learning. Learning to teach the concept of ratio is different from learning to present oneself as a teacher in the classroom, or learning to relate it to reluctant learners, or learning to plan the curriculum, or how to work with one's colleagues or how to cope with one's own anxieties".
>
> (Calderhead and Shorrock, 1997 p. 18)

It was suggested in section 2.6 that, since pupils have problems in understanding difficult ideas in chemistry, it is likely that student teachers also have difficulty in teaching these ideas. This research study has shown the truth of this statement. However, it has also been shown that, if specific strategies are put in place to help student teachers, then tangible positive results may be obtained. Even though all the student teachers involved in this research project have a similar academic background (BSc honours graduates), each of them starts out on the road to science teaching with many different personal attributes and background experiences on which to draw. Whilst the emphasis on the constructivist view of learning is on the fact that pupils come to the classroom with different background experiences that influence their learning, student teachers also come to their training course with different backgrounds. Hence, it should not be so surprising that various aspects of the Intervention Package have been adopted to varying degrees by different students.

Without doubt, one of the most heartening and satisfying aspects of this research project has been the enthusiastic response to the materials of the Intervention Package from the student teachers. Student teachers clearly welcome strategies that help them to become better teachers of science. The picture painted by Brown and McIntyre (1993) is one that resonates with student teachers and those involved in teacher training throughout the world:

> "The environment in which teaching is carried out has profound effects on what teachers do and the standards they expect to achieve. This is well illustrated and documented in, for example, the experiences of student teachers. It is not unusual for such students, about to embark on teaching practice to be encouraged to select a set of objectives for a lesson, plan appropriate activities to achieve those objectives and set out to evaluate the extent to which their strategy has been successful. Not infrequently the students return to the college or university after a spell in a school bewailing the fact that teaching is not so straightforward and their best laid plans have gone awry because of unexpected events, constraints, disruptions and so on. The model they have been given, they often claim is unrealistic and takes inadequate account of the practicalities of schools and classrooms. "
>
> (Brown and McIntyre, 1993 p. 69)

Scenes like the one described above could be made less frequent by the incorporation of strategies such as the ones incorporated into the Intervention Package into teacher-training courses. Whilst one cannot expect student teachers to have the same degree of fluency in the classroom as experienced teachers, nevertheless the implementation of an intervention strategy targeted at a particular problem area can have very beneficial effects.

The findings of this study should be of assistance to other practitioners who work in the area of helping to prepare students for careers in science teaching. Whilst there will be differences in training courses for science teachers , it is hoped that the depth of data presented here offers those involved in such courses the chance to assess the extent the findings have relatability, i.e. can be transferred to other situations. In addition, the findings emphasise the key role that the university tutor/supervisor has to play in the process of professional development of student teachers. The concept of the Intervention Package may also be found useful in other areas, e.g. helping student teachers to develop teaching strategies to assist weak pupils in their study of science. In addition, a similar theoretical framework to that used in this study could be developed to assist in the analysis of the data gathered in other studies related to teacher training, e.g. the introduction of innovative teaching strategies like discussions, role play and brainstorming.

8.5 Methodological Critique

When discussing the procedure for carrying out a case study, Anderson (1999) described case study research as follows:

> "A case study is difficult to do well, therefore the researcher contemplating a case study should be experienced in all the separate requisite methods. He or she should have a deep understanding of the relevant literature, be flexible, be able to ask good questions, listen, observe, and have an enquiring open mind"
> (Anderson, G., 1999 p. 154)

The researcher in this study did his best to live up to this! The methodology employed in this study attempted to gain a better understanding of how student teachers draw on the guidance they are given in their training course about dealing with pupils' misunderstandings in chemistry. It is recognised that there are a number of limitations to the study in terms of its design. Some of these limitations are of a more general nature and arise from the case study approach used in the study. Other limitations emerge from specific design features of this particular study.

The more general limitations concern the extent to which the findings of a case study can be generalised and the possible impact a practitioner researcher may have when undertaking a research study. The more specific limitations concern features such as the use of two different cohorts of student teachers in the study and the limited number of observations made of any one individual student teacher. This latter factor could be seen as providing only slender evidence on which to base decisions that student teachers have enhanced expertise. Additionally, it could be argued that there are potential limitations associated with inferring evidence about motivation when significant portions of the data come from observations and questionnaires. The following section shows how the research study attempted to minimise the impact of these limitations.

Rather than talk about generalisability, this study aspires to relatability i.e. other people involved in initial teacher training would, because of the rich description, should recognise the situations described and could relate these to their own circumstances. Whilst the research was a case study in one institution, the development of the framework and the various activities of the Intervention Package could be used in any institution. However, due to some of the unique features of teacher training in Ireland, the results obtained from implementing the Intervention Package may differ in other countries.

The samples of both cohorts of student teachers are comparable in two respects: (i) Academic ability – all student teachers must have either a first class or second class honours degree to be admitted to the H.Dip.Ed. course.

(ii) In terms of teaching abilities, the range of grades on the five-point scale used in Ireland for the H.Dip.Ed science students are very comparable from year to year i.e. the two samples are similar in terms of academic ability and teaching ability.

Two particular dangers associated with practitioner research are that the actions of the researcher unduly influence the nature of the data collected, and that there is bias on the part of the researcher in the analysis and interpretation of the data. A particular concern in this study was the potential impact of the researcher's professional relationship to the students as he was their overall tutor. As described in chapter 4, for the purposes of this study, only those student teachers whose teaching practice was not supervised by the researcher were invited to participate in the study. In order to counter potential bias in the data analysis and interpretation, rich description of data is provided - particularly through the use of the theoretical framework. In addition, data from multiple sources are presented to lend strength to claims made when interpreting the data. By providing such detailed descriptions of the recording and reporting of data from different sources, it is hoped to minimise any criticism of bias on the part of the researcher in being selective of data when drawing inferences from the analysis of data.

One of the decisions that had to be made was whether to track a few of student teachers over a number of lessons or a larger number of students for a smaller number of lessons. The reason for opting for the latter course was to give the researcher a broader picture of student teachers teaching difficult ideas.

Additionally, there was the practical consideration of maximising the opportunity to gather data when difficult ideas were being taught, i.e. choosing a smaller number of student teachers would have provided far fewer opportunities to view lessons on difficult ideas.

It is recognised that only limited claims can be made about student teachers enhanced expertise on the basis of observing one lesson per student teacher. However, one purpose of the detailed post-observation interviews was to gain insights into the thought processes of student teachers and the extent to which these indicated if the aims of the Intervention Package had been realised in relation to enhanced expertise. Thus, while it could be argued that the student teachers used some of the methods introduced in the intervention with minimal expertise, the lesson observations, post-lesson interviews and questionnaires clearly showed that the student teachers had a good appreciation and insight into the value of using these methods in teaching difficult ideas in chemistry.

Lastly, there are issues associated with the problem of measuring motivation in that it cannot be observed but only inferred. Whilst one data source may not be a sound basis for making inferences about motivation, the fact that multiple data sources were used enabled corroborating evidence to be gathered such that it was appropriate to draw reasonably firm conclusions about the motivation of the student teachers.

8.6 Conclusions

This study has gathered, analysed and presented evidence to describe how student teachers draw on the guidance they are given in their training course about dealing with pupils' misunderstandings in chemistry. An Intervention Package was designed to assist student teachers to teach difficult ideas in chemistry. A theoretical framework was developed to assist in the analysis of the data. In addition, a model for assessing the effectiveness of the Intervention Package was devised using the findings from a number of key research projects in the area of curriculum evaluation. The analysis of data shows that, in the area of teaching difficult ideas, there is definite evidence for the fact that beginning teachers can improve their expertise in terms of the Harland and Kinder typology of INSET outcomes.

This study has shown that it is possible to improve the ability of student teachers to tackle the problem of teaching difficult ideas in chemistry. Firstly, by incorporating various resources into an Intervention Package, it has been shown that student teachers are willing to make use of these resources in the classroom. Secondly, it has been shown that student teachers can be sensitised to the constructivist view of learning and can discuss and reflect on this view of learning in interviews, questionnaires and group discussions. This view of learning enables the student teachers to have a deeper insight into what is involved in science teaching and hence to implement classroom strategies and teaching approaches to help overcome pupils' misunderstandings about difficult ideas in chemistry. This leads to the fostering of a greater climate of understanding in the classroom. Thirdly, it has been shown that student teachers express a very positive attitude towards an intervention strategy that is designed to help their classroom teaching in a very practical way.

The Intervention Package has now been integrated into the practice of the researcher.

APPENDICES

Appendix I: Summary of research plan and time line of work.

TIME PERIOD	WORK TO BE CARRIED OUT
Year 1 **1999-2000** **(Academic year)**	Background reading and planning phase • Survey of literature on misunderstandings in science. • Documentation and categorisation of misunderstandings. • Investigate what research has been done into beginning teachers' teaching of difficult ideas. • Formulate research question. • Investigate research instruments used to try to access teachers' thinking - Repertory grids (Fischler) - Brown and McIntyre model. - Other research instruments? • What intervention strategies have been carried out? • What evaluations have been carried out on these research strategies? • Write literature review chapter. • Start planning the design of research instrument.
Year 2 **2000-2001** **(Academic year)**	Piloting phase. Establishing a benchmark of current practice. • Writing of review of work on accessing teachers' thinking about their decisions and actions. • Development of research methodology. • Testing of research instrument. • Observation and videotaping of lessons. • Interviews with student teachers – development of structure of diagnostic questions and interviews. • Questionnaires for student teachers. • Gathering of data. • Transcription of baseline interview data. • Summarise baseline videotape data • Preliminary analysis of data – interview data and video data. • Development of intervention package to try to address misunderstandings taking difficulties of teachers and pupils into account. • Refinement of research instrument. • Begin writing up methodology chapter.

Table 4.1 Summary of time frame within which each aspect of research project was carried out.

Year 3 **2001-2002** **(Academic year)**	The research phase • Finalising of Intervention Package. • Implementation of Intervention Packages. • Implementation of research instrument. • Finalise questionnaires. • Gathering of data – school visits, questionnaires, interviews, videotaping of lessons, studying of lesson plans, responses to activities in intervention package etc. (see orange sheet for details of data). • Observation of lessons in similar areas of chemistry to those observed in pilot phase. • Transcription of interviews. • Continue writing methodology chapter and start baseline data chapter. • Analysis of interview data. • Summary and analysis of videotape data.
Year 4 **2002-2003** **(Academic year)**	• Data collection finalised. • Literature search to develop and write up theoretical framework for baseline data analysis. • Writing continued on Developing Framework • Baseline data revisited in light of theoretical framework developed. • Additional analysis of data in light of framework developed. • Writing continued on Baseline Data Analysis.
Year 5 **2003-2004** **(Academic year)**	• Chapter on baseline data analysis completed. • Analysis of post-intervention data completed. • Literature search on models for developing strategy for analysis of effectiveness of Intervention Package. • Write up strategy for analysis of effectiveness of Intervention Package. • Write up chapter on assessing effectiveness of Intervention Package. • Write Conclusions chapter. • Refinement of literature review chapter (updating) and refine other chapters as required.

Table 4.1 (continued) Summary of time frame within which each aspect of research project was carried out.

Appendix II: Form used to establish timeline of observed lesson.

Record of lesson observed

Code: Date:

Student: School:

Time (mins)	*Event*	*Notes from observation*
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

[Continued to 40 minute mark]

Appendix III: Example of summary notes for lesson used as aide memoir for researcher.

Name of student teacher: Maire. File reference: VPI/5
First year – Solutions, dissolving.
Starts with concept cartoon poster, three people discussing melting into water, disappears and no longer there and dissolve in water.
Class discussion – ends with show of hands.
Went into didactic type of mode with overhead transparency explaining terms solute, solvent, etc.
Asks student to write down examples of common solutions they know and why they think they are solutions.
INTERESTING POINT HERE TO ACCESS THEIR THINKING.
Asks students to read out examples of what they have written. Good discussion e.g. fizzy drinks, washing powder and water, etc.
Asks about what happens to particles when dissolve.
Asks about mass of beaker and sugar that she has set up but gets no answer from class. Has no diagram for it.
Generates some questions from pupils.
Does demo experiment but digital readout not clear..
Brings up pupil to read digital balance but back of pupil to class, other pupils cannot see it – and also back of teacher to class.
Pupil reading mass and calling out to class – mass of solution sum of mass of solvent and solute.
Summarises points.
STUDENT TEACHER VERY TIED TO HER NOTES.
Questions asked very closed ones – what is solvent, what is solution, etc.
Shows diagram of OHP to explain what happens when solute added to solvent.
Didactic mode – explains terms dilute and concentrated no reference to everyday examples.
Discusses why melting in concept cartoon not correct.
Now explains melting, change of state, using poster, evaporation of liquid, etc
Ice melts to water and water to steam.
Talks about particles vibrating when heated and liquid formed.
Explains melting point on OHP – very didactic. Some questioning but limited use of closed questioning.
Uses ROLE PLAY with students as particles. Not very effective.
Mannerisms – after every sentence, says "ok?".
Explained distinction between melting and dissolving but no time for questioning.
Class ended quite abruptly when bell sounds,
No proper recapitulation.

Appendix IV: Format of grid used to summarise data from various research techniques.

Factor	*As exemplified by ...*	*Evidence from baseline questionnaire data* *N = 24*	*Evidence from baseline interview data* *N = 12*	*Evidence from baseline observation data* *N = 12*	*Evidence from baseline lesson plans data* *N = 12*
1. View of science	Body of principles Method of enquiry A practical subject Important social institution (STS)				
2. View of learning.	Transmission versus active learning Control and choice offered to pupils over activities				
3. View of teaching.	Nature of presentation Classroom climate Links to everyday life				
4. View of science teaching	Exploring pupils' ideas and understanding. Relevant strategies for teaching particular topics or sub-topics Approach to teaching a particular topic				
5. Subject knowledge	Subject specialisation. Sense of confidence in teaching Ability to handle questions				
6. Local conditions	Assessment of course. Backup help from school. Type of pupils				
7. Personal reflection and other feedback.	Student teachers imperfect subject knowledge and inexperience. Get feedback from pupils.				

Appendix V: Interview Schedule: Baseline student teachers

QUESTION	PROMPTS/PROBES
What did you want pupils to know or be able to do by the end of the lesson?	General prompts/probes Can you explain that a little more? Any other reason? How do you feel about that? Is this a problem? Is there anything else you would like to say? Can you give me more detail? Neutral statements: I see, I understand, OK.
How did you reach your decision about this?	
How did you set about planning the lesson?	
What resources did you consult?	
Let's think about the structure of the lesson. What did you think the pupils would already know about this topic? How did you reach your decision about this?	
Let's look at an extract of the video tape of the lesson.	Discuss aspects of the videotape
What did you hope the strategy you used at the beginning of class would achieve? Do you feel it has worked? How could it have been improved?	Prompts/probes
What did you learn from the pupils' responses to your questions.	Anything else? Could you explain that in a little more detail?
You used a number of audio visual aids in your lesson. Could you tell me why you used these? Did you think these were effective? Which ones did you feel worked well?	Overhead transparencies. Data Projector Internet Models
Pupil activities (worksheets, tasks, etc) A. You incorporated some pupil activities into your lesson. Could you talk to me about the reasons you included these? B. You made a decision not to include any pupil activities into your lesson. Could you talk to me about the reasoning behind this?	Can you expand on this a little more? Any other reasons? Where did you get the idea for these activities? Any other sources?
Did the responses from the pupils require you to modify your lesson plan?	Prompts/probes
Let's look at another excerpt from the video. What made you ask that question?	Prompts/probes

What did you have in your lesson plan to try to see what students learned?	Discuss lesson plan
Before you gave the lesson, what did you think would be the easy bits for the student to understand	Prompts/probes
Before you gave the lesson, what did you think would be the difficult bits for the pupils to understand?	Prompts/probes
Now that you have given the lesson, what did you think were the difficulties?	Prompts/probes
What did you think was good about the lesson?	Prompts/probes
If you were to repeat that lesson, what changes, if any, would you make?	Prompts/probes
Before we finish, is there anything else you would like to say about the lesson that has not come up in our conversation?	Are there other things you thought were good about your teaching? What was it about that that was good?

Appendix VI: Interview Schedule: Post-Intervention student teachers

QUESTION	PROMPTS/PROBES
What did you want pupils to know or be able to do by the end of the lesson?	<u>General prompts/probes</u> Can you explain that a little more? Any other reason? How do you feel about that? Is this a problem? Is there anything else you would like to say? Can you give me more detail? Neutral statements: I see, I understand, OK.
How did you reach your decision about this?	
How did you set about planning the lesson?	
What resources did you consult?	
Let's think about the structure of the lesson. What did you think the pupils would already know about this topic? How did you reach your decision about this?	
Let's look at the first few minutes of the video tape of the lesson. I notice that one of the things you did in your lesson was .... (diagnostic questions, concept cartoons, etc) I'd be very interested in your personal views or the value or otherwise of this sort of activity. What made you decide on using that strategy at the beginning of class? What sort of things did you learn from using it? What do you personally think are the benefits or drawbacks of the teaching strategy you used?	Why did you make an attempt to find out what the students already know about the topic? Could you explain this in a little more detail please? You may remember that we talked about teaching difficult ideas in our science methodology session. What personally made you decide <u>not</u> to use some of the ideas we discussed? In your personal opinion, would a constructivist approach have worked in this lesson?
What did you hope the strategy you used at the beginning of class would achieve? Do you feel it has worked? How could it have been improved?	Prompts/probes
A. You used some diagnostic questions during the lesson. What gave you the idea for these. Or B. You did not use any diagnostic questions in this lesson. Is there any reason for this?	Could you explain that in a little more detail? Any other reasons? Could you explain that in a little more detail? Any other reasons?
What did you learn from the pupils' responses to your questions.	Anything else? Could you explain that in a little more detail?
You used a number of audio visual aids in your lesson. Could you tell me why you used these? Did you think these were effective?	Overhead transparencies. Data Projector Internet Models

Which ones did you feel worked well?	
Pupil activities (worksheets, tasks, etc) A. You incorporated some pupil activities into your lesson. Could you talk to me about the reasons you included these? B. You made a decision not to include any pupil activities into your lesson. Could you talk to me about the reasoning behind this?	Can you expand on this a little more? Any other reasons? Where did you get the idea for these activities? Any other sources?
<u>If no evidence that the students used anything from the Intervention Package.</u> Now the topic you have been teaching today is one that pupils find difficult. If you remember, we had a look at some of these difficulties earlier this term and some of the things people have suggested that could happen in lessons when you teach this topic. Now, I don't mind that you didn't use them but what I am interested in are the reasons you did not use them. Could you tell me a little bit about how you set about planning the lesson and why you didn't use these ideas.	Can you tell me a little more about what makes you say that?
Did the responses from the pupils require you to modify your lesson plan?	Prompts/probes
Let's look at another excerpt from the video. What made you ask that question?	Prompts/probes
What did you have in your lesson plan to try to see what students learned?	Prompts/probes
Before you gave the lesson, what did you think would be the easy bits for the student to understand	Prompts/probes
Before you gave the lesson, what did you think would be the difficult bits for the pupils to understand?	Prompts/probes
Now that you have given the lesson, what did you think were the difficulties?	Prompts/probes
What did you think was good about the lesson?	Prompts/probes
If you were to repeat that lesson, what changes, if any, would you make?	Prompts/probes
Before we finish, is there anything else you would like to say about the lesson that has not come up in our conversation?	Are there other things you thought were good about your teaching? What was it about that that was good?

Appendix VII: Preliminary questionnaire for baseline student teachers.

There is considerable interest at the moment in what constitutes "effective teaching and learning" in schools. This is of particular importance in the case of science where pupils find difficulty understanding a number of ideas encountered in their study of science. A research study is currently being carried out in this area between the Department of Education UCC and the Department of Educational Studies, University of York. Your opinion on what you feel teachers need to do to promote effective learning will be of great help to me in planning sessions for you and, in the longer term, in planning future courses for H.DipEd. students. I would like you to write down what you think teachers need to do to bring about effective learning in science There is no "right or wrong answer to this question but I am really interested in your views.

Appendix VIII: Questionnaire for student teachers on materials used in Intervention Package.

QUESTIONNAIRE FOR SCIENCE METHODOLOGY STUDENTS

1. Please indicate the science classes you have been teaching as part of your teaching practice this year.

☐ FIRST YEAR ☐ SECOND YEAR ☐ THIRD YEAR ☐ TRANSITION YEAR ☐ FIFTH YEAR

The remaining questions in this questionnaire relate to that part of our course in which we discussed the teaching of difficult ideas in science – particularly in relation to difficult ideas in chemistry.

2. The first session dealt with pupil's learning in science. You may recall that we examined the results of diagnostic tests given to your own students and we looked at different views and theories of teaching and learning.

How would you describe the usefulness of this session to your teaching practice?

☐ VERY USEFUL ☐ FAIRLY USEFUL ☐ NOT VERY USEFUL ☐ OF NO USE

What aspects, if any, of this first session did you draw on in your teaching practice?

____

____

____

3. The second session dealt with children's misunderstandings of ideas in chemistry. You may recall that we examined some research findings on pupils' misunderstandings in science, looked specifically at the range of misunderstandings in chemistry and built up a hierarchy of chemistry topics in order of difficulty.

How would you describe the usefulness of this session to your teaching practice?

☐ VERY USEFUL ☐ FAIRLY USEFUL ☐ NOT VERY USEFUL ☐ OF NO USE

What aspects, if any, of this second session did you draw on in your teaching practice?

____

____

____

4. The third session dealt with teaching strategies to help overcome children's misunderstandings of ideas in chemistry. You may recall that we looked at the factors that emerge from the research literature and which inform us about the sorts of changes we need to bring about in lessons. We also examined some sample materials that have been prepared for classroom use in order to help overcome misunderstandings in science among pupils.

How would you describe the usefulness of this session to your teaching practice?

☐ VERY USEFUL ☐ FAIRLY USEFUL ☐ NOT VERY USEFUL ☐ OF NO USE

What aspects, if any, of this third session did you draw on in your teaching practice?

____

____

____

5. Of the various teaching strategies suggested in session 3, please indicate the approximate extent to which you made use of these when teaching difficult ideas in science during your teaching practice.

	Never (No lesson)	Occasionally (1 – 3 lessons)	Frequently (4 – 6 lessons)	Often (More than 6 lessons)
Card sorting				
Checklists				
Concept Cartoons				
Diagnostic questions				
Discrepant event.				
Obtaining written statements from pupils				
Posters				
Predict and explain				
Questionnaires				
Socratic questioning				
Thought experiments				
Other ____________ (please specify)				

6. When preparing lessons on difficult ideas in science, please indicate the resources you used to help you prepare the lesson plan.

7. The sessions in the course dealt mainly with difficult ideas in chemistry. However, the supporting materials and readings also covered difficult ideas in physics and biology. Please describe the ways, if any, you used materials relating to teaching difficult ideas in physics and biology in your lessons.

8. Have you any further comments on the three sessions that have not been covered by the above questions?

Thank you for completing this questionnaire. The very best of luck in your future careers.

Appendix IX: Final questionnaire issued to student teachers.

The following is a list of factors (in alphabetical order) that a previous group of H.Dip.Ed. students felt bring about effective learning in science. Please pick out in order of importance the 5 factors that you think are most important – put 1 opposite the one you think is most important, 2 opposite the next more important one, etc. There are no right or wrong answers but I am really interested in your views.

Encourage pupils' ideas ____________

Find pupils' knowledge at start ____________

Good presentation ____________

Know material well yourself ____________

Maintain pupil interest ____________

Practical work ____________

Project work ____________

Pupil participation ____________

Regular homework and worksheets ____________

Strict but fair discipline ____________

Teacher enthusiasm ____________

Use audio visual aids ____________

Use everyday examples ____________

Vary teaching methods ____________

Vary topics ____________

Please write down anything that you think is missing from the above list. (Please think about this!). Thank you for taking the time to complete this questionnaire – your help is greatly appreciated

____

____

____

____

____

Appendix X: Feedback form used with student teachers when discussing results of diagnostic tests.

Pupil's learning in science – what's it all about?

Activity 1

Please complete the sentence: "The thing that surprised me most when I read the scripts

was ____

Pupil's learning in science – what's it all about?

Activity 1

Please complete the sentence: "The thing that surprised me most when I read the scripts

was ____

Appendix XI: Summary sheet for research paper.

Title of paper ______________________________

Authors of paper ______________________________

Name of journal ______________________________

Volume No ____________ Pages ____________ Year ____________

1. What aspect of scientific understanding was investigated?

____

____

2. What did the researchers do?

____

____

____

____

____

____

____

3. What was found out by the research study?

____

____

____

____

4. What are the implications for teachers?

____

____

____

SIGNED ____________

Appendix XII: Summary of session 1 of Intervention Package.

Session 1. Pupils' learning in science – what's it all about?

Aims

- To encourage student teachers to reflect on what is involved in learning and teaching science.
- To introduce some of the main views on learning in science.

Content

A brief introduction on teaching and learning will be given to students. This will also include reference to the aims of science teaching. This will be followed by students working individually and in groups on a series of cartoon drawing showing various views of teaching and learning. After a plenary discussion, an overview will be given by the tutor of the various models on learning in science. Students will then discuss in groups the results of the diagnostic tests they carried out with pupils before formal science teaching began. In conclusion, a discussion will be held on the dominant role of constructivism in science education.

Activity	Outline	**Time (approx).**
Student activity 1. Individual and group discussion task.	Working in groups, students examine the summaries of the results of the diagnostic tests they carried out with pupils before formal teaching began. Each student is asked to complete the sentence: "The thing that surprised me most when I read the scripts was..........."	15 mins
Tutor presentation	Teaching and learning, common terminology, aims of science teaching.	15 mins
Student activity 2. Individual and group discussion task.	Each student studies cartoon drawings showing different views of teaching and learning and discusses their own model of teaching.	15 mins
Student activity 3. Individual and group discussion task.	Each students study series of paired statement about teaching and learning. Indicate one from each that they agree with.	15 mins
Tutor presentation	How do pupils learn? 1. Transmission of knowledge model. 2. Piaget's theory of cognitive development. 3. Discovery learning. 4. Constructivism as model of learning.	20 mins
Conclusion. Class discussion.	Why is constructivism the dominant view of learning among science educators?	10 mins

Outcomes

At the end of this session the student teachers should:

- Be able to describe some of the aims of science teaching
- Be able to describe some models of learning as they apply to science.
- Be aware that constructivism is the dominant view of learning among science educators today and appreciate that pupils' learning in science is affected by their own ideas that they bring to science lessons.
- Be able to describe key features of constructivism.

Appendix XIII: Summary of session 2 of Intervention Package.

Session 2. Children's misunderstandings of ideas in chemistry.

Aims

- To introduce student teachers to some of the main research findings on pupils' misunderstandings in science.
- To encourage student teachers to reflect on some misunderstandings in science that they have studied in the research literature.
- To make students aware of the problem with misunderstandings in chemistry.

Content

This session will begin with a group discussion in which each student will make a short informal presentation to the rest of the group on a research paper that he or she has studied. Each group will be asked to submit five key points that the members of that group have learned through preparing their presentation and listening to others. After this, a presentation will be made by the tutor giving a brief introduction to the area of pupils' misunderstanding of ideas in science and specifically an overview of misunderstandings in chemistry. Students will be asked to contribute their own suggestions about areas in chemistry in which misunderstanding occur. In a concluding discussion, some factors common to these areas of misunderstanding will be deduced and the limitations of much of the research will be discussed.

Activity	Outline	Time (approx.)
Student activity 4. Individual and group discussion task.	Each student will make a five-minute presentation to each person in their group and circulate a one-page summary of the research paper that he/she has studied.	40 mins
Tutor presentation. Questioning of class. Student activity 5.	• Misunderstandings in science. Terminology used. Historical background up to present time. • Overview of misunderstandings in chemistry. • General methodology of research. • Hierarchy of chemistry topics will be built up from answers given by students to questions. • Why the problem with chemistry is so acute.	25 mins
Student activity 6. Class discussion. Conclusion.	• What are common factors to misunderstandings? • What are the limitations to research? • What are the implications for teaching?	25 mins

Outcomes

At the end of this session the student teachers should:

- Be aware of the fact that children have many misunderstandings in science – and particularly in the area of chemistry.
- Be able to describe some of the misunderstandings children have.

Appendix XIV: Summary of session 3 of Intervention Package.

Session 3. Teaching strategies to help overcome children's misunderstandings of ideas in chemistry.

Aims

- To encourage the student teachers to reflect on the types of teaching strategies that are of assistance in overcoming children's misunderstandings of ideas in science.
- To introduce the student teachers to the research literature findings that inform us about the teaching strategies required to tackle the problem areas of misunderstandings in science – and chemistry in particular.

Content

This session will begin with the student teachers reporting in their own groups on their ideas regarding the implications for teaching that arose out of session 2. This will be followed by a short plenary discussion. The tutor will then give a presentation on the factors that emerge from the research literature and which inform the sorts of changes we need to bring about in lessons. This will be followed by a group discussion task in which the students are asked to study some examples of materials prepared for classroom use in order to help overcome misunderstandings in science among pupils. Finally, the various points that have emerged from the group discussion and from the literature will be summarised in terms of a "tool kit" of teaching strategies.

[continued on next page]

Activity	Outline	Time (approx)
Student activity 7. Individual and group discussion task.	Students report and discuss their ideas that arose out of the previous session on the implications of pupils' misunderstandings for teaching	20 mins
Tutor presentation	The features of children's ideas that emerge from the literature: • Perceptually dominated thinking. • Limited focus. • Undifferentiated concepts. • Linear causal reasoning. • Predominant conceptions.	20 mins
Student activity 8. Individual and group discussion task	In small groups students will examine samples of classroom materials prepared to help overcome misunderstandings in chemistry among pupils in 12 – 15 age range. This material will include some examples of diagnostic questions which could be used at the start of a topic to access thinking. It will also include some examples of concept cartoons. Each group is given one topic from the hierarchy built up in the last session and asked to produce two diagnostic questions and a concept cartoon for this topic.	20 mins
Tutor presentation and Classroom discussion	Generic strategies to help overcome misunderstandings: • Opportunities for pupils to make own ideas explicit e.g. classroom discussion, brainstorming, etc. • Pupils actively involved in own thinking: model building and role play. • Introduce discrepant events. • Socratic questioning. • Give pupils practice in using ideas in a range of situations.	15 mins
Tutor and Group Student activity 9. Discussion. Conclusion and Summary	Written statements, posters, sort cards, thought experiment, design and make, predict and explain, think and explain, checklists, questionnaires, analogies, etc. Strategies to elicit pupils' prior understanding and strategies to teach the topic. How can we assess the effectiveness of teaching in promoting conceptual change? • Difficulty in short term. • Longer term goals.	15 mins

Outcomes

At the end of this session the student teachers should:

- Be able to describe some of the learning difficulties associated with misunderstandings in chemistry
- Be capable of making suggestions for classroom practice which help to overcome these misunderstandings in chemistry.
- Be capable of developing teaching strategies to help overcome children's misunderstandings of ideas in chemistry.
- Be aware of the fact that the misunderstandings may still persist after the lesson and know that further developmental work may be required.

Appendix XV: The Intervention Package

Pupils' learning in science - What's it all about?

- Declan Kennedy

Session 1

Student Activity 1

- Working in groups, examine the summaries of the results of the diagnostic tests you have carried out with your pupils.
- Complete the sentence on the form: "The thing that surprised me most when I read the scripts was.....".
- Discuss the results of the tests with your colleagues.

Imagine that I come to observe one of your lessons

How easily could I answer the following questions:

1. What was taught in the lesson?
2. How well was it taught?
3. Who taught the material in the lesson?
4. Was the material taught in a scientifically correct way?

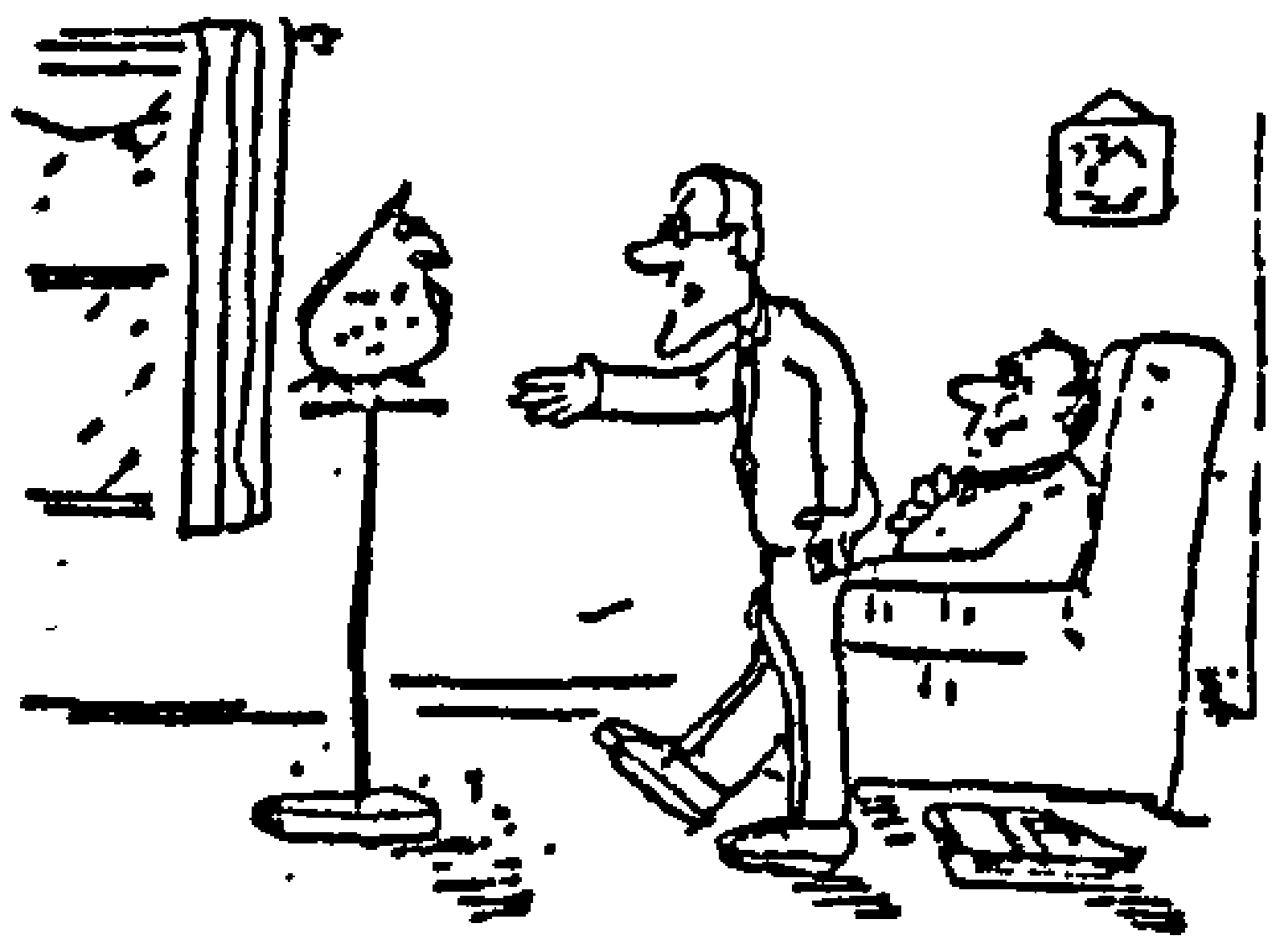
Suppose we now repeat the same four questions and substitute "learned" for "taught"

1. What was learned in the lesson?
2. How well was it learned?
3. Who learned the material in the lesson?
4. Was the material learned in a scientifically correct way?

(Scaife 2000)

- These latter four questions are impossible to answer - unless you are a mind reader!
- There is no guarantee that what is taught is what is learned - educational research indicates that the two can often be poles apart.
- In order to help pupils to learn, we need to know about the theories of how people learn.
- Many of these theories are based on research carried out in the classroom.

I taught my parrot how to speak



I can't hear it saying anything.

I said I taught it. I didn't say it learned anything

Some terminology

- Knowledge: Information about the world.
- Learning: The process by which changes occur in knowledge, skills, understanding, beliefs, values and attitudes.
- Understanding: The capacity to apply knowledge and skills appropriately in various contexts.

- Why bother about learning - why not focus on teaching?
- The more we know about learning, the better teachers we become.

"The primary aim of science teaching is to bring about effective learning in the pupils. As a result of our teaching, pupils should be developing the following:

- Secure knowledge and understanding of science which they can apply to unfamiliar situations
- An awareness of how the applications of science affect our lives and the society in which we live.
- Interest and curiosity about science.
- Some appreciation of the nature and limitations of science."

(Gould 1995)

Student Activity 2

- The cartoon drawings show different views of teaching and learning.
- Discuss these drawings.
- Which one fits in best with your own view of teaching?

STUDENT ACTIVITY 3

- From the handout* supplied, tick one box on each row to indicate which statement you agree with most strongly.
- When you have done this, discuss each choice with your colleagues in your small group.
- Share your ideas and views with the rest of the class in the plenary discussion.

*Views on Teaching and Learning - Crown Copyright.

Plenary discussion of students ideas and views.

How do pupils learn?

1. Transmission of knowledge model -cartoon

- Teaching simply involves transferring a piece of knowledge from the teacher to the learner.
- This model may be suitable to describe a simple factual piece of information being obtained by a pupil.
- Is too simple to help us understand the learning of more complex ideas.

What's wrong with this simple model?

- It portrays the pupil as a passive recipient of knowledge rather than actively involved in his/her own learning.
- It implies the message is received without any modification or distortion. In fact the pupil has to interpret the message and may change it considerably.
- It implies that the pupil is a "tabula rasa" on which new knowledge can be written. In fact, the prior knowledge of the pupil has a significant effect on how the information is received and interpreted.

2. Learning and mental development model

- Associated with the work of Jean Piaget
- He studied the kinds of tasks and problems that children can solve at different ages.
- Proposed a theory of children's cognitive development.
- Identified various stages of development:

Sensory motor stage (0 - 2 years): reasoning directly associated with senses and motor actions.

Pre-operational stage (2 - 7 years): Can form mental representations of items - even if they cannot see something, they know it exists.

Concrete operational stage (7 - 11 years): Can classify, sort and order objects. Idea of conservation of matter (e.g. *Plasticine*) has been developed.

Formal operational stage (11 - 14): Can carry out abstract logical operations, e.g. ratio and proportion, density, acceleration, etc.

- Learning in certain areas of science cannot take place until pupils reach the formal operational stage.
- Some research (Shayer et al 1976, Lawson and Renner 1978) indicates that some pupils reach the formal operational stage much later and others do not reach it at all.
- Some materials have been developed (CASE) to try to accelerate the progress of pupils towards formal operational thinking.

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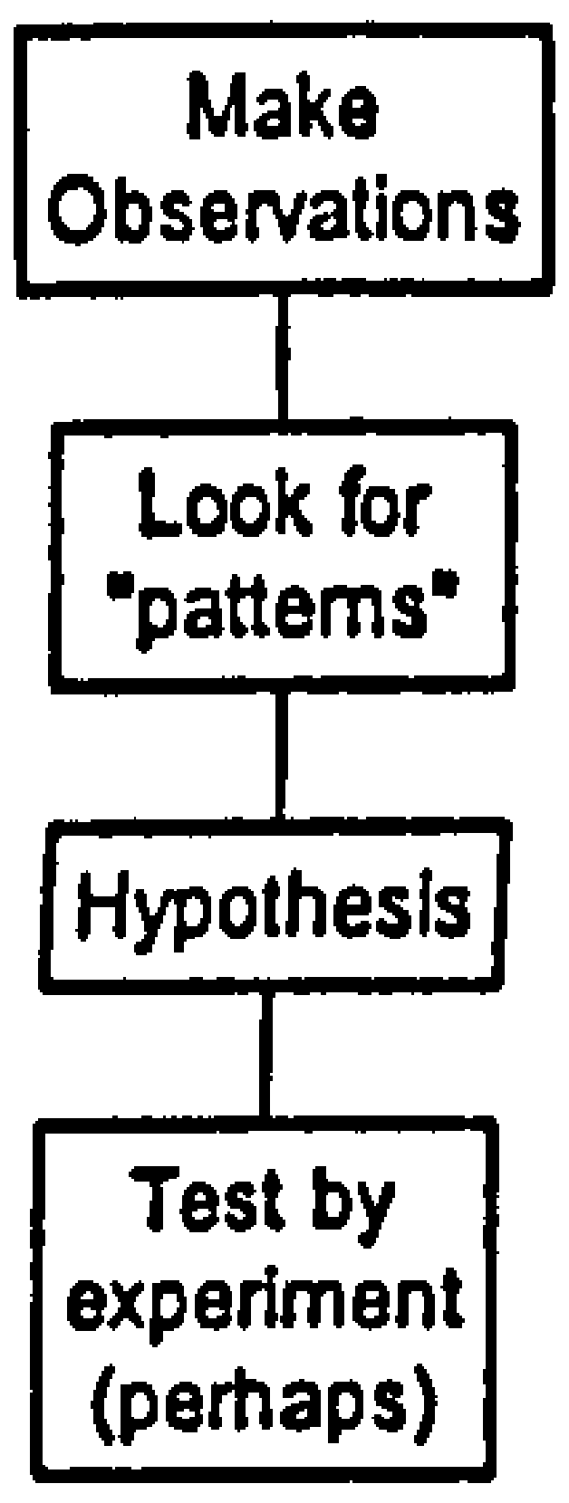
3. Discovery Learning



Make Observations

Look for "patterns"

Hypothesis

Test by experiment (perhaps)

Problems with discovery learning

Pupils do not "discover" what we want them to discover.

- They do not identify the "pattern" in their results which we think is obvious.
- Their observations or measurements do not always accord with the accepted explanation due to experimental error.

- Pupils know that the teacher knows the answer!

- "What's suppose to happen sir/miss?"
- "Have we got the right results?"

(See references)

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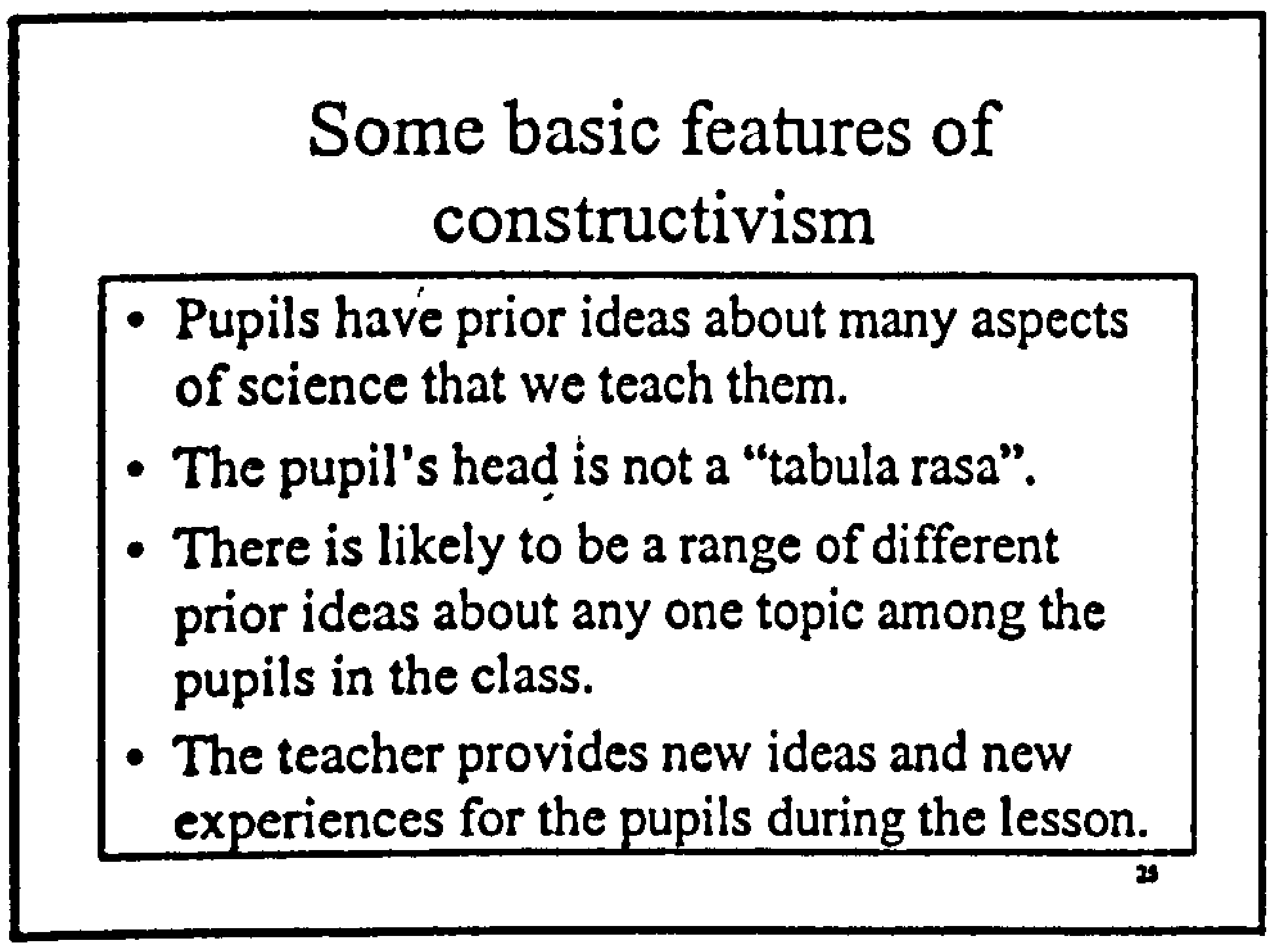
4. Constructivism as a model of learning

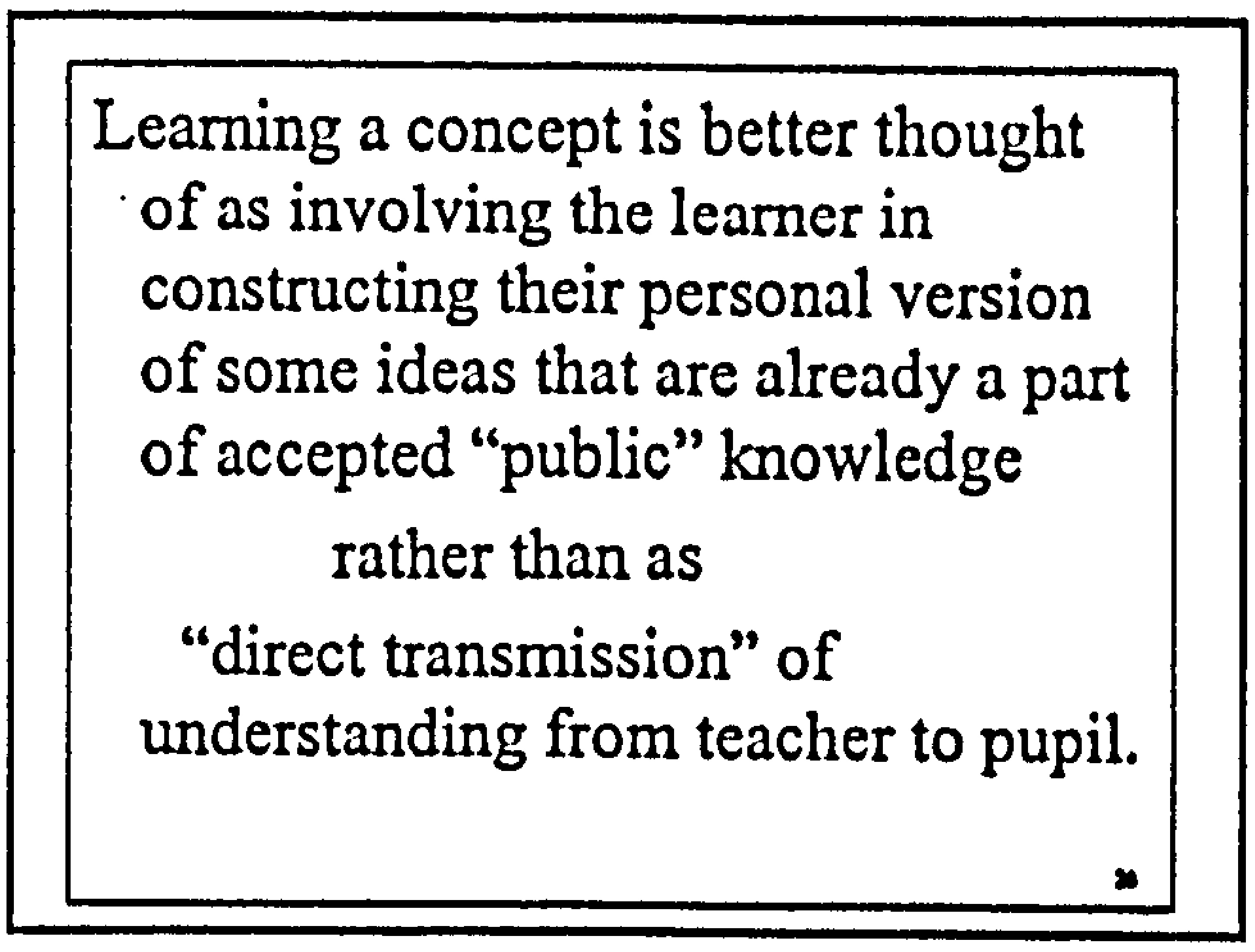
"The view that knowledge cannot be transmitted but must be constructed by the mental activity of learners underpins contemporary perspectives on science education"

Driver et al. 1994



Some basic features of constructivism

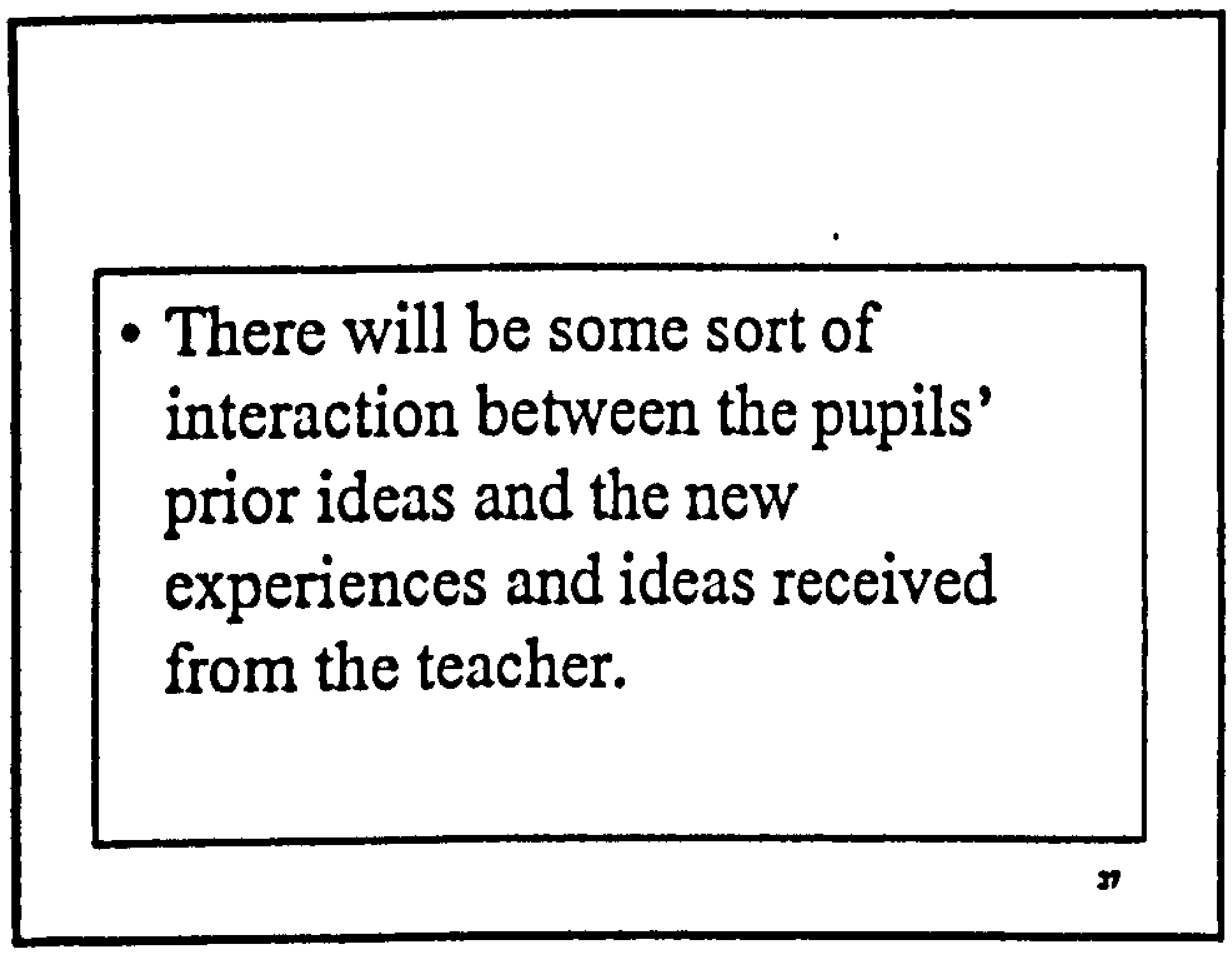
- Pupils have prior ideas about many aspects of science that we teach them.
- The pupil's head is not a "tabula rasa".
- There is likely to be a range of different prior ideas about any one topic among the pupils in the class.
- The teacher provides new ideas and new experiences for the pupils during the lesson.



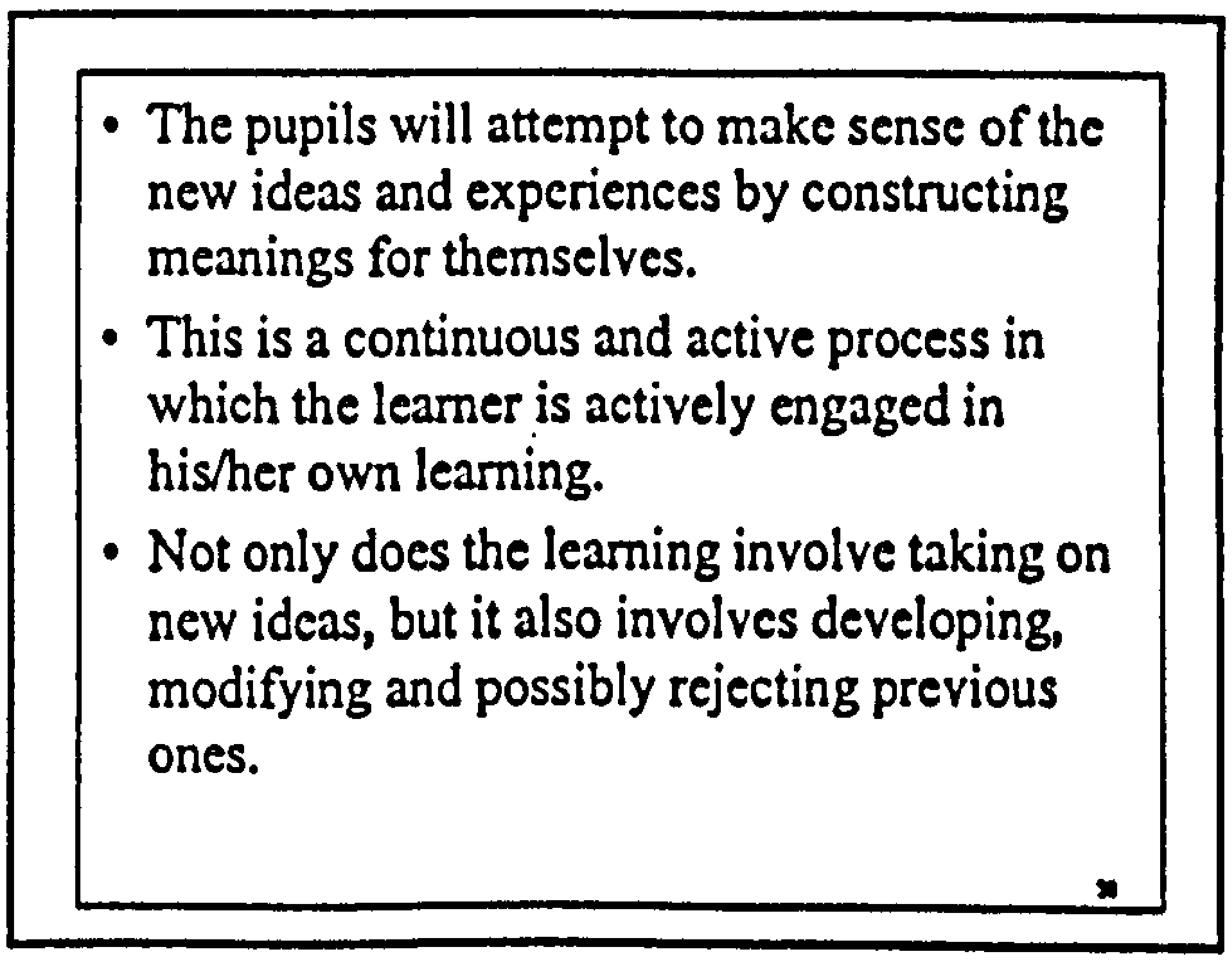
Learning a concept is better thought of as involving the learner in constructing their personal version of some ideas that are already a part of accepted "public" knowledge

rather than as

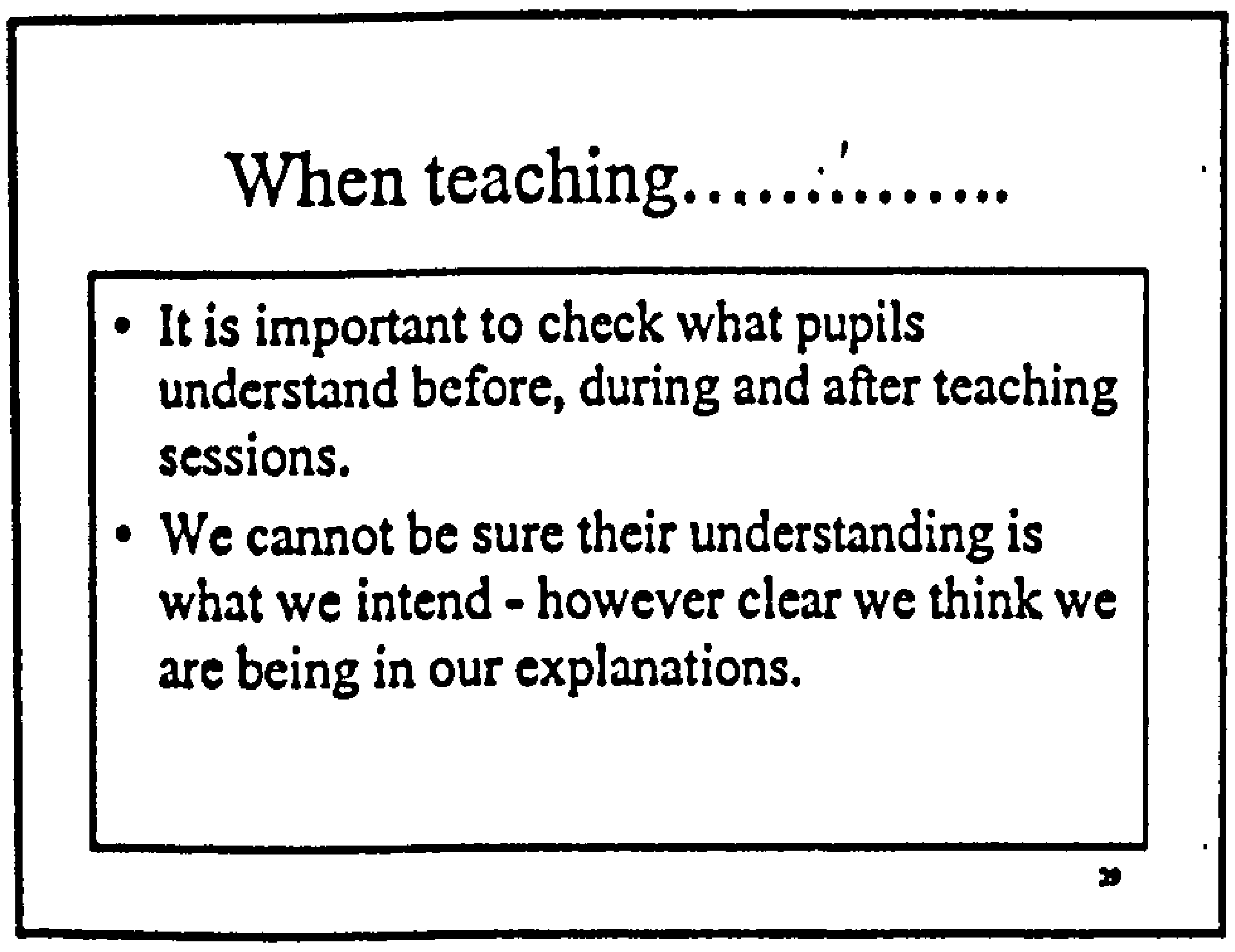
"direct transmission" of understanding from teacher to pupil.



- There will be some sort of interaction between the pupils' prior ideas and the new experiences and ideas received from the teacher.

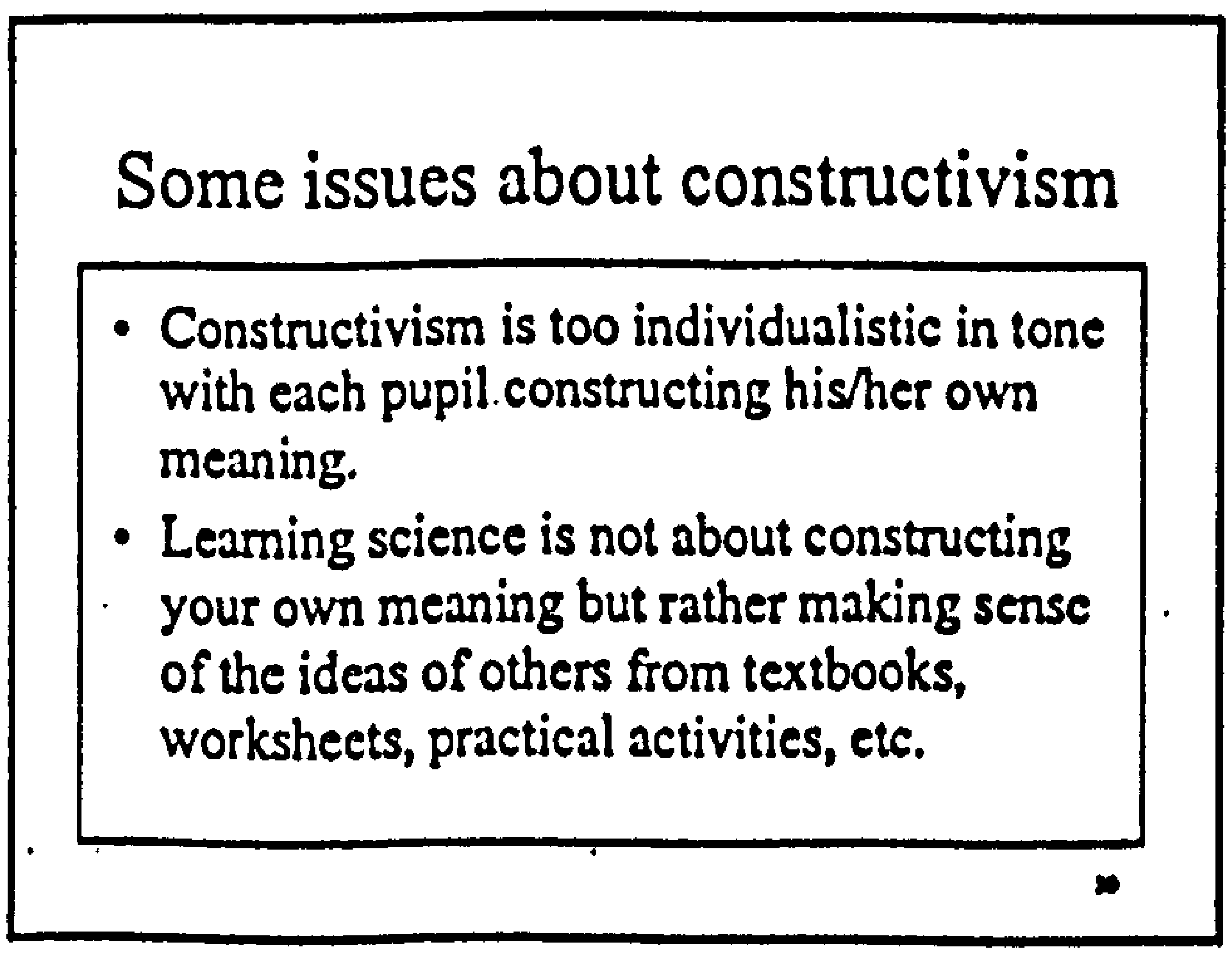


- The pupils will attempt to make sense of the new ideas and experiences by constructing meanings for themselves.
- This is a continuous and active process in which the learner is actively engaged in his/her own learning.
- Not only does the learning involve taking on new ideas, but it also involves developing, modifying and possibly rejecting previous ones.



When teaching..............

- It is important to check what pupils understand before, during and after teaching sessions.
- We cannot be sure their understanding is what we intend - however clear we think we are being in our explanations.



Some issues about constructivism

- Constructivism is too individualistic in tone with each pupil constructing his/her own meaning.
- Learning science is not about constructing your own meaning but rather making sense of the ideas of others from textbooks, worksheets, practical activities, etc.

Assignment for next week

- Each group is given a folder. Each folder contains six papers from the literature dealing with difficult ideas in science - 2 in physics, 2 in chemistry and 2 in biology.
- Each of you is asked to take one of these papers away, study it and make a brief report on the paper you have read using the form supplied.

- Make a photocopy of your report for each of the members in your group.
- Come prepared to give a five-minute talk to the others in the group about the paper you have read.

Reference

Driver, R. (1983) *The pupil as Scientist?* Milton Keynes: Open University Press.

Children's misunderstandings of ideas in chemistry

Science - a struggle for many pupils

Learning outcomes following from teacher's instruction can be disappointing in terms of:

- How much the students remember.
- How well they understand the material.
- How much of the material they can apply in their everyday lives.

Research on misunderstandings in science

- Most of work carried out in 1980s and 1990s.
- Numerous studies in the science education literature in this area.
- Different terminology used: ***alternative frameworks***, ***misconceptions***, ***alternative conceptions***, ***misunderstandings***, etc.

- Research shows that these misunderstandings are highly resistant to change (Novak 1988, Nussbaum and Novick 1982, Barker 1994).
- Major implications for teachers.
- Briggs and Holding (1986) documented ideas that 15 year old pupils had about fundamental concepts in chemistry.
- Researched areas of **chemical change, masses of reacting substances and meanings to common terms** like ***element***, ***mixture*** and ***compound.***

- The research showed clearly that pupils had problems continually shifting between the macroscopic and microscopic representations of systems.
- Pupils are more comfortable in the macroscopic system and try to construct new understanding in this system.
- Driver et al. (1994): Individuals have to make personal sense of these new ideas.
- No simple rules for pedagogical practice emerge from constructivist view of learning.

Does a context-based approach influence the understanding of key chemical ideas?

- Research has found (Ramsden 1997) that with pupils aged 16+, under 25% understood the following key ideas:
- Conservation of mass when precipitation reactions occur.
- Periodic Table as a means of predicting properties of compounds.
- Periodic Table to predict formulas.

What are the problem areas?

1. Particulate nature of matter

- Difficulty with idea of empty space between the particles and particles being in constant motion.
- Difficulty with describing expansion of a gas.
- The concept of matter as a continuous medium found to be persistent despite teaching (Novick and Nussbaum 1981)
- Most pupils did not accept the idea of conservation of mass when reactants and products were in the gaseous phase (Mas et al 1987)

2. Atomic Structure, Atoms and Molecules

- Harrison and Treagust (1996) investigated the variety of student models of atomic structure.
- Showed drawings to students and used pencil and paper exercises.
- Students whose abstract reasoning is weak had particular problems.
- Problems with terminology like "nucleus", "shells" and "electron cloud".

3. Dissolving and Solubility

- Longden, Black and Solomon (1991).
- Pupils were asked to fill in drawings part of which were blank.
- Many pupils had difficulty explaining dissolving in terms of the particle theory.
- A significant percentage represented a new compound being formed. This was also found by Ebenezer and Erickson (1996).

- A high percentage of pupils felt that outside actions (stirring, mixing, heating) were necessary for substances to dissolve. (Blanco and Prieto 1997).
- Pupils had problems with idea of "clear solution" (cup of coffee?)
- Use of term "dissolving"in everyday speech, e.g. "dissolving into thin air".
- Meaning of "particle": pupil = granule of sugar, teacher = atom or molecule.

4. Dissolving and melting

- Pupils frequently do not distinguish between dissolving and melting (Cosgrove and Osborne 1981).
- Pupils had the idea of sugar or salt added to water, melting and becoming a liquid (Ebenezer and Erickson 1996). The visible characteristics guided their reasoning - solid sugar becomes liquid sugar.
- Hot water provides the heat to melt the sugar.

- Everyday experiences of students - "when a sweet it sucked it melts in your mouth"
- "Melting" and "dissolving" used synonymously by pupils (Ebenezer and Gaskell 1995).
- Chemistry teaching: solution is always clear, a solution is a perfect mixture at the particle level, outside actions only influence the speed of dissolution (stirring) or the amount that dissolves (heating).

5. Chemical Formulas and Equations

- Symbols used by chemists to represent atoms and molecules cause problems for students (Enlon, Ben-Zvi, Silverstein 1982)
- This problem also existed in balancing equations (Yarroch 1985).
- Even pupils who could balance the equations, had poor understanding of what was happening (diagrammatic representations).
- Had misunderstandings about meanings of subscripts and coefficients.

6. Acids and Bases. pH

A number of misunderstandings were found in this area (Nakleh and Krajcik 1994):

- Confusion about the term "strong" as applied to acids and bases "more hydrogen gas comes from a strong acid than a weak acid"
- "Bases are opposite to acids" - if acids harmful, bases are harmless; if acids are bitter, bases should be sweet, etc.

- pH is a measure of acidity but not basicity
- Acids and bases react to form a mixture rather than chemically react to form salt and water.
- Misunderstanding of role of indicator "acids destroy bases by causing phenolphthalein to change colour".
- Acid base titrations. (It was found that those who had assistance of a computer exhibited greater understanding). Real time data collection - pH reading and graph developing. (Linn et al. 1993)

7. Chemical Reactions

It has been found (Anderson 1986) that pupils have various ways of explaining about chemical reactions:

1. Not concerned about trying to explain an observation: "It's just like that".
2. The new substance has simply been displaced from another position, e.g. tarnishing of copper piping is caused by a substance inside the pipe penetrating the pipe.

3. Modification - the new substance is the same substance as before although in a changed form, e.g. when alcohol burned, the new substance is just alcohol vapour. (Pfund 1982, Mehuet et al, 1983).
4. Transmutation - changing of one element into another. When steel wool observed burning, formation of black substance explained by students in terms of iron changing into carbon (Andersson and Renstrom 1981).

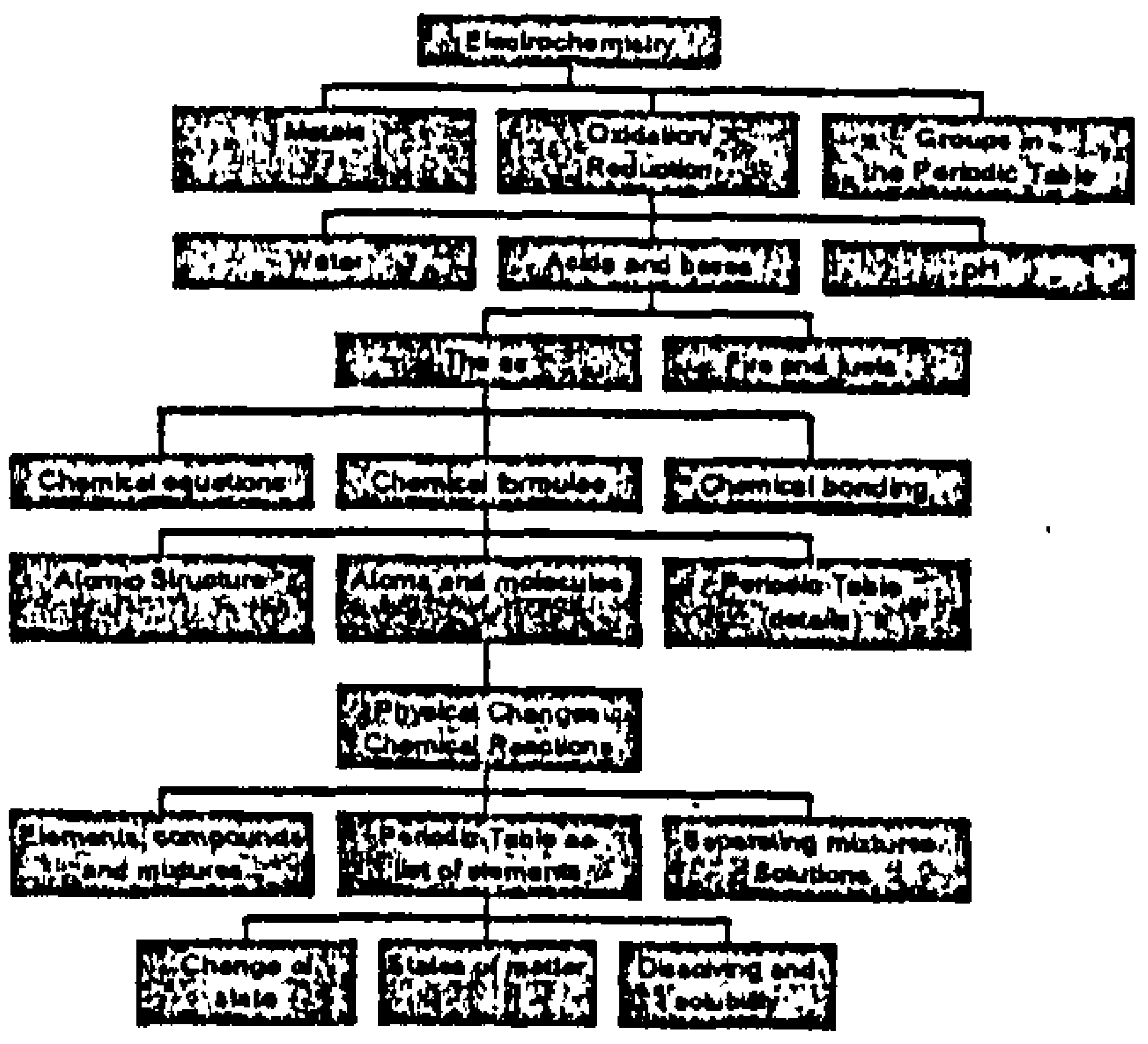
5. Chemical interaction - the original substance ceases to exist and a new substance is formed. Andersson and Renstrom (1983) found that 15% of pupils aged 12 - 15 had a correct understanding of corrosion of copper piping.

- The above authors point out the limitations of written questions and answers when testing understanding. They point out the need for further questioning to test the pupils' understanding.

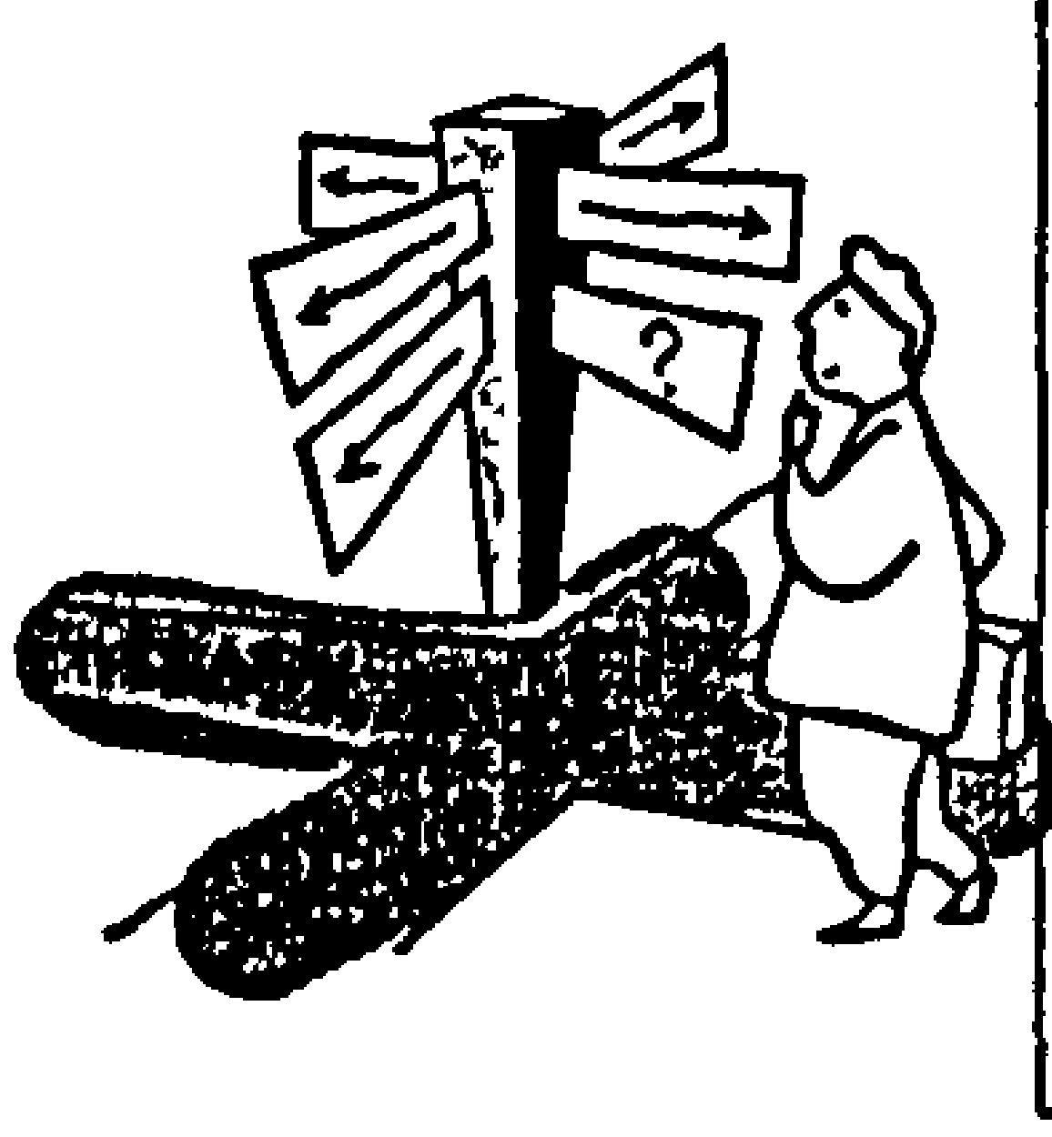
Class Discussion

Could we build up a hierarchy of chemistry topics in the Junior Certificate course based on the evidence in the literature and on our own experience in learning chemistry in school and teaching it?

Hierarchy of Chemistry Topics (Junior Cert Chemistry)



For you to do for next session!



In the light of what you have learned in the class discussions and presentations about pupils' misunderstandings, write a short account (1 page) of what you think are the implications for teaching.

References

- Driver, R., Guesne, E, and Tiberghein, A. (1985). *Children's Ideas in Science.* Buckingham: Open University Press.
- Driver, R., Squires, A., Rushworth, P. and Wood-Robinson, V. (1994). *Making sense of Secondary Science.* London: Routledge.

Teaching strategies to help overcome children's misunderstandings of ideas in chemistry

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Individual and Group Discussion Task 1

Students report and discuss their ideas that arose out of the previous session on the implications of pupils' misunderstandings for teaching.

What does the literature tell us?

Some important generic features of children's ideas and their implications for teaching emerge from the literature (Driver et al. 1985).

Among these are the following:

- **Perceptually dominated thinking.** There is a tendency for pupils initially to base their reasoning on observable features in a problem situation, e.g. sugar "disappears" when it dissolves rather than continuing to exist but in the form of particles too small to see.

- Thus, in teaching science we try to lead pupils to construct mental models for entities (e.g. particles of matter) which are not perceived directly.
- **Limited focus.** There is considerable evidence for children considering only limited aspects of particular physical situations, e.g. when pupils were asked about the burning of a substance in a closed system, they made predictions about the mass of the system on some of the changing features ("smoke" being formed, "smoke" dissolving in water, etc) rather than considering the contents in terms of the closed system

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- **Undifferentiated concepts.** Pupils' ideas tend to be more inclusive and global than those of scientists. This means that in some circumstances pupils tend to slip from one meaning to another without necessarily being aware of it, e.g. their notion of weight often carry connotations of volume, pressure and density. Similarly the words "conductor" and "insulator" are often explained in terms of holding warmth or coldness.

- **Linear causal reasoning.** Pupils often have difficulty explaining changes because their reasoning tends to follow a linear causal sequence, i.e. they put forward a cause which produces a chain of effects. For example, when considering a substance being heated, pupils look on this as a process in which heat is being supplied to a receptor. However, from a scientific point of view, the situation is symmetrical with two systems interacting - one gaining energy and the other losing it. Thus, pupils can understand that an input of energy may change a solid to a liquid but have difficulty appreciating what happens when a liquid turns to a solid.

- **Predominant conceptions**. As discussed in the last two session, there are many ideas which are prevalent and influence children's thinking about a range of situations, e.g. the difficulty with the idea of particles being continually in motion since motion requires a force to maintain it, the idea of "sucking" and the role of atmospheric pressure.
- These ideas are very resistant to change and recur despite teaching (Leach and Scott 2000). Therefore, they have to be given particular consideration in planning for long term learning by pupils.

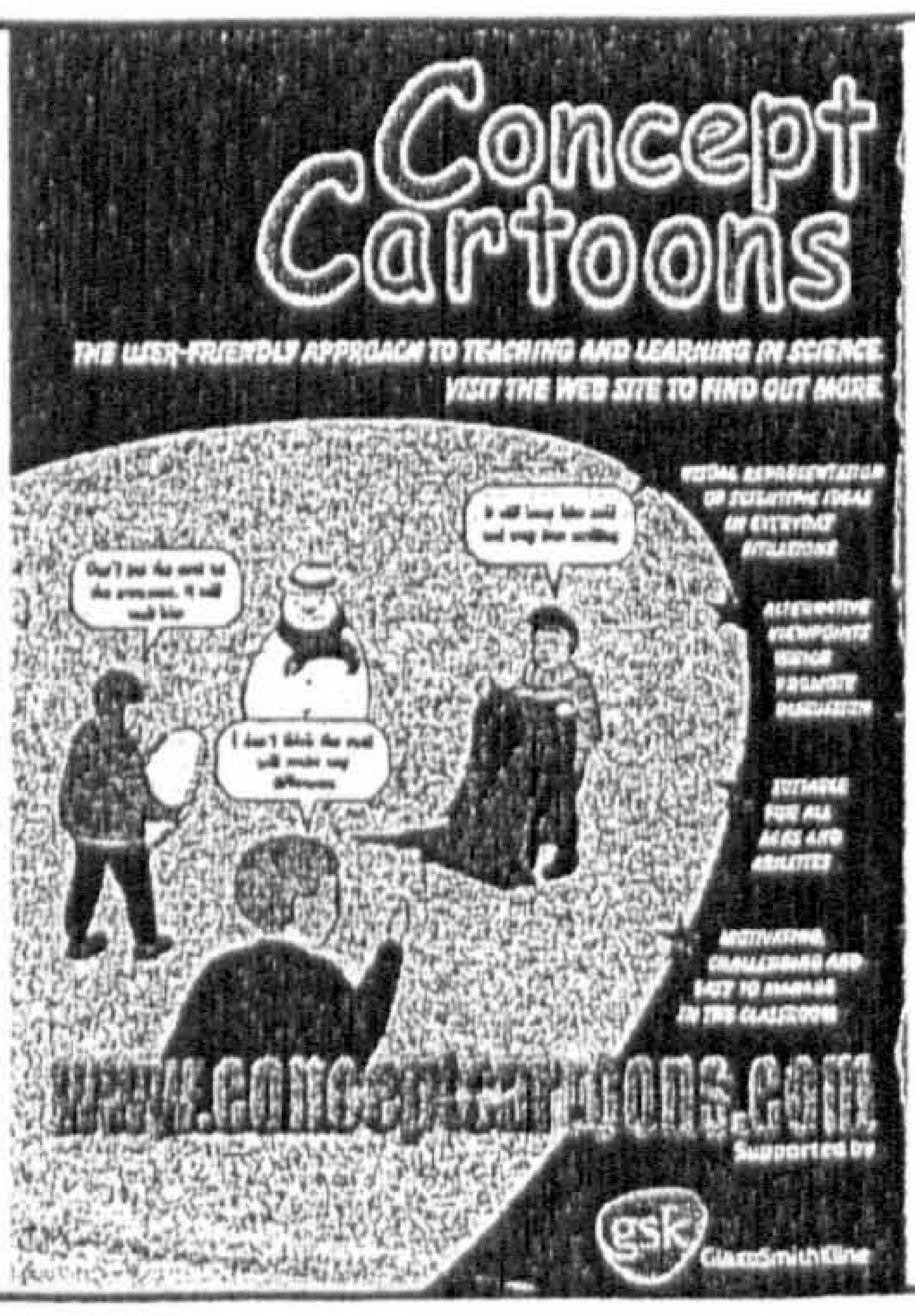
Individual and Group Discussion Task 2

- Students examine samples of classroom materials prepared to help overcome misunderstandings in chemistry among pupils in 12 - 15 age group.
- Material includes some examples of diagnostic questions which could be used at the start of a topic to access thinking.
- The material will also include some examples of concept cartoons.

- Each group is given one topic from the hierarchy of chemistry topics built up in the last session.
- Each group must produce two diagnostic questions and a concept cartoon for this topic.
- A box of chocolates to the best group!

8.5 Lemonade

What do YOU think?



8.3 When Water is Boiling

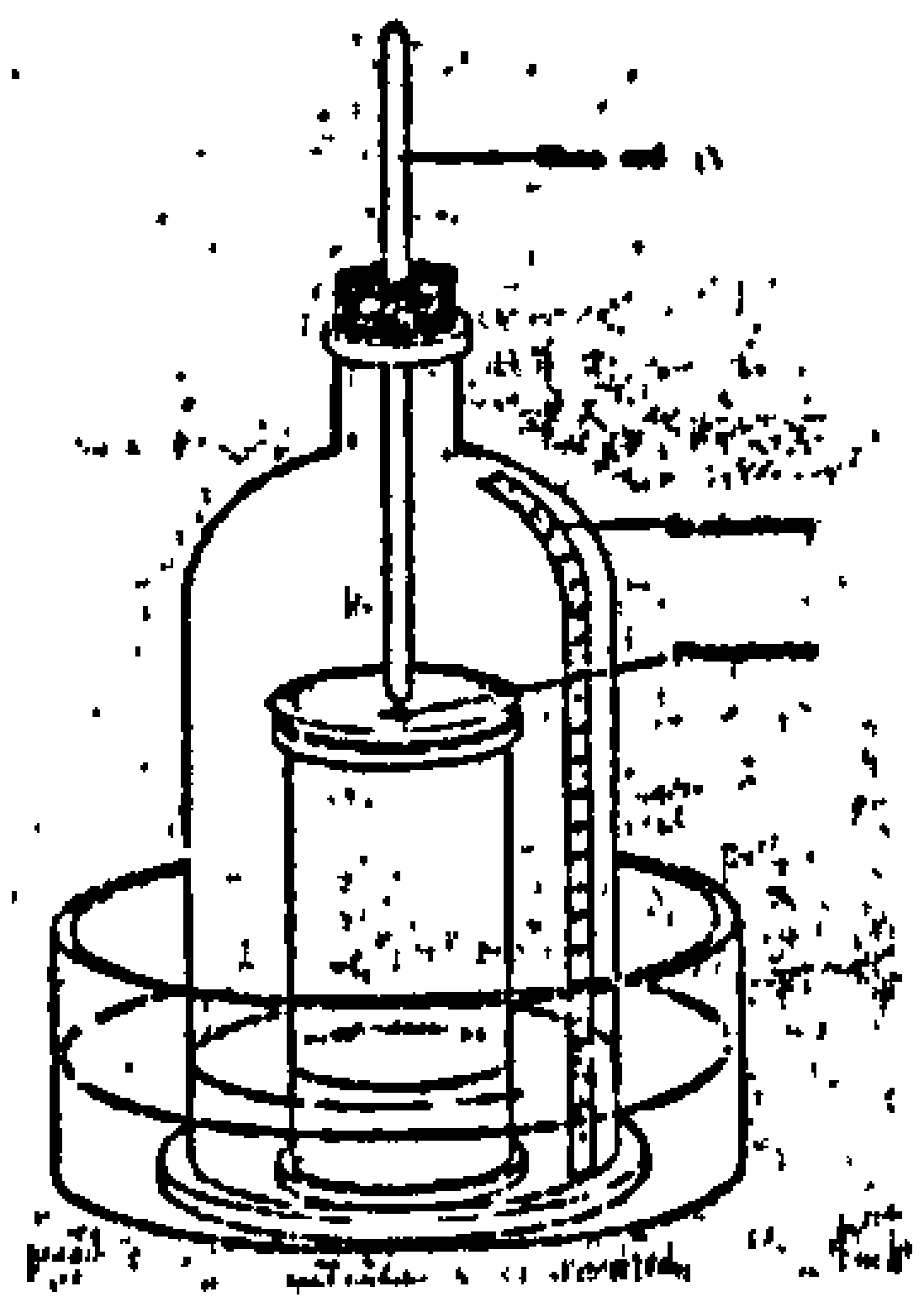
What do YOU think?

Strategies which research studies suggest help in overcoming misunderstandings in science among pupils.

- **Provide opportunities for pupils to make their own ideas explicit.** Examples of this would be asking pupils to write down or draw or in some other way to represent how they are thinking about a situation. This could also be done in whole class discussions or in small group situations.

- **Encourage the pupils to consider different possible explanations for events.** Get pupils actively involved in reflecting on their own thinking, encourage them to consider a range of possible interpretations for events and to attempt to evaluate these for themselves. This could be done by "brainstorming" in the class as a whole, through discussion in small groups, through instructional materials or the introduction of new ideas by the teacher.

Example of generation of range of possible explanations.



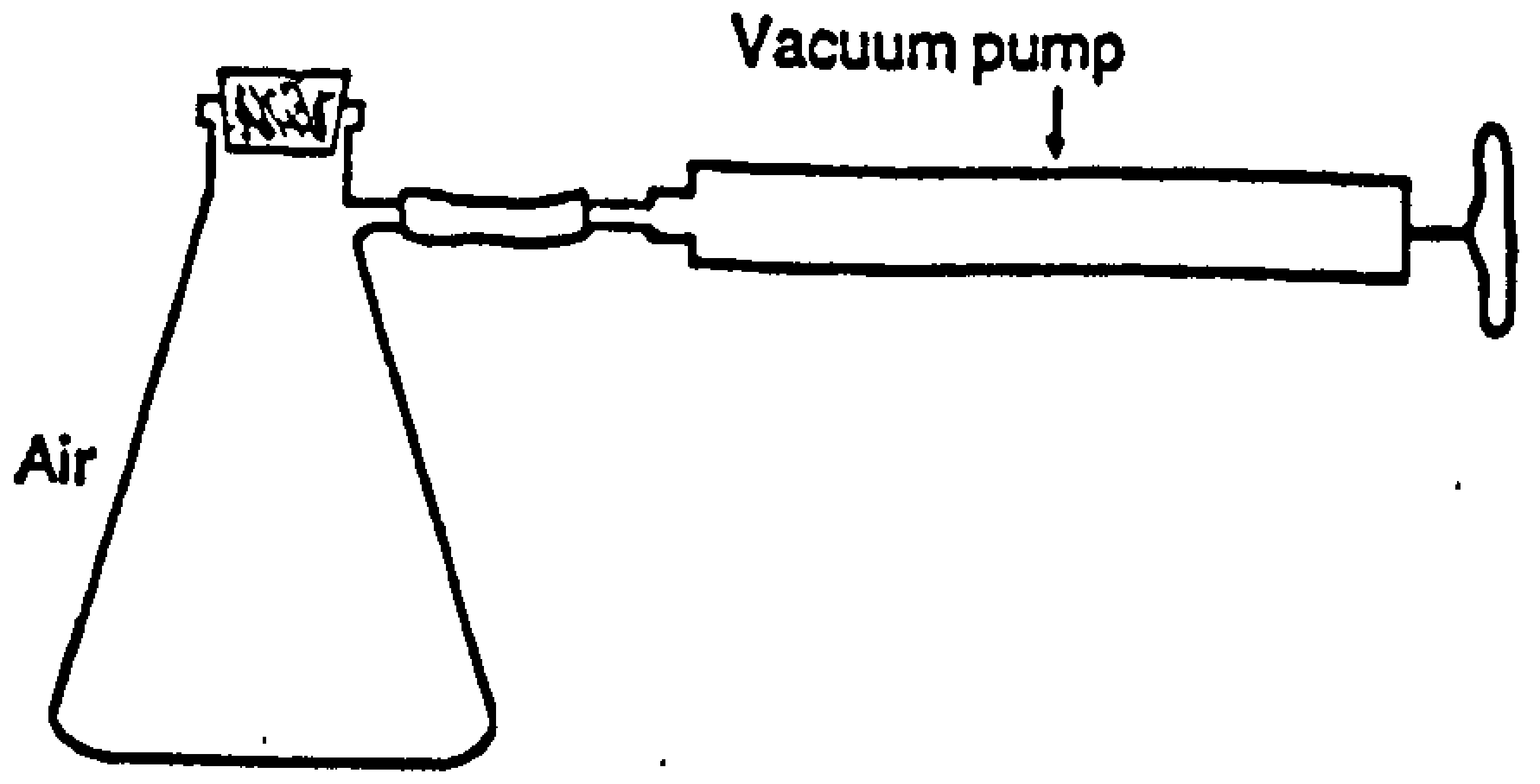
What is happening?

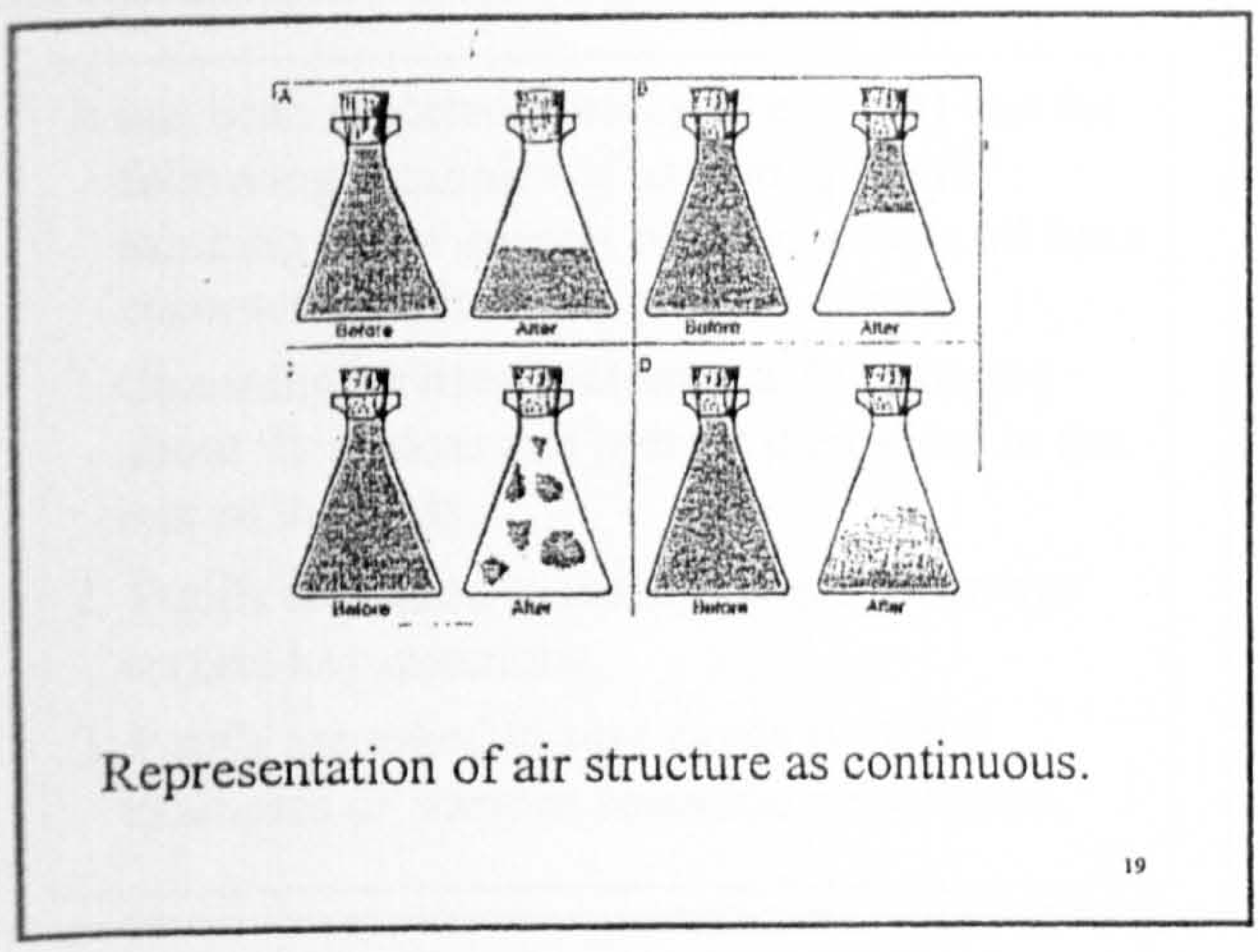
- "Smoke being formed".
- "Cloud being formed"
- "It's changing into white powdery stuff".
- "It's clearing up because the smoke has escaped".
- "The cloud has changed into water"
- "The water rises up and the smoke dissolves". etc.

- **Introduce discrepant* events.** Observing an unexpected event may stimulate pupils to thing about the situation. The "conceptual conflict" (Nussbaum 1985) produced may make a pupil dissatisfied with his or her current ideas and hence to see the need for change. However, even if conceptual conflict is produced in a pupil, this may not in itself lead to correct understanding.

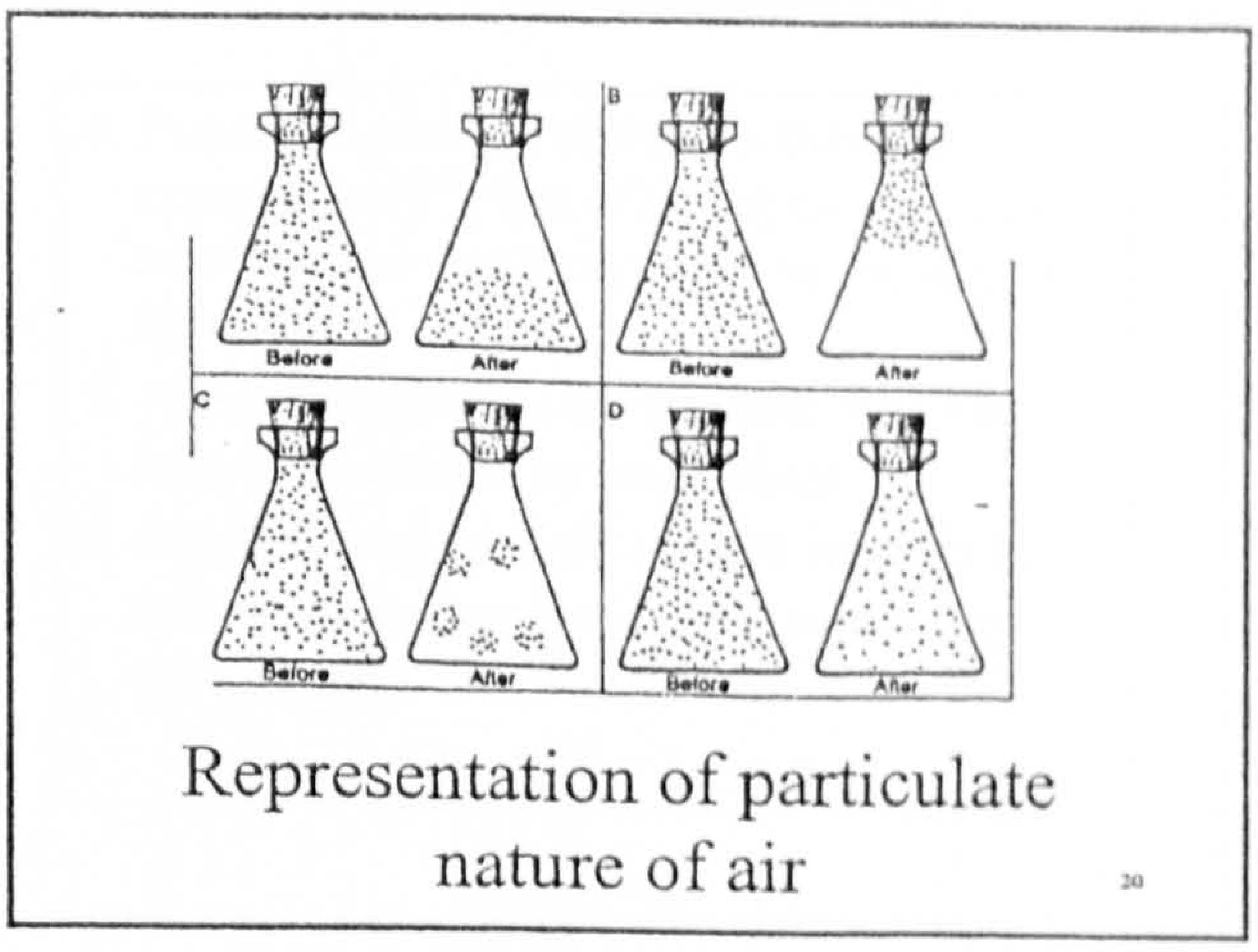
*Irreconcilable, incompatible.

Example of discrepant event being introduced (Nussbaum 1985)

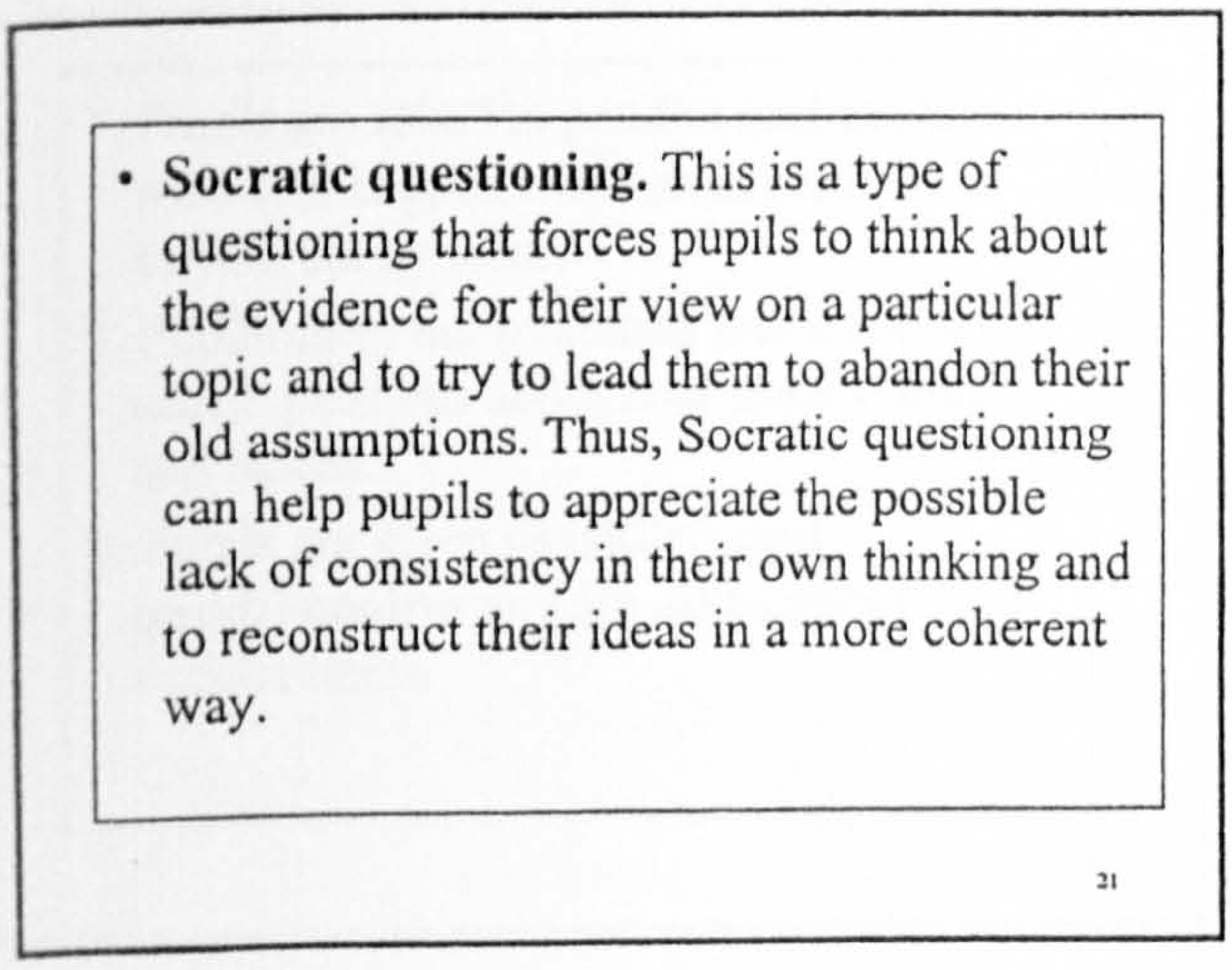




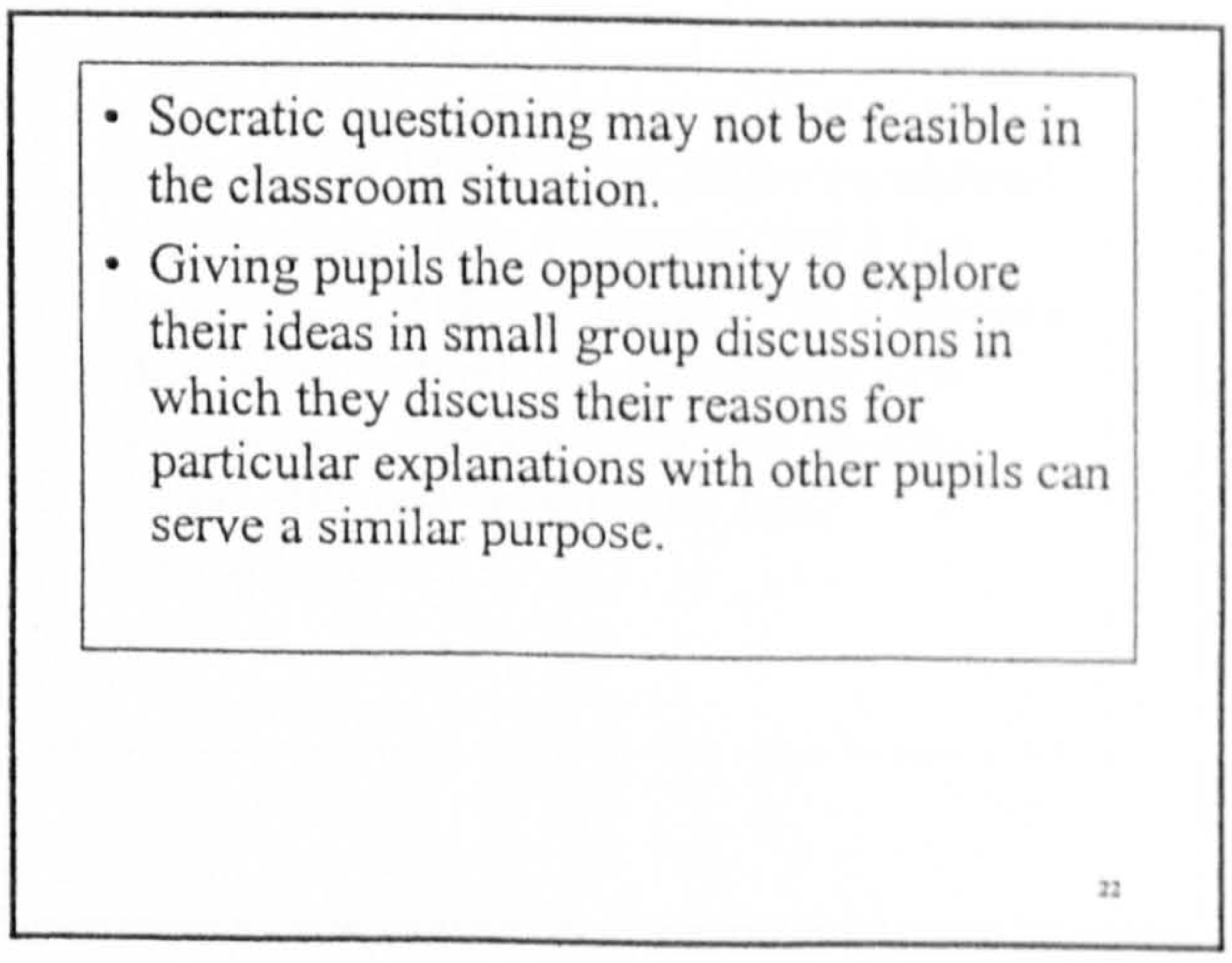
Representation of air structure as continuous.



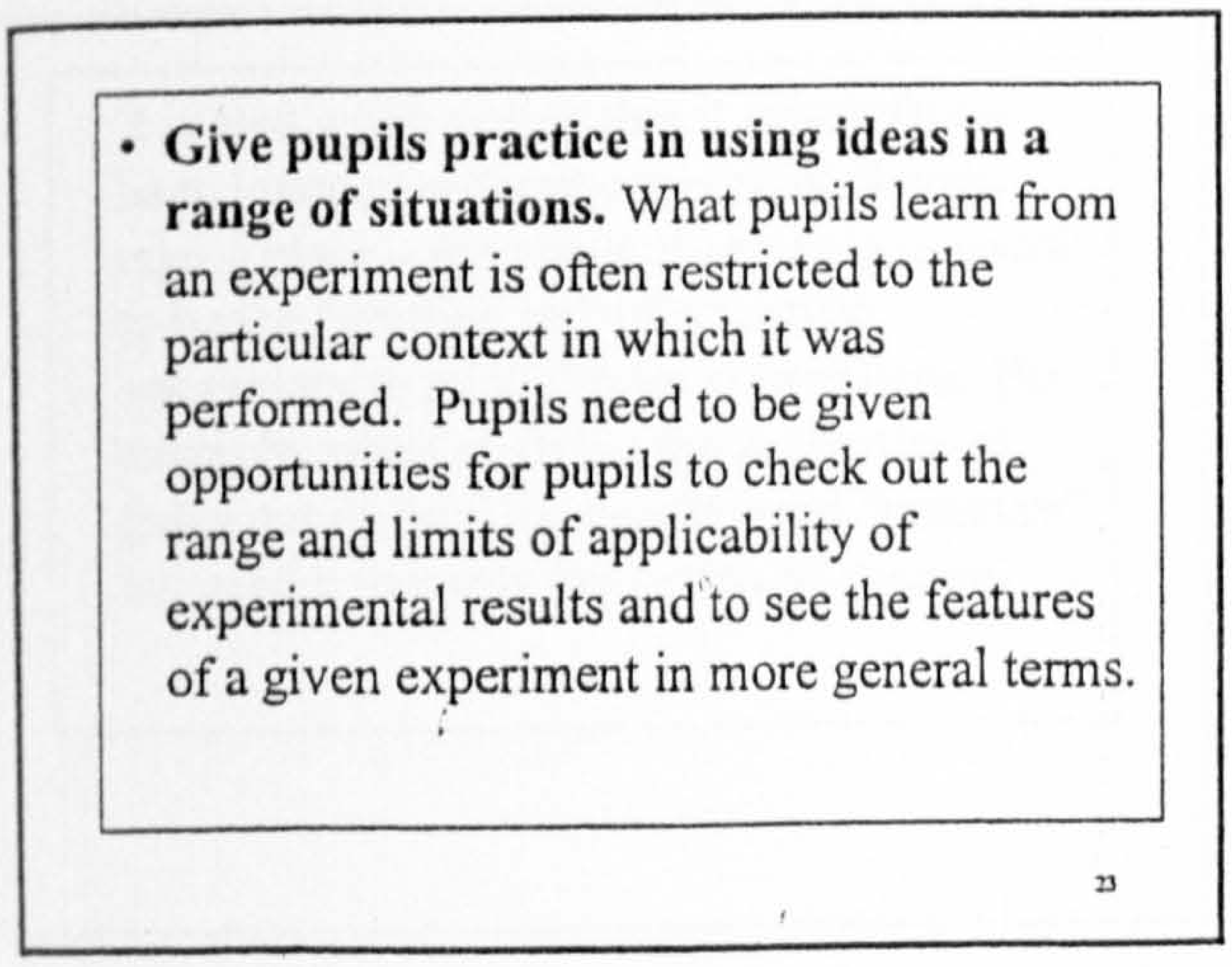
Representation of particulate nature of air



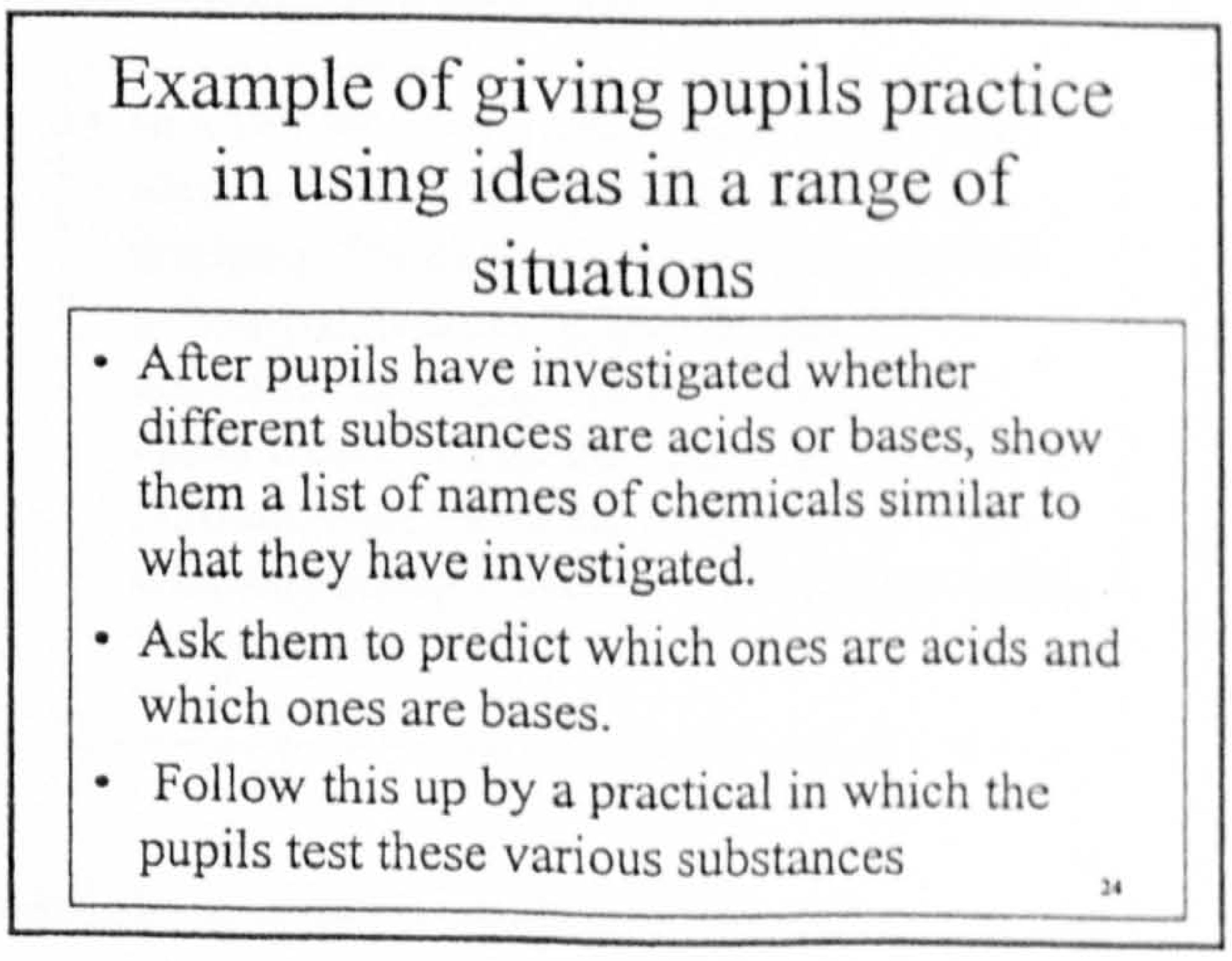
- **Socratic questioning.** This is a type of questioning that forces pupils to think about the evidence for their view on a particular topic and to try to lead them to abandon their old assumptions. Thus, Socratic questioning can help pupils to appreciate the possible lack of consistency in their own thinking and to reconstruct their ideas in a more coherent way.



- Socratic questioning may not be feasible in the classroom situation.
- Giving pupils the opportunity to explore their ideas in small group discussions in which they discuss their reasons for particular explanations with other pupils can serve a similar purpose.



- **Give pupils practice in using ideas in a range of situations.** What pupils learn from an experiment is often restricted to the particular context in which it was performed. Pupils need to be given opportunities for pupils to check out the range and limits of applicability of experimental results and to see the features of a given experiment in more general terms.



Example of giving pupils practice in using ideas in a range of situations

- After pupils have investigated whether different substances are acids or bases, show them a list of names of chemicals similar to what they have investigated.
- Ask them to predict which ones are acids and which ones are bases.
- Follow this up by a practical in which the pupils test these various substances

It has been reported (Driver et al 1994) that the following examples of exploring pupils' thinking about aspects of science have all been successfully trialled in science classes.

1.Obtaining written statements from pupils about their ideas and present their ideas to the rest of the class.
2. Pupils are asked to make posters to answer certain key questions.
3. Pupils are asked to sort cards showing examples of various scientific phenomena.

4. Pupils are asked to discuss a thought experiment ("What will happen if...") in small groups and report back to the rest of the class.
5. Pupils are asked to design and make an item to be used in an experiment.
6. Pupils are asked to think and explain in writing an answer to a question posed by the teacher.

7. Pupils are asked to predict and explain what will happen when an experiment is carried out by them.
8. Pupils carry out practical work and are asked questions about their observations and results.
9. Pupils are given checklists and questionnaires and are asked about various items.

- An important point emerging from research (Driver et al 1985) is that where conceptual change does occur, it appears that it is a long-term and slow process. This is because pupils have a tendency to interpret new situations in terms of what they already know, thus reinforcing their prior conceptions.

- It is also worth noting that it is possible to have learning without conceptual change taking place – the result of teaching appears to be the "grafting on" of scientific vocabulary to pupils' prior conceptions. For example, when studying the properties of gases pupils used the taught word "pressure" but used it to imply the notion of suction.

- In a similar way, pupils often modify new ideas to fit in with their present ways of thinking. For example, in studying the role of oxygen in burning, pupils readily accepted that oxygen was necessary but rather than develop the concept of chemical combination, they tended to think of what was happening in terms of the oxygen being "burnt away".

How can we assess the effectiveness of teaching in promoting conceptual change?

- As pointed out by some researchers (Driver et al 1985), this can be difficult to assess in the short term. We may need to rethink our view of teaching by being prepared to adopt longer-term goals for the conceptual learning of pupils.
- Can children adopt new ideas and change their existing ideas in the short period of time allocated to a lesson?

> "The atmosphere of learning will not be that of the 'ordered classroom' with pupils working silently; nor will pupils be engaged in practical 'doing' all of the time. Animated talk and arguments are likely to be the hallmark of fruitful science lessons."
>
> Driver, R. et al (1994). *Making sense of Secondary Science*. London: Routledge. (p 6)

Assignment for you to do!

1. Study the "Concept Cartoons" book in the Resource Centre.
2. The accompanying handout shows an activity designed to accompany the teaching of elements, compounds or mixtures. Design a similar activity to accompany the teaching of the topic physical and chemical changes.

References

- Levinson, R. (Ed). *Teaching Science.* (1994). Buckingham: Open University Press.
- Ogborn, J., Kress, G., Martins, I. and McGillicuddy, K. *Explaining Science in the Classroom*. Buckingham: Open University Press.
- Osborne, R. and Freyberg, P. (1985) *Learning in Science.* Auckland: Heinemann.

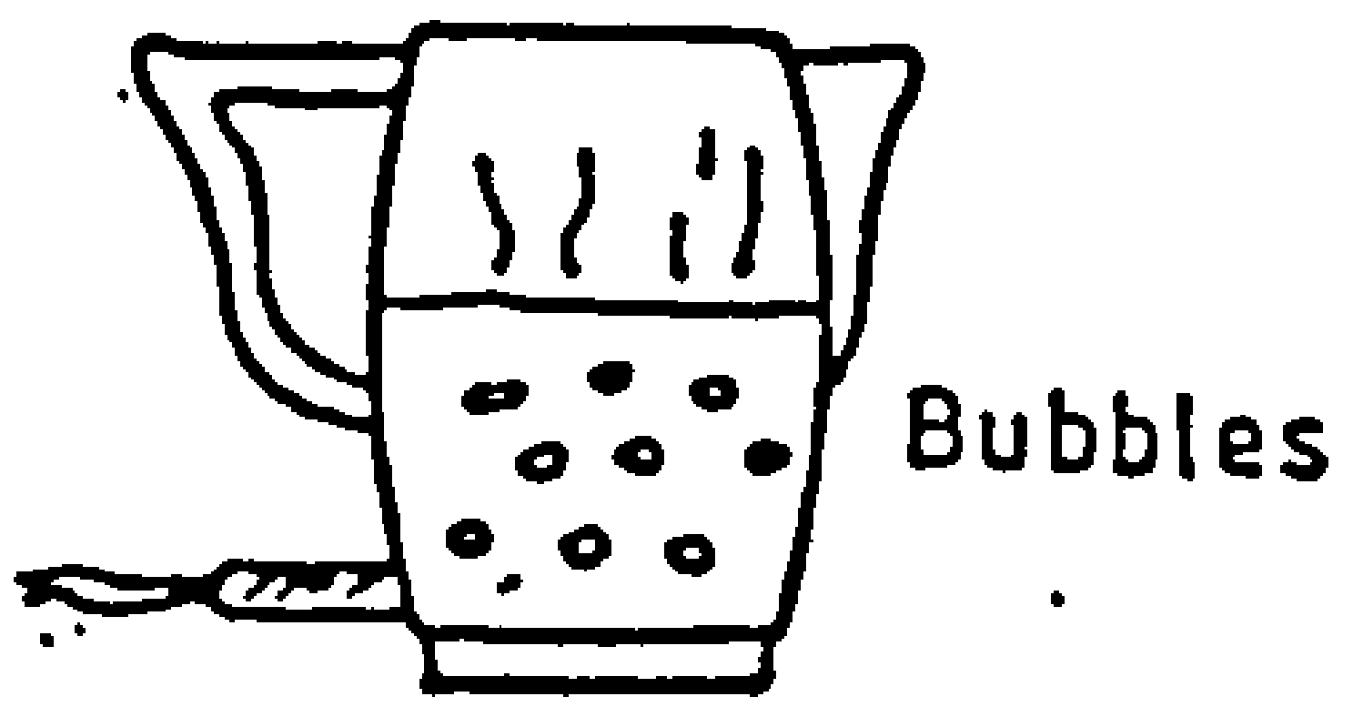
References (continued)

- Scaife, How children learn, in Wellington Teaching Science Contemporary Issues and practical approaches. London: Routledge
- Turner, T. and DiMarco, W. (1998) Learning to teach Science in the Secondary School. London: Routledge.
- Wellington, J. and Osborne, J. (2000) *Language and Literacy in Science Education.* Buckingham: Open University Press.

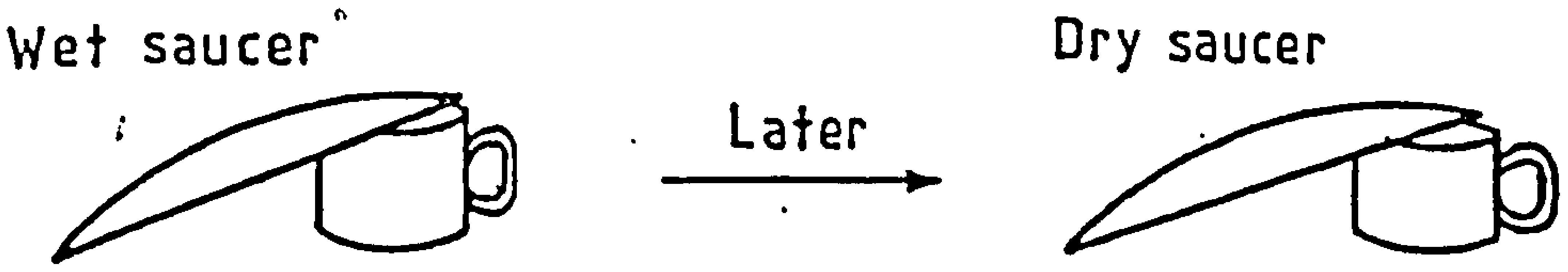
The questions on this paper are not part of an examination. The questions are being asked because we are interested in your views on certain topics in science. Please think carefully about each question before giving your answer. For each question, please put a circle around the answer that you think is correct or tick the box next to the answer that you choose.

NAME ______________________ AGE ________________

1. When a kettle boils there are large bubbles in the water. What are the bubbles made of?
   (a) Air
   (b) Steam
   (c) Heat
   (d) Oxygen or hydrogen

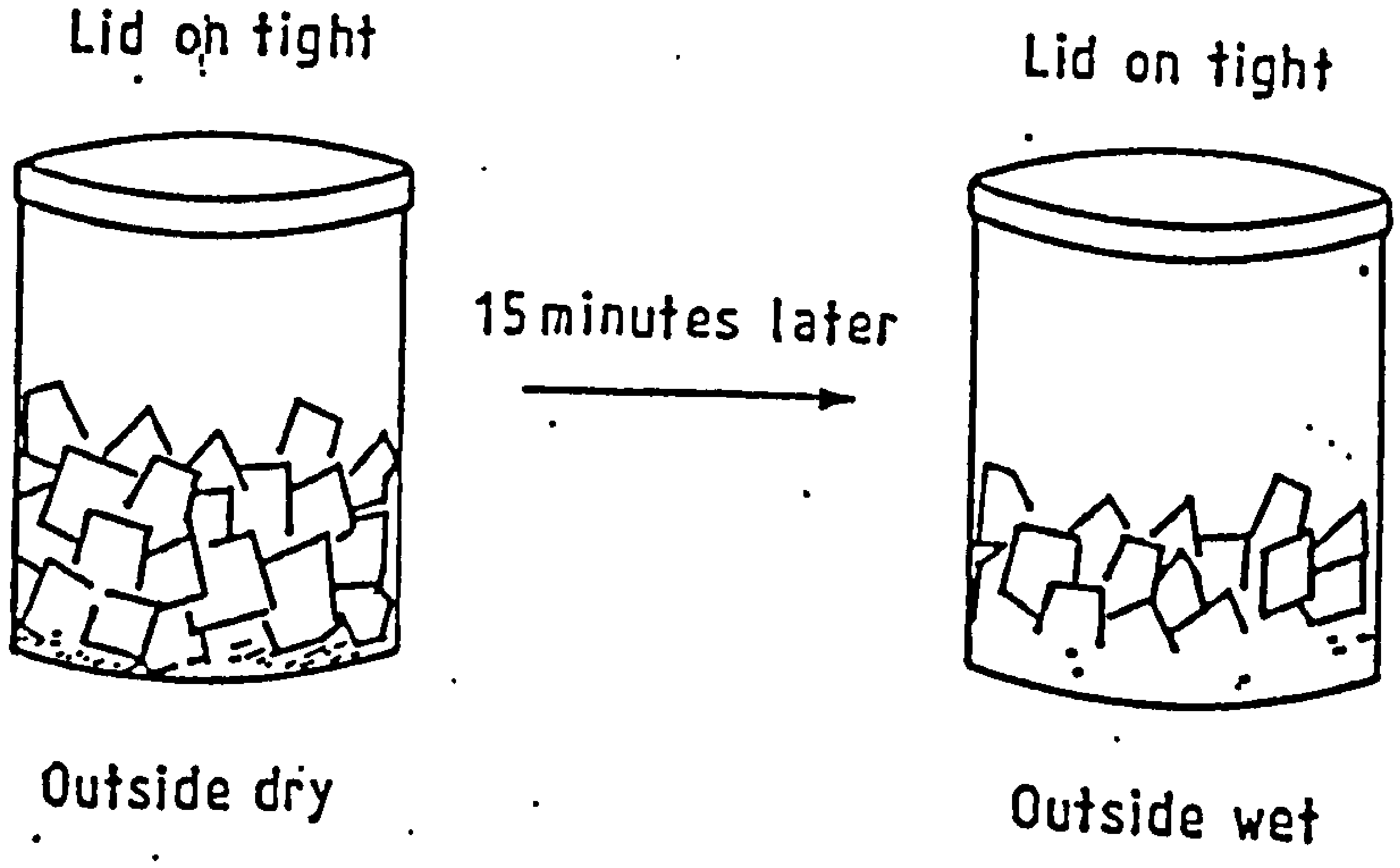


2. If a wet saucer is left on the bench after it has been washed, then after a while it is all dry.



What happens to the water that doesn't drip onto the bench?
(a) It goes into the saucer.
(b) It just dries up and no longer exists as anything.
(c) It changes into oxygen and hydrogen in the air.
(d) It goes into the air as very small bits of water.

3. A small jar is filled with ice, the lid is screwed on tightly, and the outside of the glass is dried with a tea towel. Fifteen minutes later the outside of the jar is all wet.

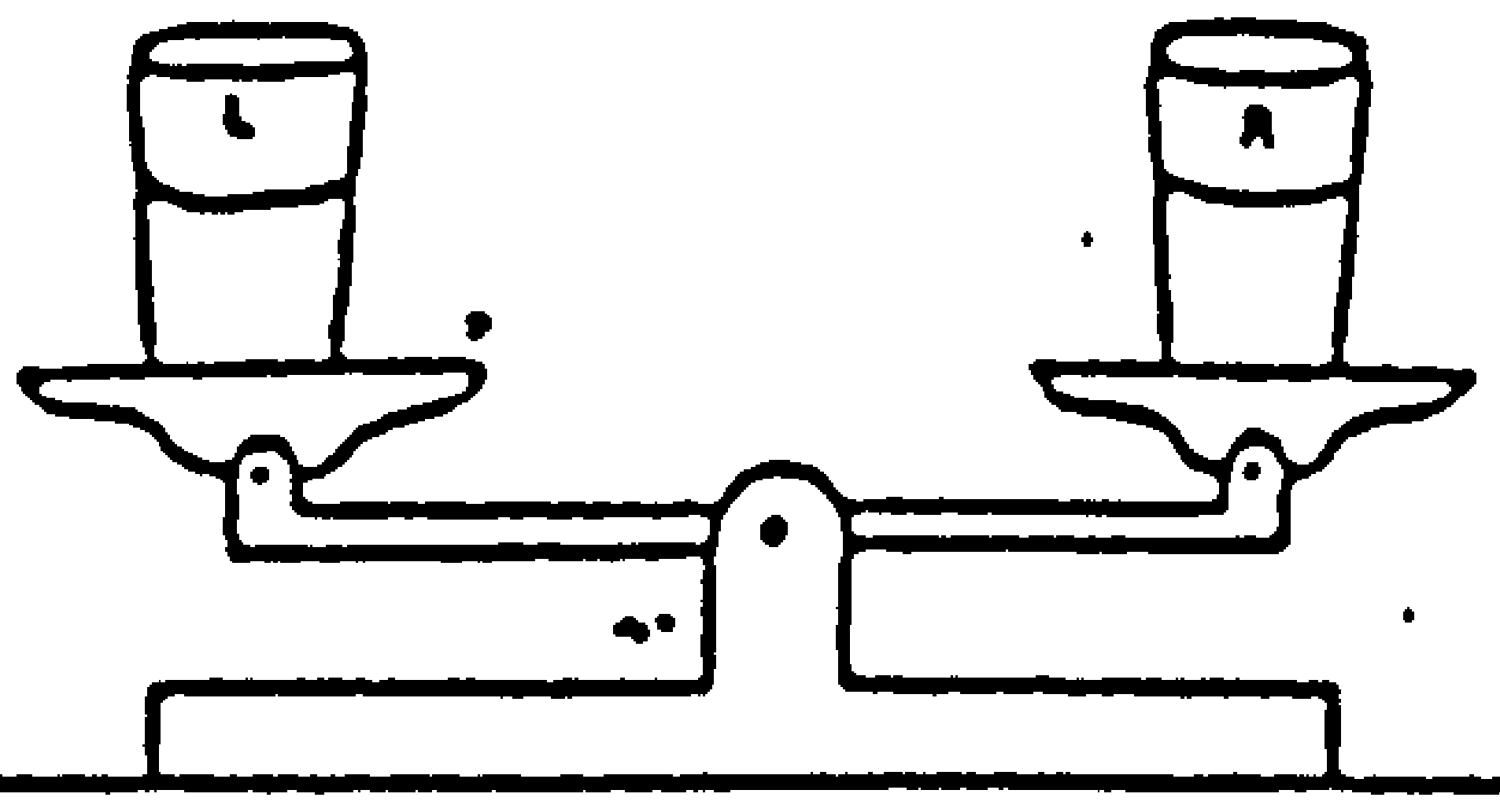


Where has the water on the outside of the jar come from?
(a) The water from the melted ice comes through the glass.
(b) The coldness causes oxygen and hydrogen in the air to form water.
(c) Water in the air sticks to the cold glass.
(d) The coldness comes through the glass and turns to water.

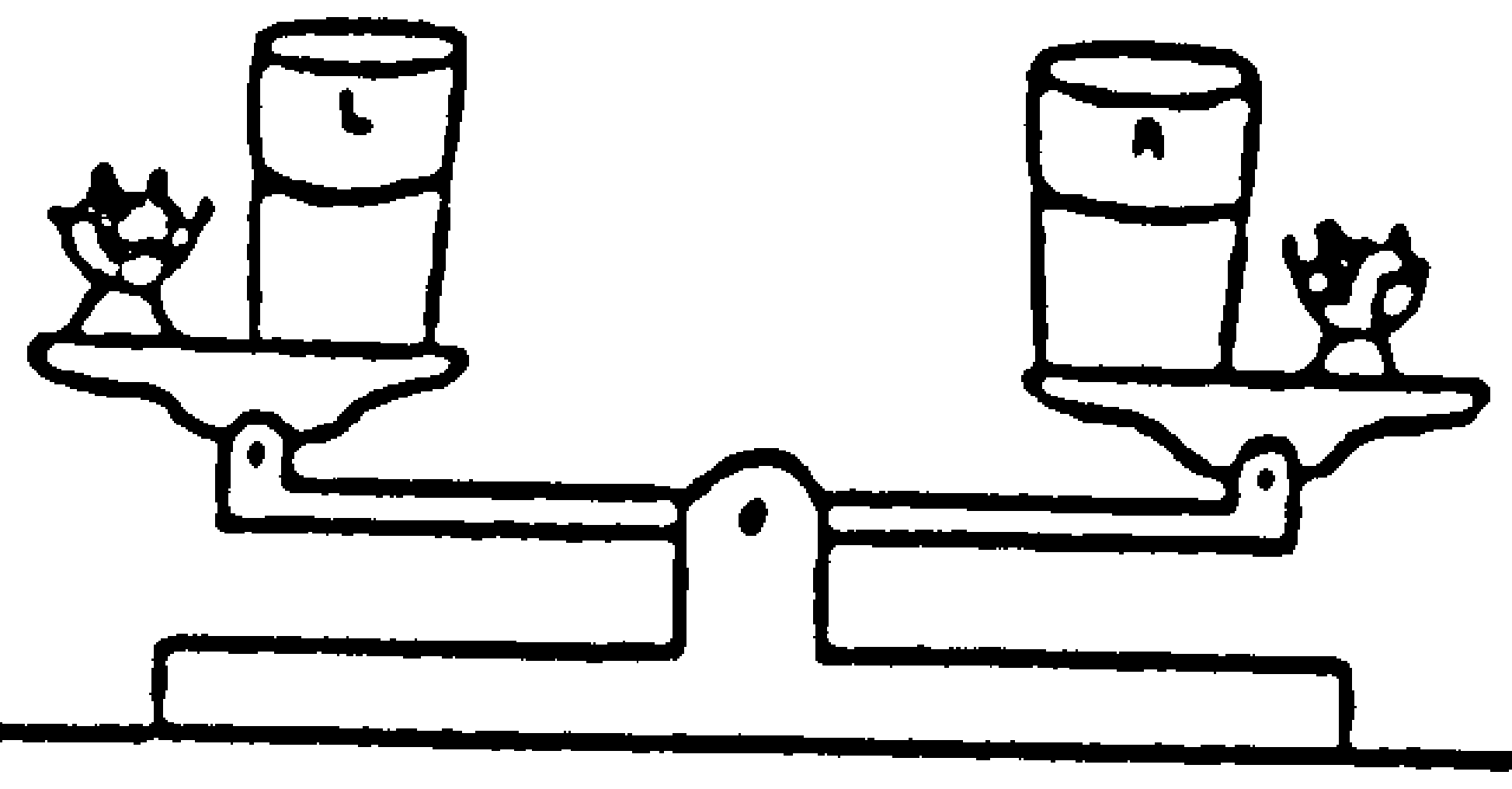
Liz and Rob

Liz and Rob are playing with new scales, mugs and egg-cups; please follow what they do.

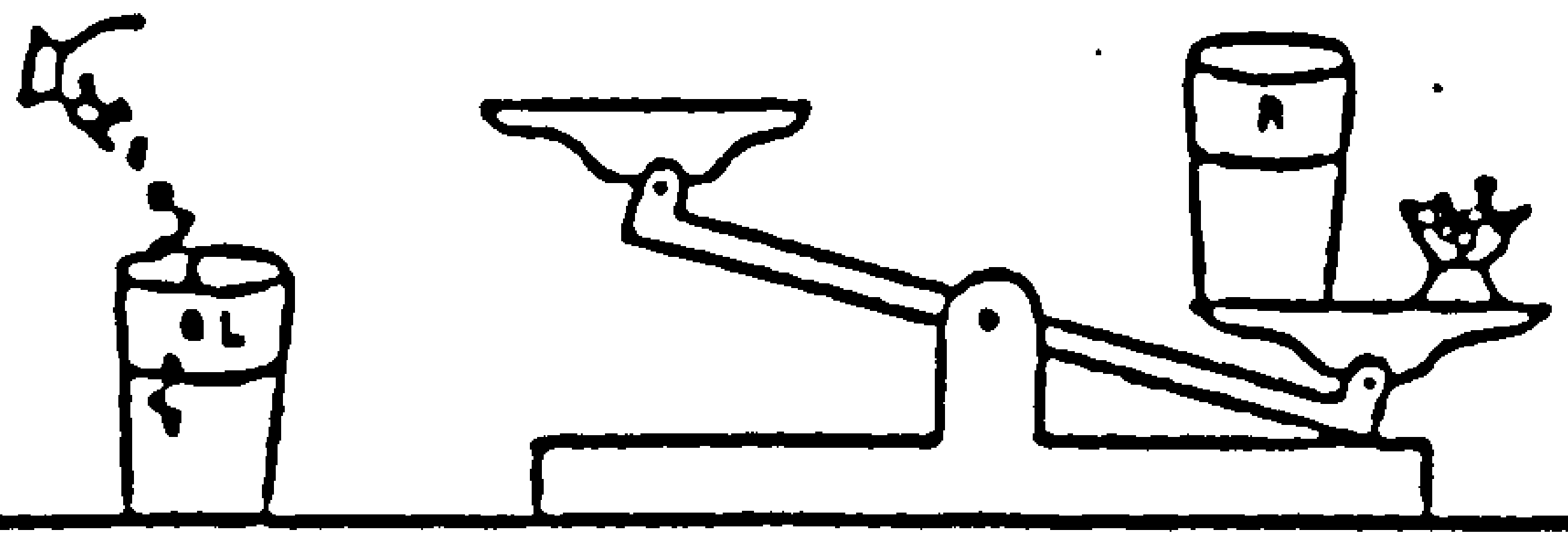
1. They pour water into their mugs and the scales balance. They say: "The mugs are the same weight."



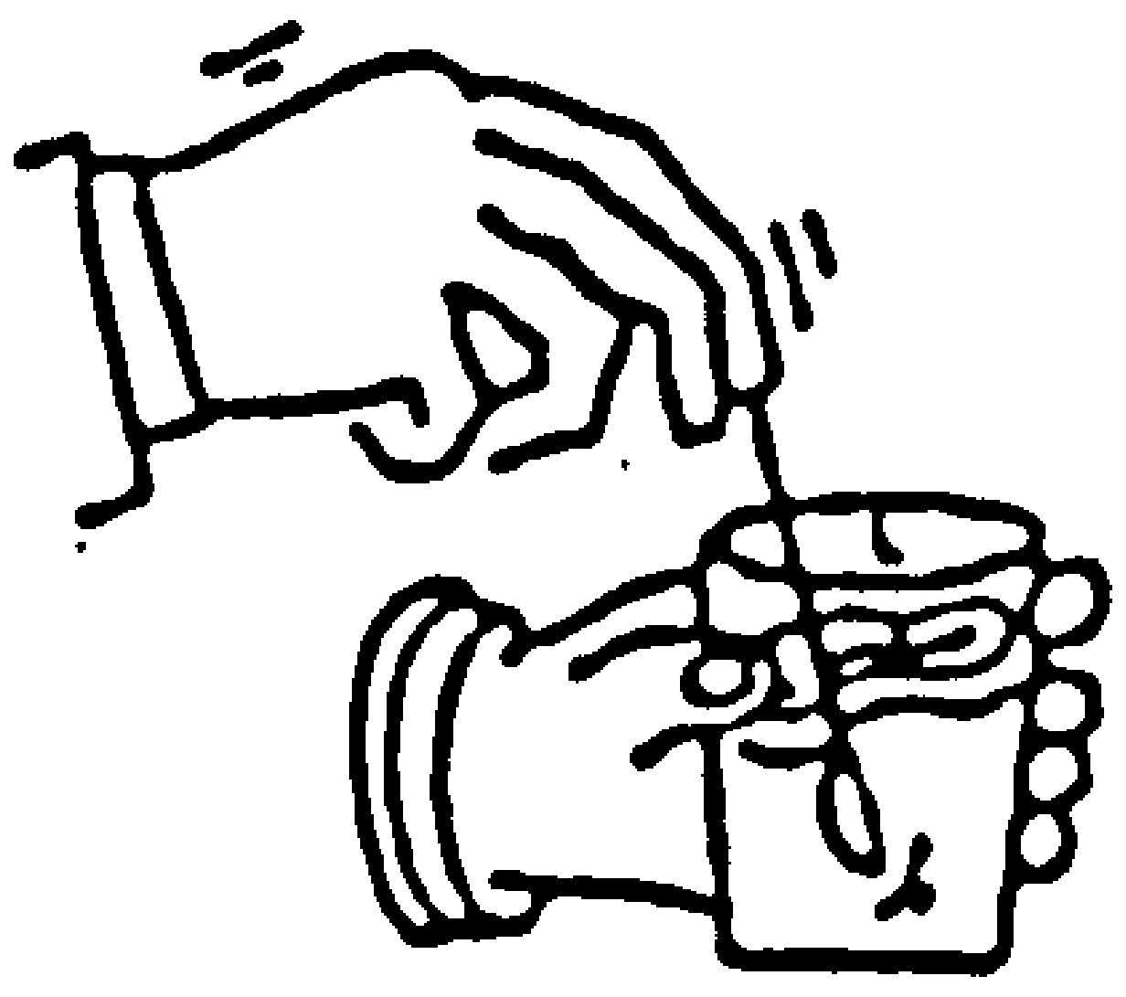
2. Then they fill their egg-cups with enough sugar granules to make the scales balance again.



3. Liz takes her mug off the scales and pours her sugar into her mug. Rob leaves his alone.

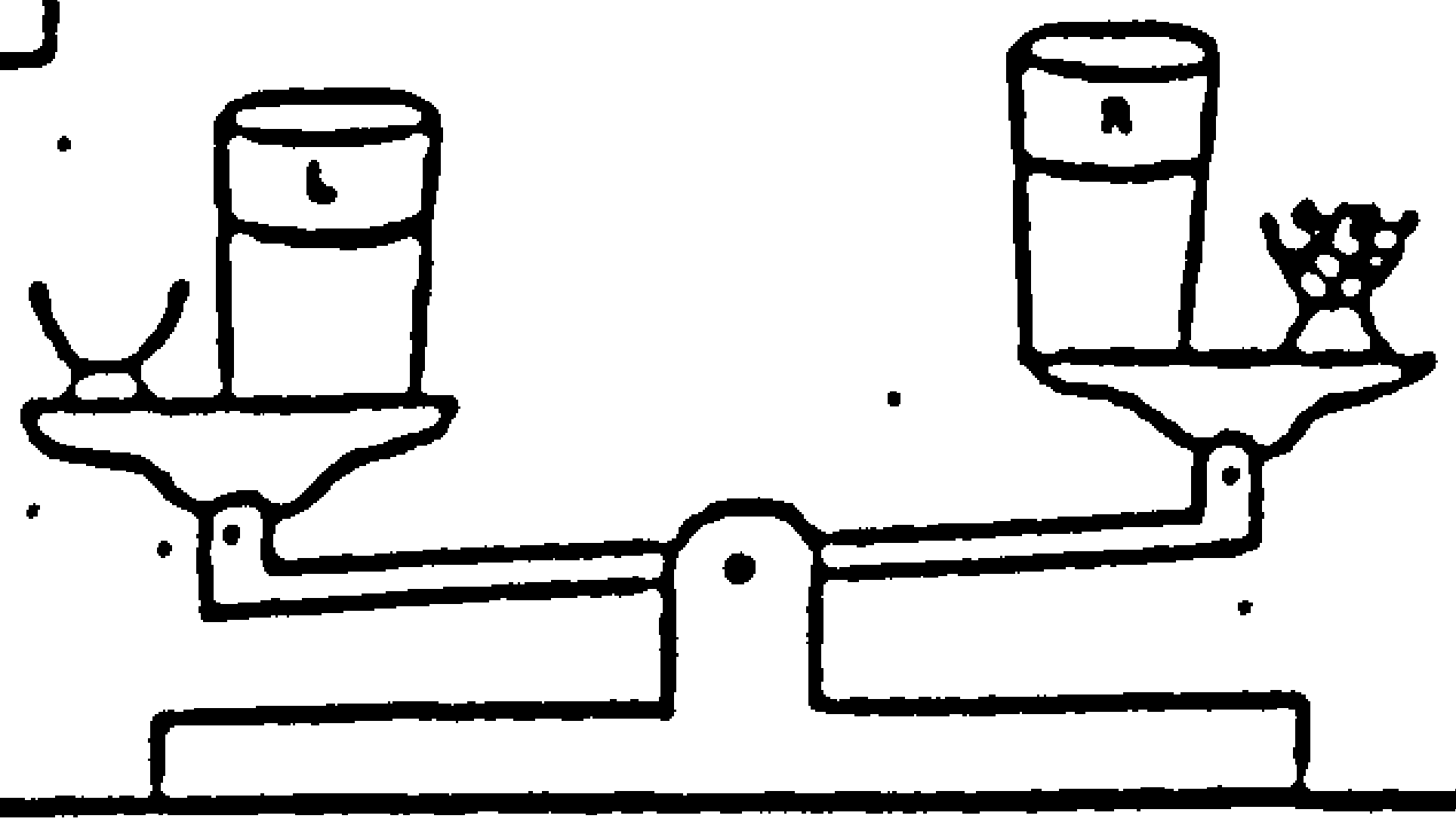


4. Liz stirs the water until she cannot see the sugar granules.

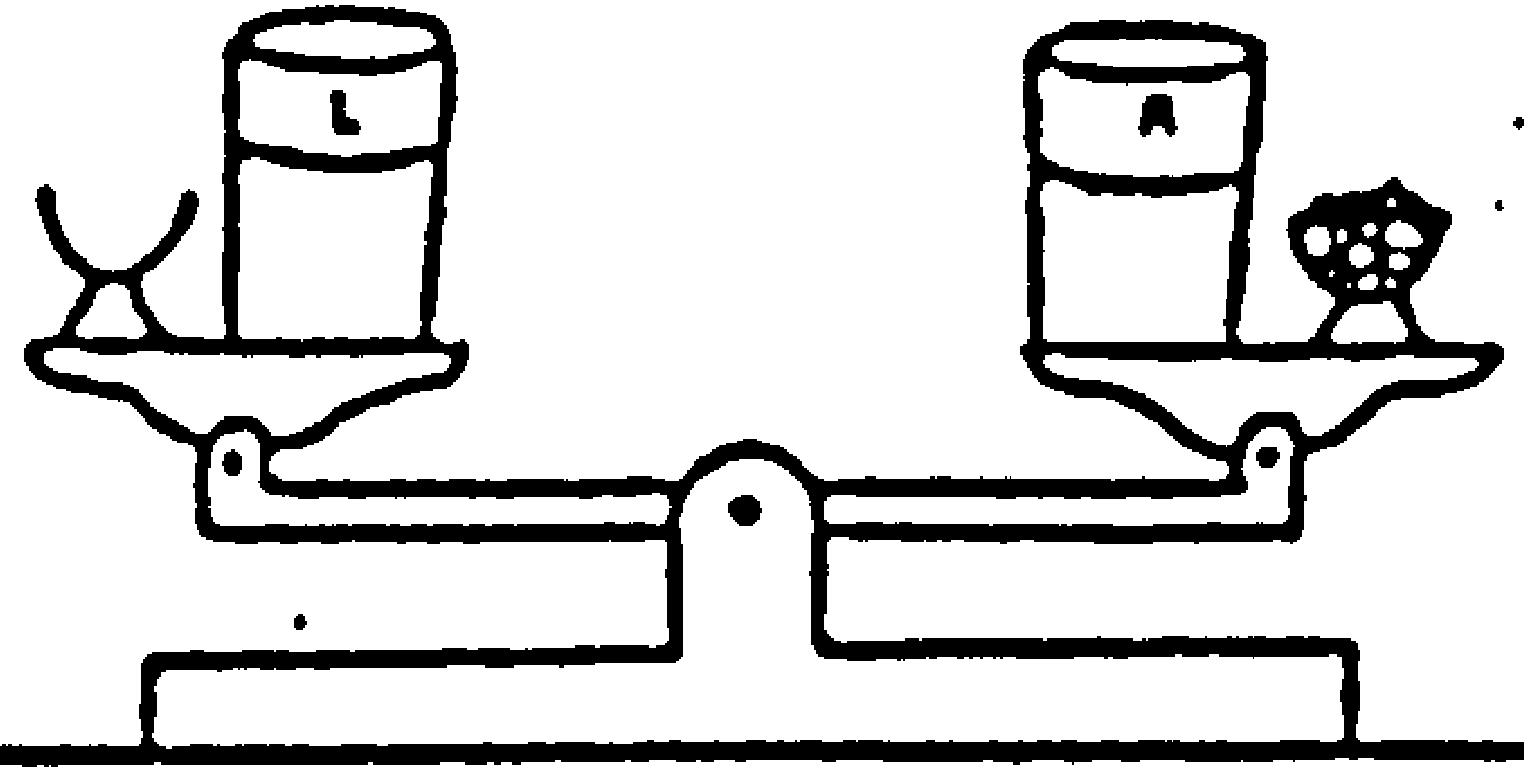


5. If Liz puts her mug and egg-cup back on the scales, do you think the scales will look like pictures A, B or C below?

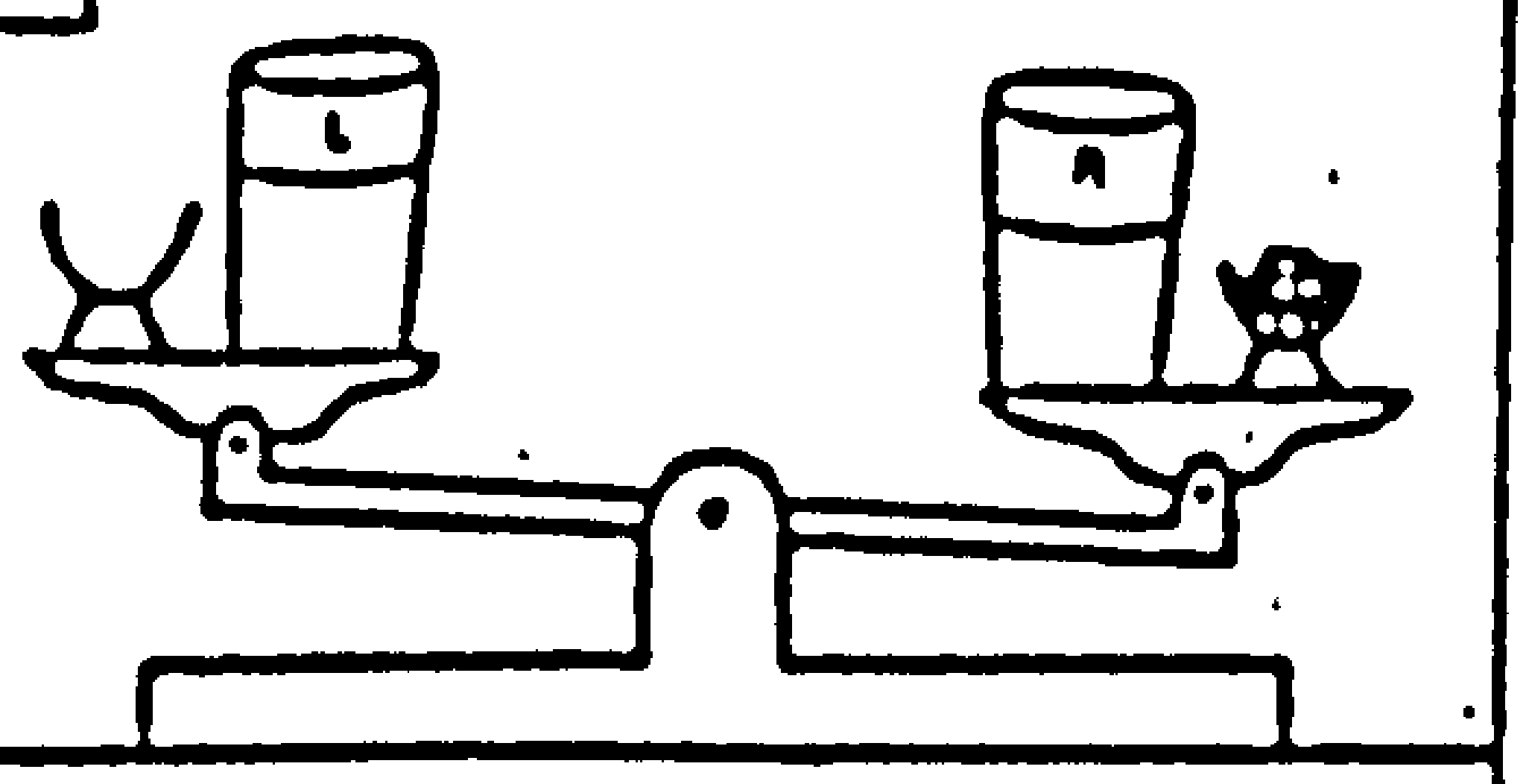
A



B



C



A ☐ B ☐ C ☐

Please tick (✓) one box.

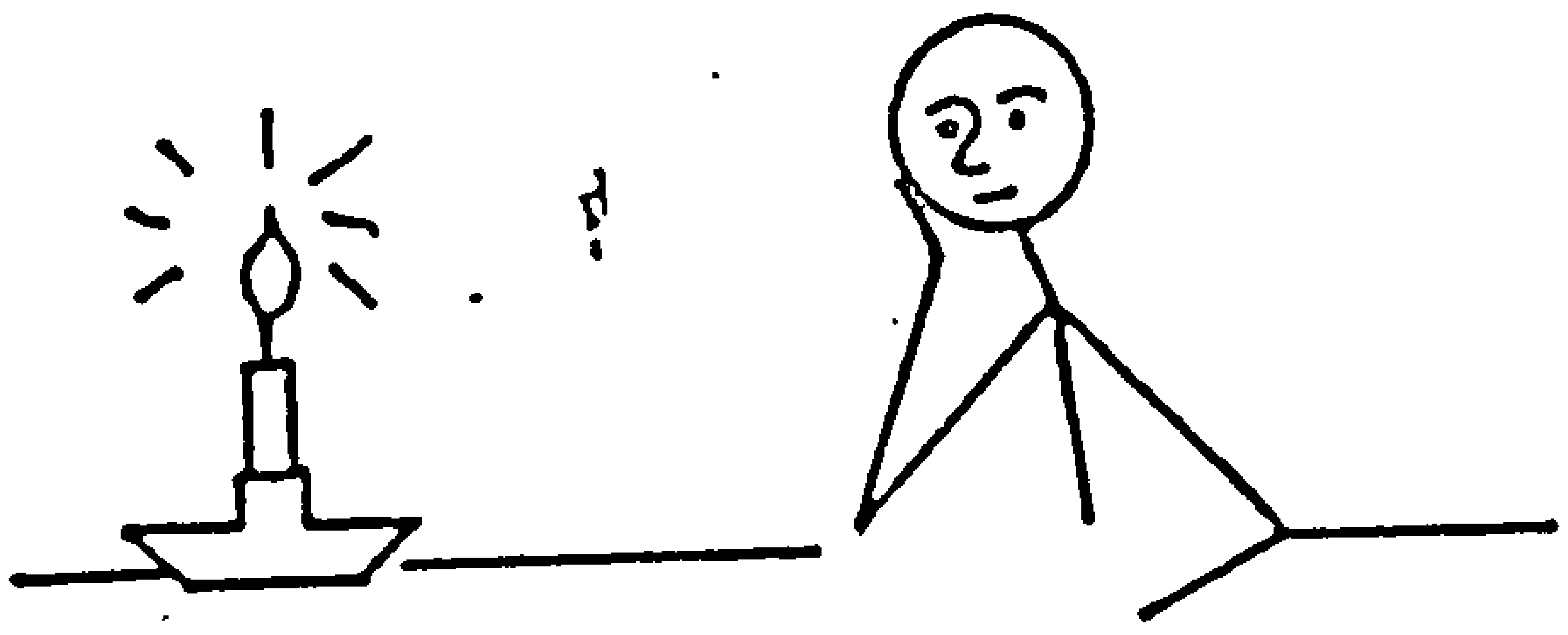
Please say why you chose this answer:

I chose this answer because ....

....

....

....



You are watching a candle burning during the day.

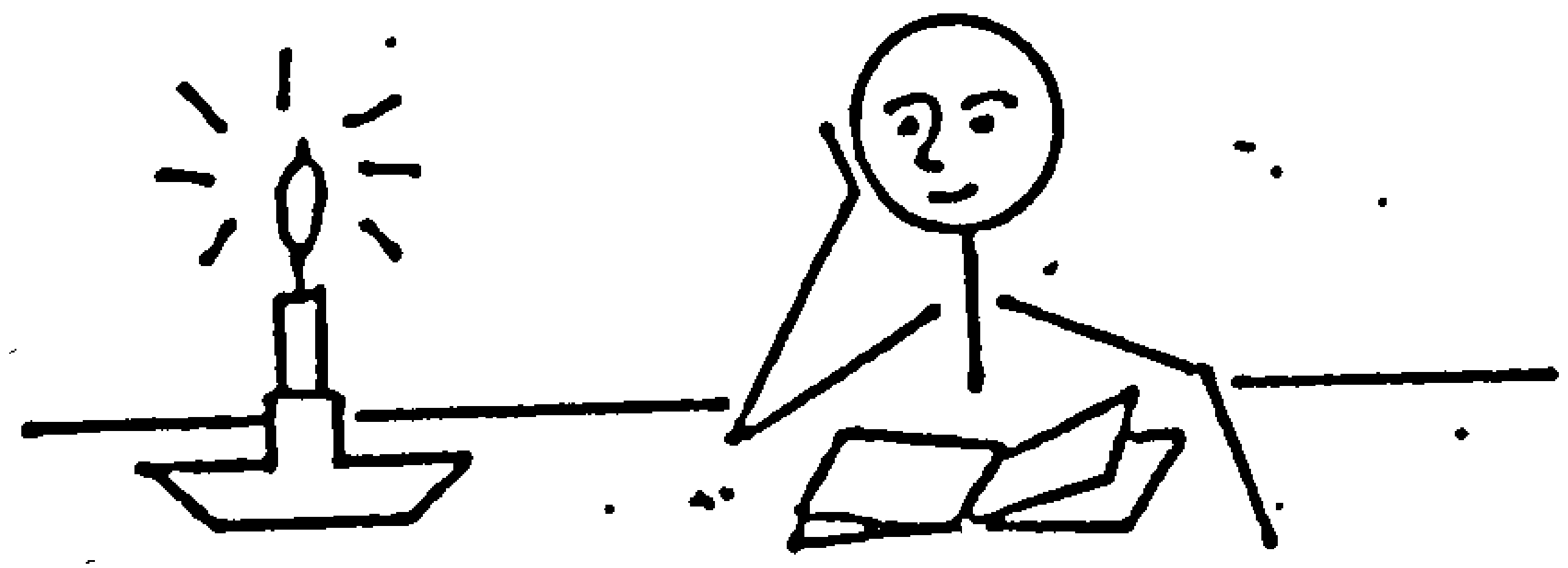
The light from the candle:

A: stays on the candle.

B: comes out about halfway towards you.

C: comes out as far as you but no further.

D: comes out until it hits something.



There is a power cut during the night. You are using a candle.

The light from the candle:

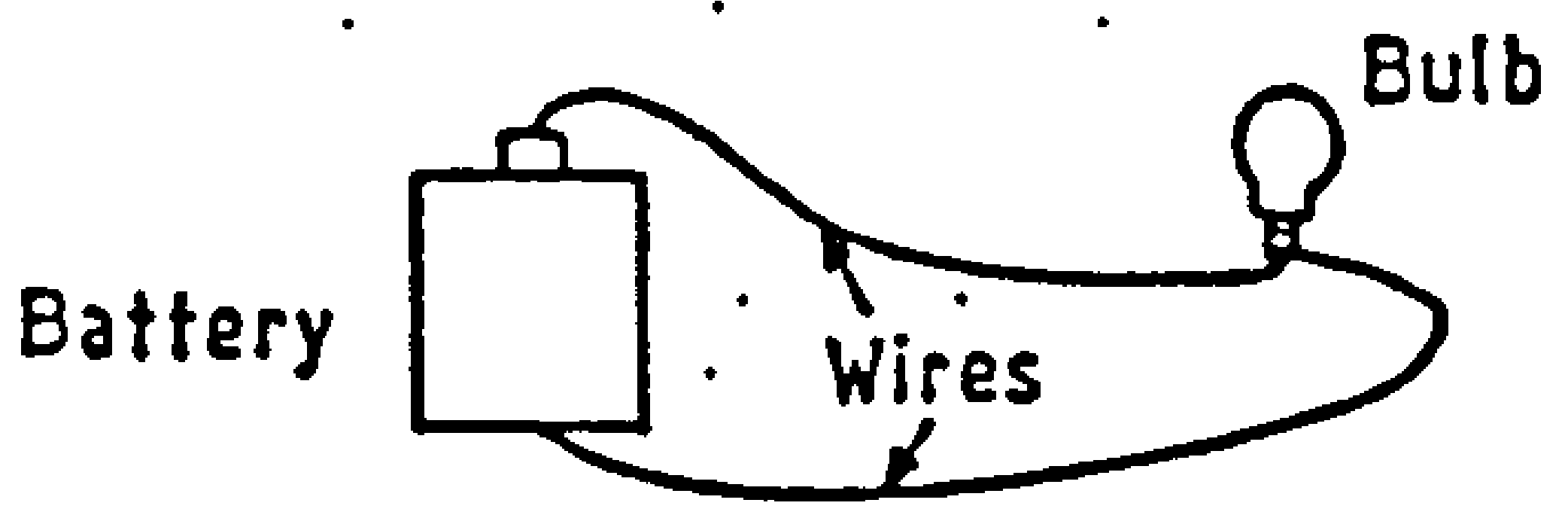
A: stays on the candle.

B: comes out about halfway towards you.

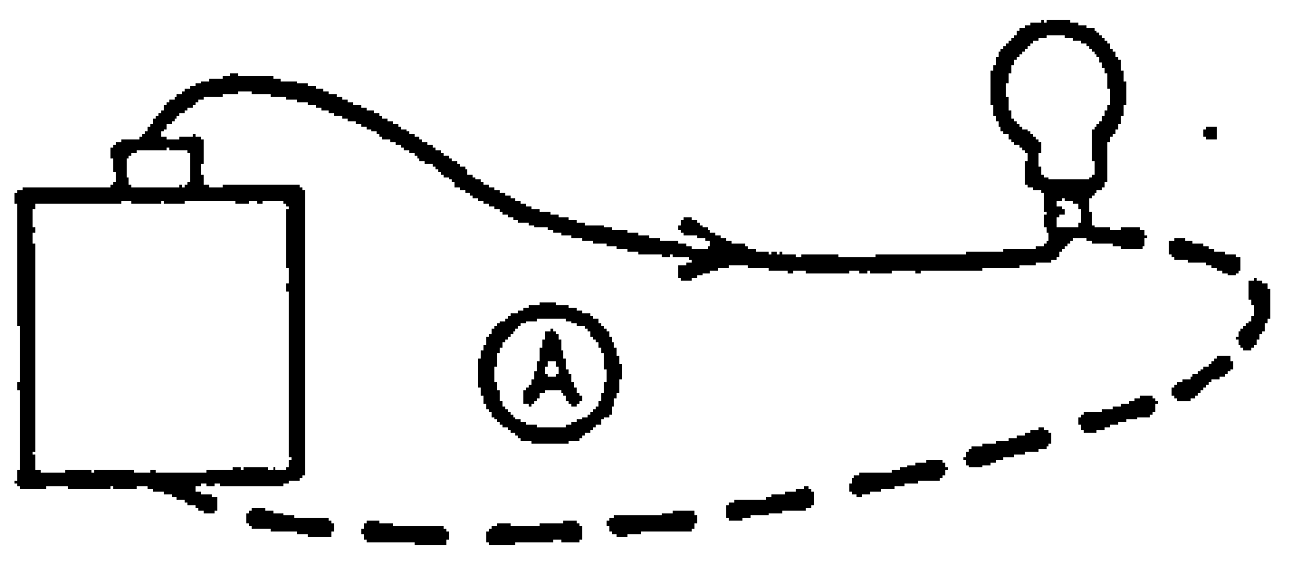
C: comes out as far as you but no further.

D: comes out until it hits something.

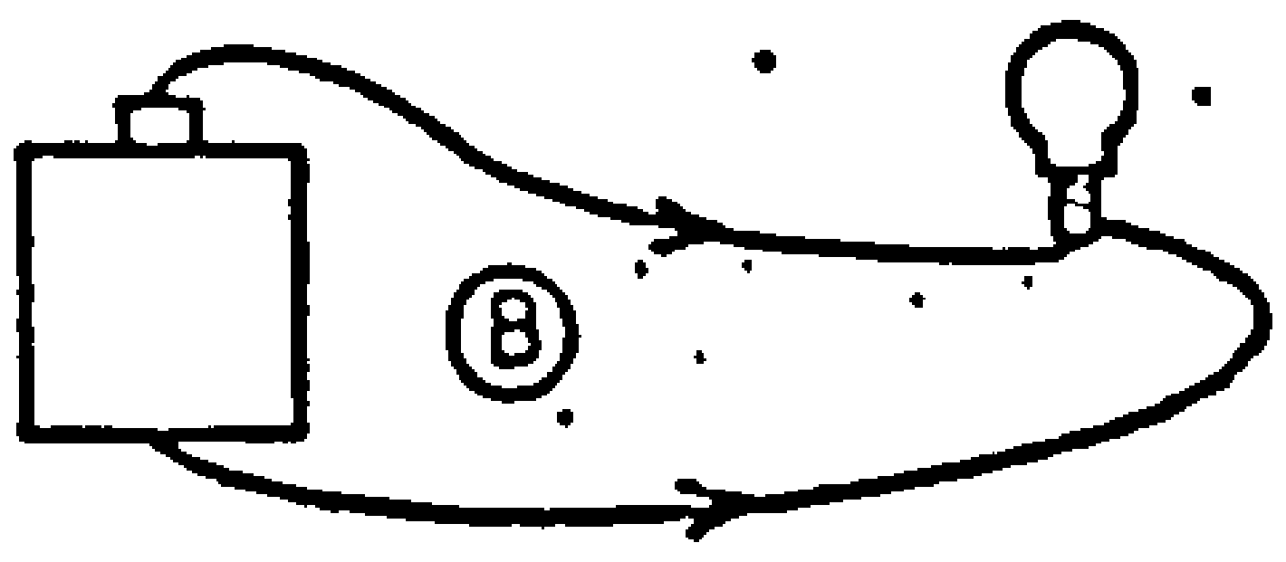
6\. A Battery is connected up to a torch bulb as shown in the diagram. The bulb is glowing.



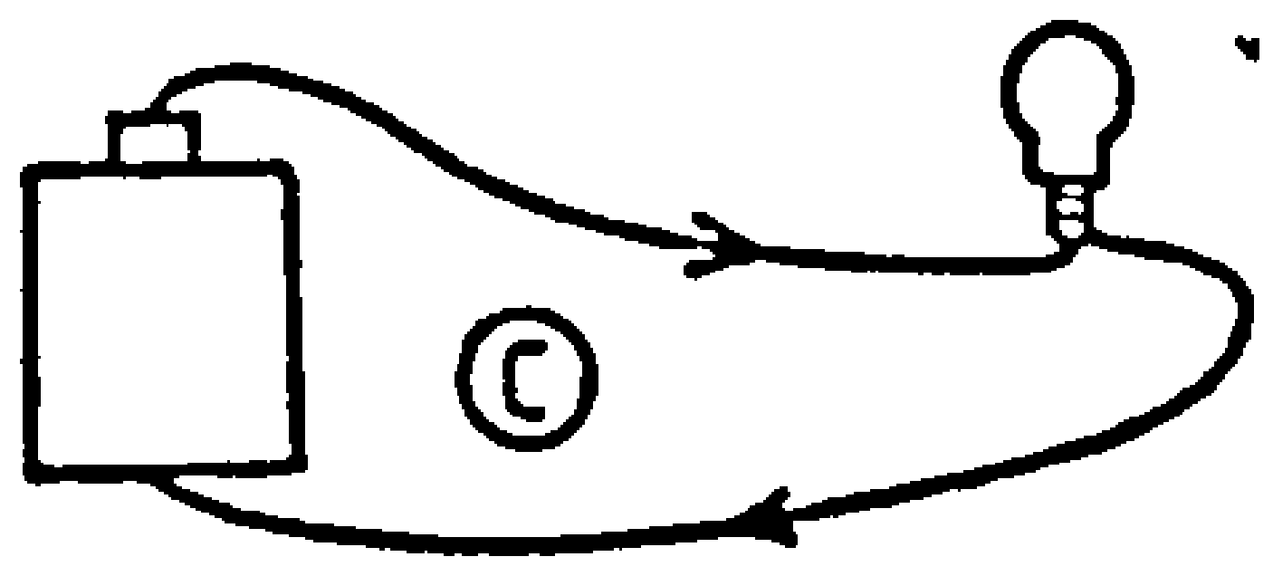
In the way you think about it, the electric current in the wires is best described by which diagram?



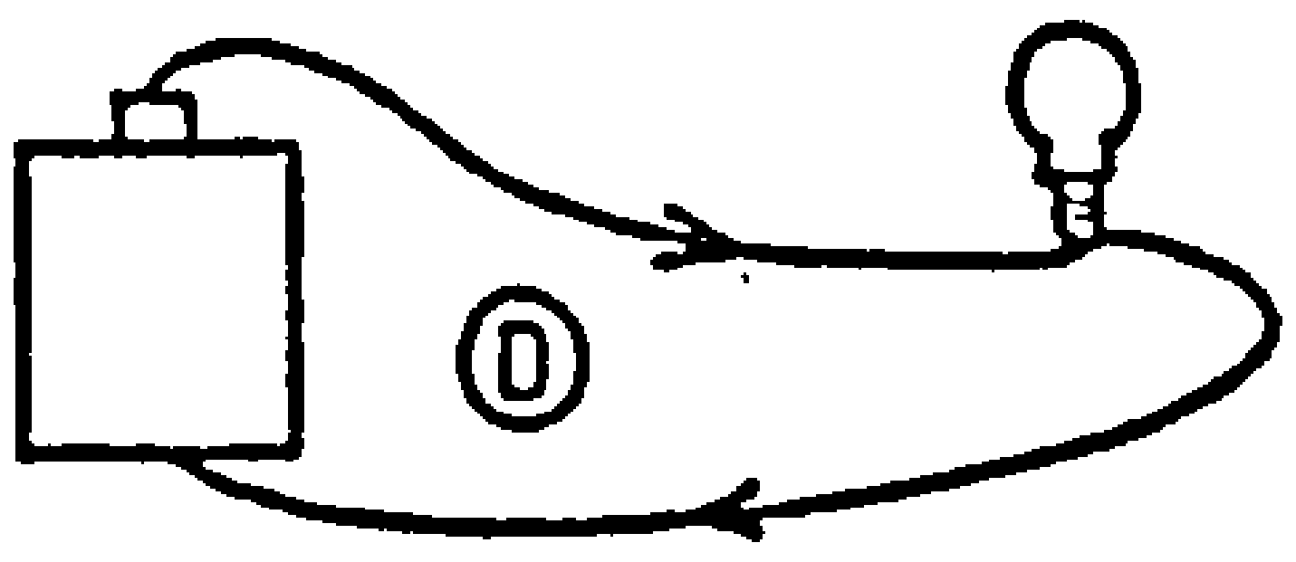
There will be no electric current in the wire attached to the base of the battery.



The electric current will be in a direction toward the bulb in both wires.

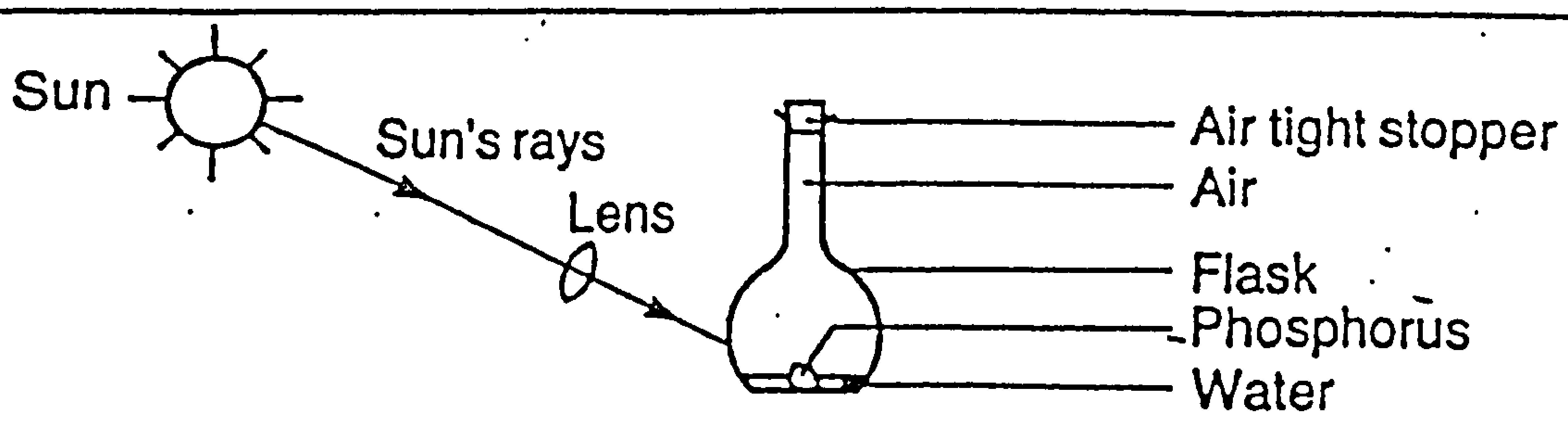


The direction of the electric current will be as shown. The current will be less is the "return" wire.



The direction of the electric current will be as shown. The current will be the same in both wires.

A☐ B☐ C☐ D☐



A piece of phosphorus was held in a flask as shown in the diagram. The mass of the flask and contents equalled 205 g. The sun's rays were focussed on the phosphorus, which then caught fire. The white smoke produced slowly dissolved in the water.

After cooling, the flask and its contents were weighed again.

(a) Would you expect the weight to be:

☐ A More than 205 g

☐ B 205 g

☐ C Less than 205 g

☐ D Not enough information to answer

Tick in the box next to the answer you choose.

(b) Give the reason for your answer:

Chemical Card Game

This card game is a chemical version of "Old Maid". Each card of a pair is printed with half of a sentence, e.g. one card reads "A CATALYST" and the corresponding card reads "SPEEDS UP CHEMICAL REACTIONS". The half sentences are printed on A4 sheets of coloured card. They are cut to approximately the size of normal playing cards.

The pupils play the game in groups of five or six. (To allow for easy collecting and distributing of packs of cards, each pack of cards is a different colour). The cards are shuffled and dealt. The players then make matching pairs from the cards in their hands which they place face up on the table. Starting with the dealer, each player then holds the cards face down and allows the next player to pull one card from his hand. Each time a pair is made, it is placed on the table. The player with the joker makes every effort to pass it on, as the player who is left with the joker when all the pairs are made is the "Old Maid".

Note that the matching pairs must not only make scientific sense, but the English must also be correct, e.g. "OXYGEN CAN CAUSE" matches "A GLOWING SPLINT TO LIGHT AGAIN". While pupils may be tempted to match the former with "FOR BREATHING AND BURNING", this pairing would not be acceptable as it is not a properly constructed sentence. In this way it is hoped to stress the importance of language as well as test the pupils' understanding of science.

A CATALYST	SPEEDS UP CHEMICAL REACTIONS
ACID AND MARBLE CHIPS	REACT TOGETHER TO FORM CARBON DIOXIDE
OXYGEN IS NECESSARY	FOR BREATHING AND BURNING
CARBON DIOXIDE CAN BE USED	TO PUT OUT FIRES
78% OF THE AIR	CONSISTS OF NITROGEN

AIR IS	A MIXTURE OF GASES
THE TEST FOR CARBON DIOXIDE IS	IT TURNS LIME WATER MILKY
OXYGEN CAN CAUSE	A GLOWING SPLINT TO LIGHT AGAIN
PLANTS USE CARBON DIOXIDE TO	MAKE THEIR FOOD
ONE FIFTH OF THE AIR	CONSISTS OF OXYGEN

OXYGEN CAN BE USED	IN AN OXY-ACETYLENE BURNER
TO MAKE OXYGEN IN THE LAB	WE MIX HYDROGEN PEROXIDE AND A CATALYST
THE “FIZZ” IN DRINKS	IS CARBON DIOXIDE
SOLID CARBON DIOXIDE	IS CALLED “DRY ICE”
BURNING FOSSIL FUELS	CAN CAUSE ACID RAIN

HARMFUL GASES IN CAR EXHAUSTS	CAN BE REMOVED BY CATALYTIC CONVERTERS
ACID RAIN CAN	DAMAGE BUILDINGS, DESTROY TREES, POISON LAKES.

Changes in chemistry

In science we describe the changes that occur to substances as either **physical changes** or **chemical changes**. Explain what you think these terms mean:

a physical change is ____

____

____

a chemical change is ____

____

____

Below and over the page you will find three examples of substances being changed. The diagrams show (some of) the molecules or other particles before and after the change. For each example:

decide whether the change is *physical* or *chemical*,

try to explain your reasons.

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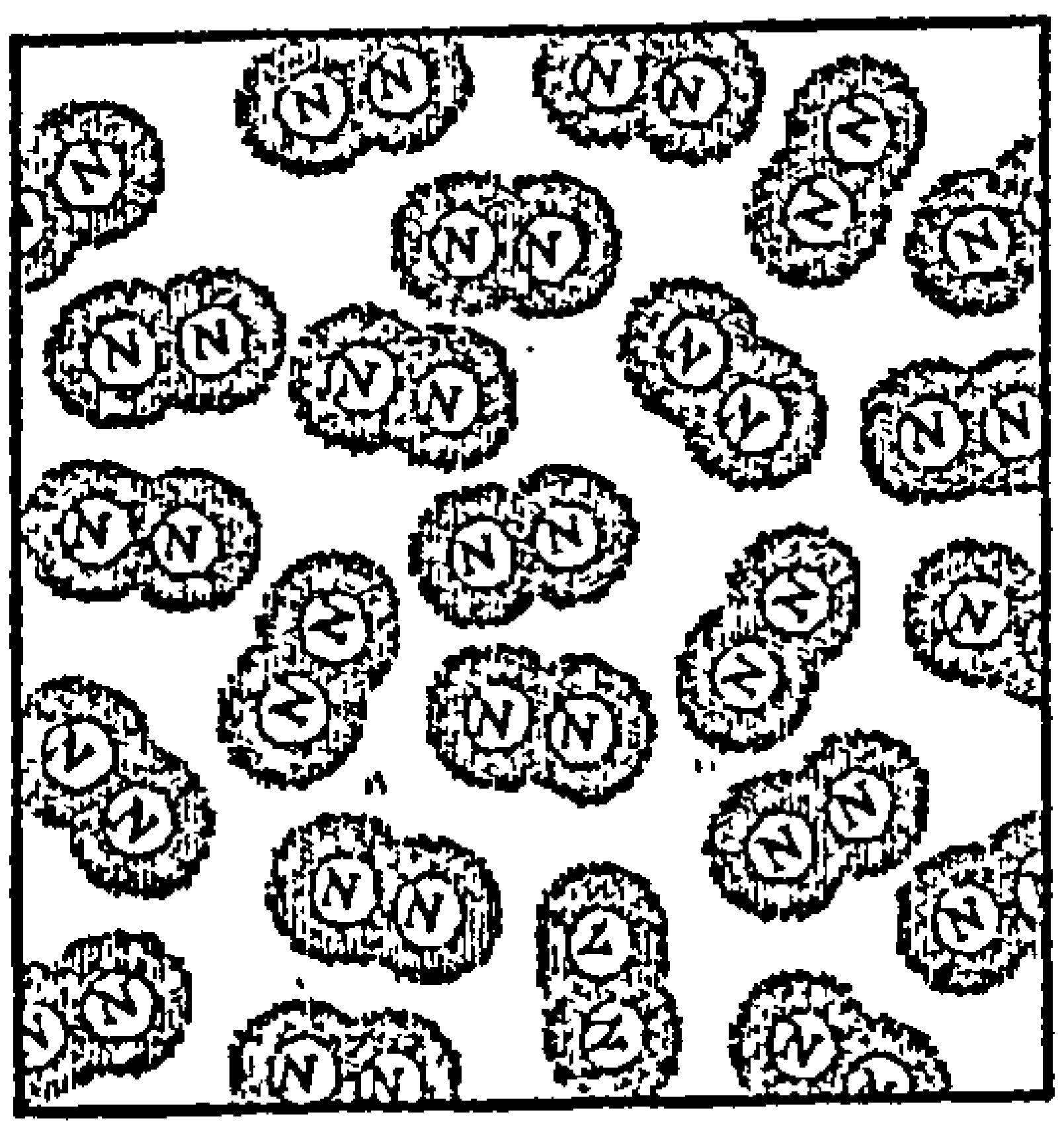
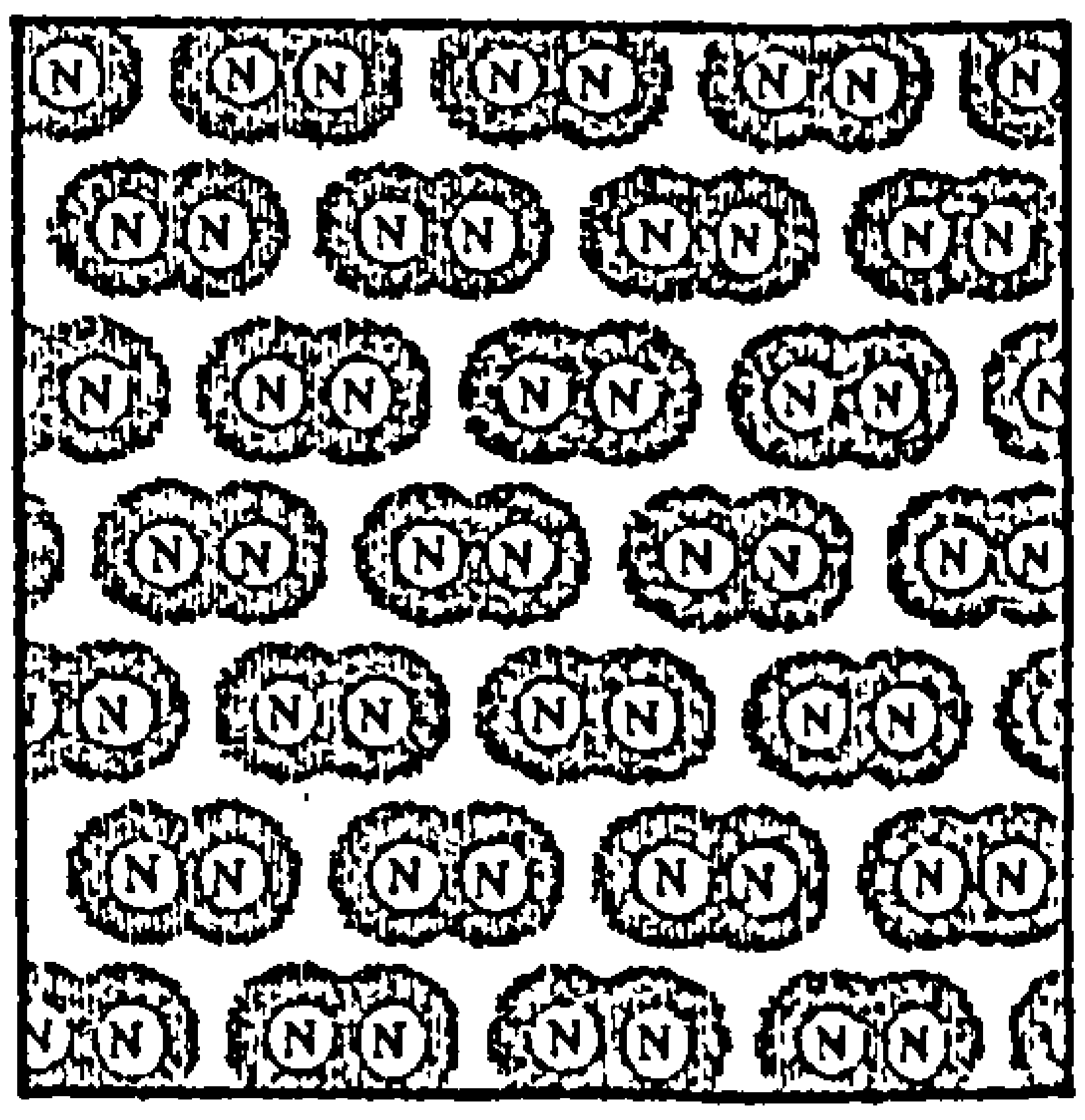
1. Some very cold liquid nitrogen is cooled even further, until it freezes:



before



after

This is a ______________________ change because

____

____

____

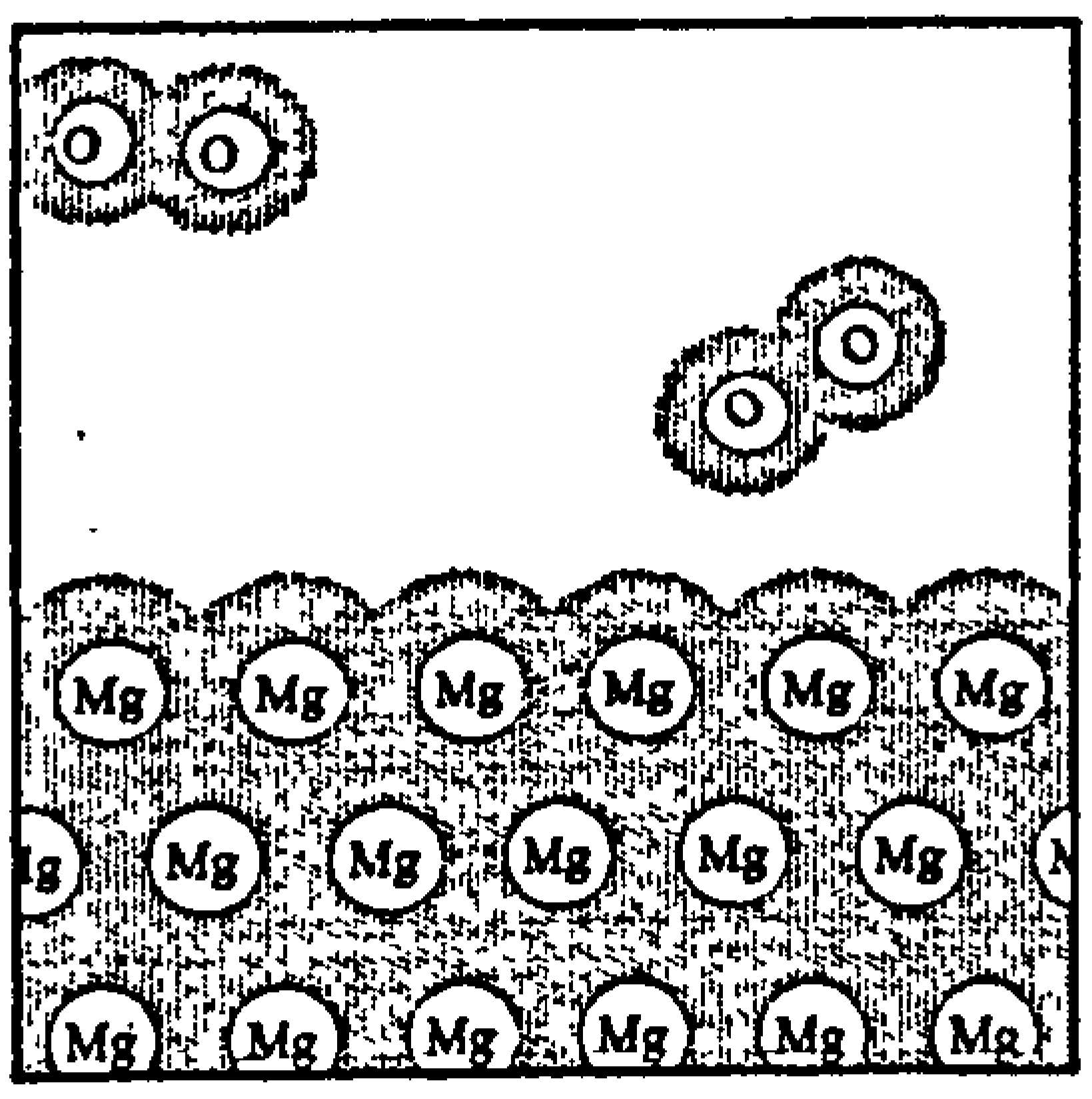
____

---

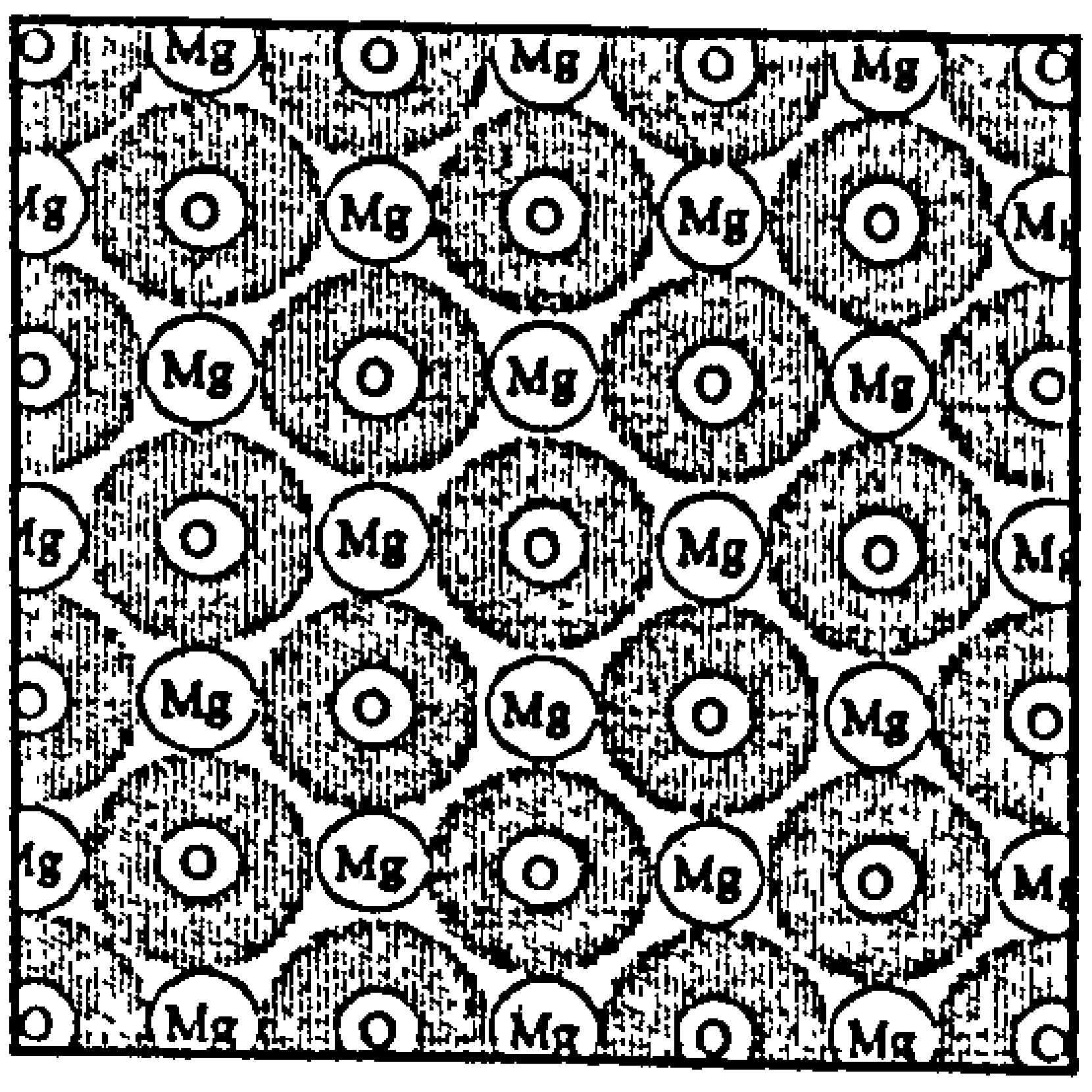
now turn over

Changes in chemistry

2. Some magnesium is heated in oxygen until it burns:



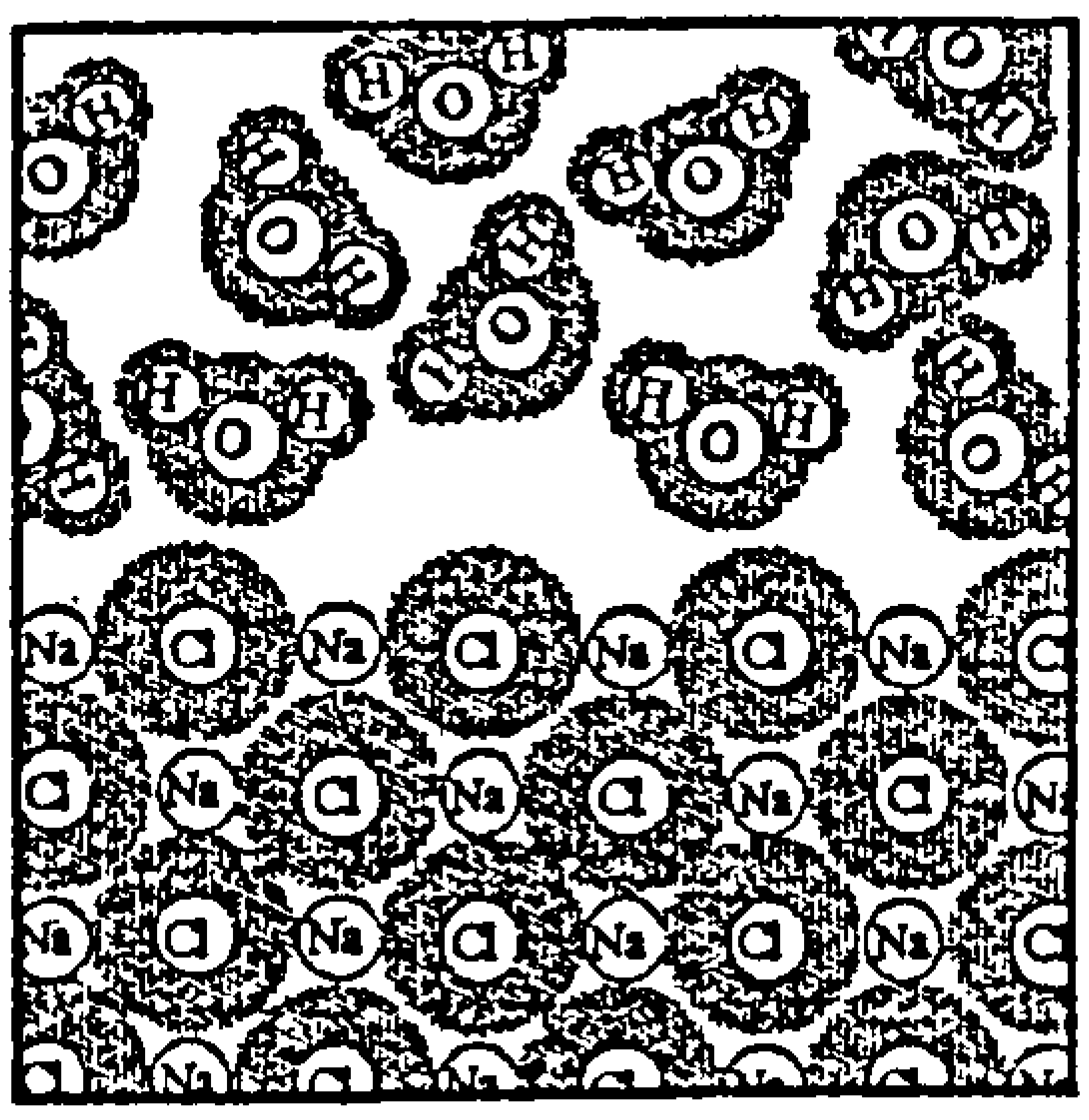
before



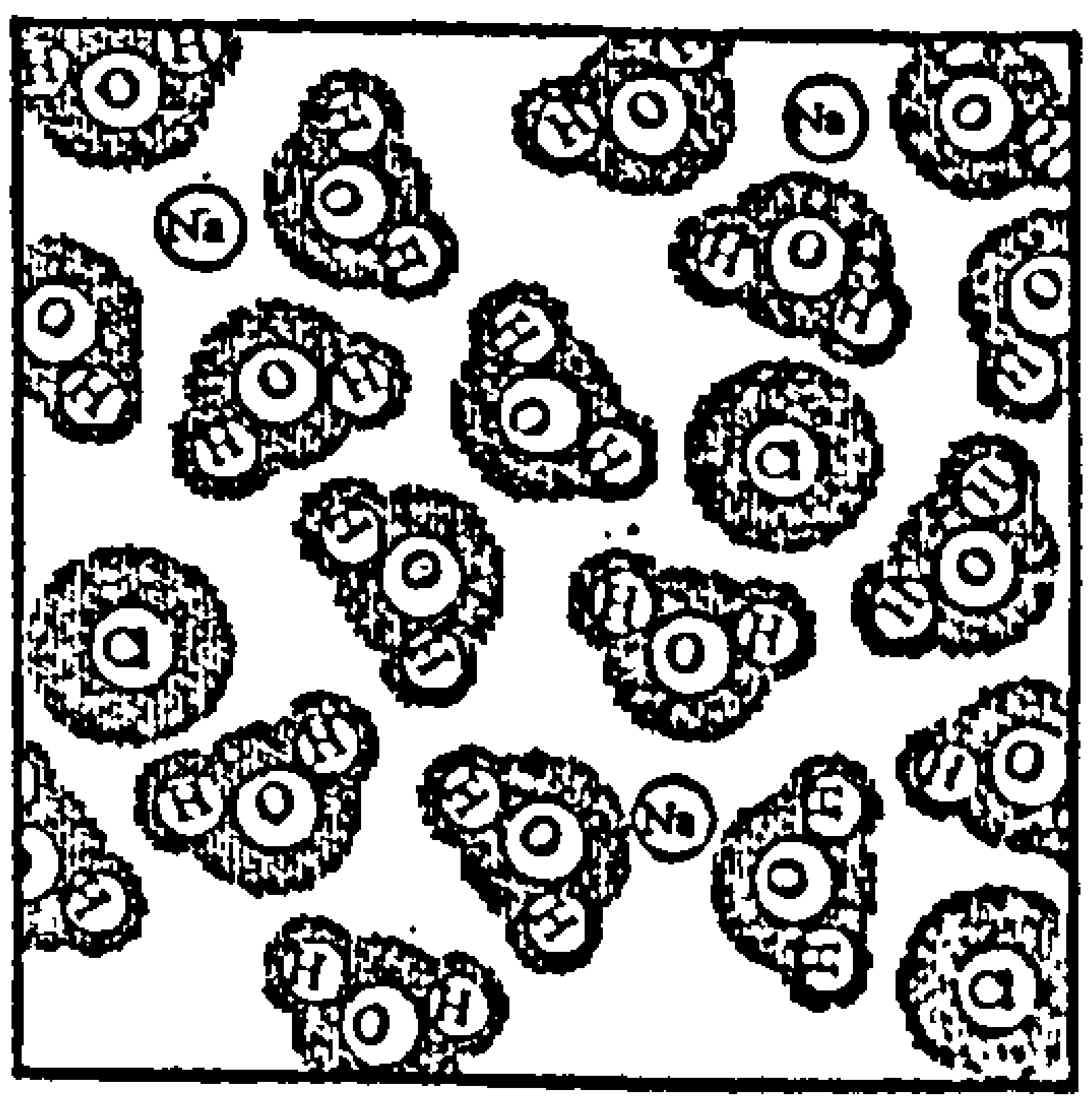
after

This is a ______________________ change because

3. Some sodium chloride is added to a beaker of water, and left to dissolve:



before

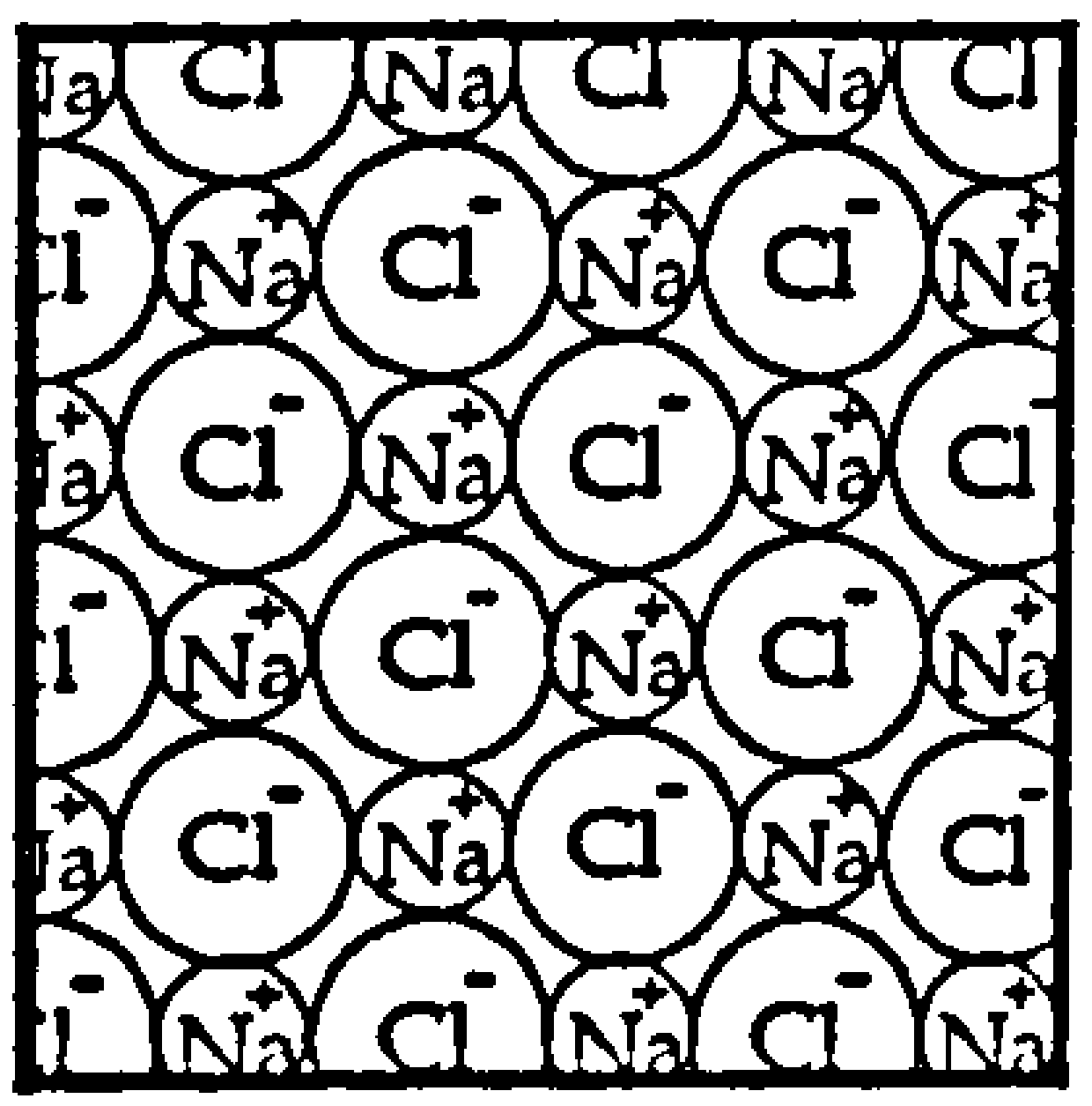


after

This is a ______________________ change because

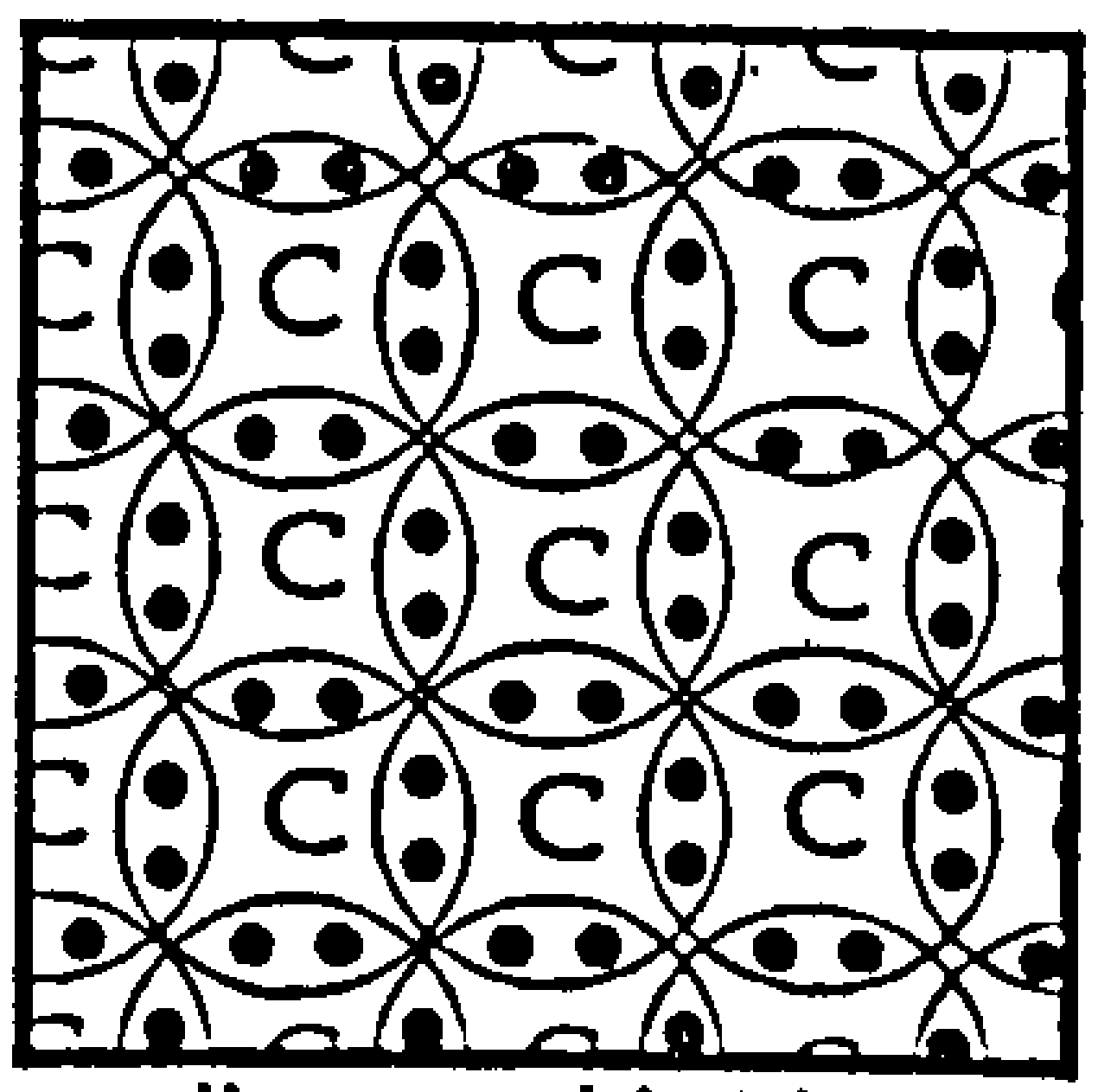
Spot the bonding

This exercise comprises of a set of diagrams showing a range of chemical species and systems. For each daigram: either *write the name or names* of the type or types of **bonding present**, or write *none* (if there is no chemical bonding) or *do not know* if you are unsure.



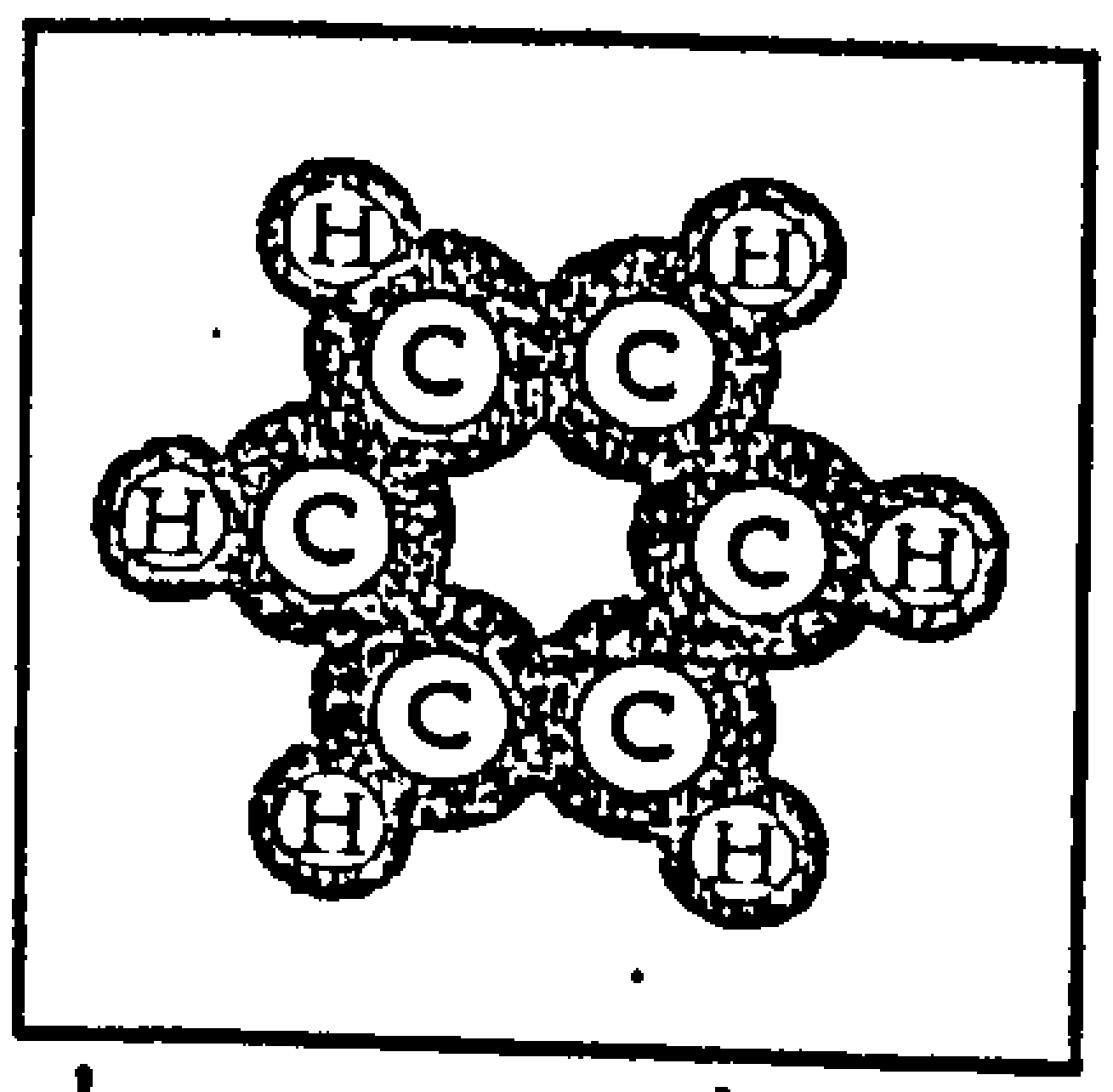
sodium chloride lattice

1.



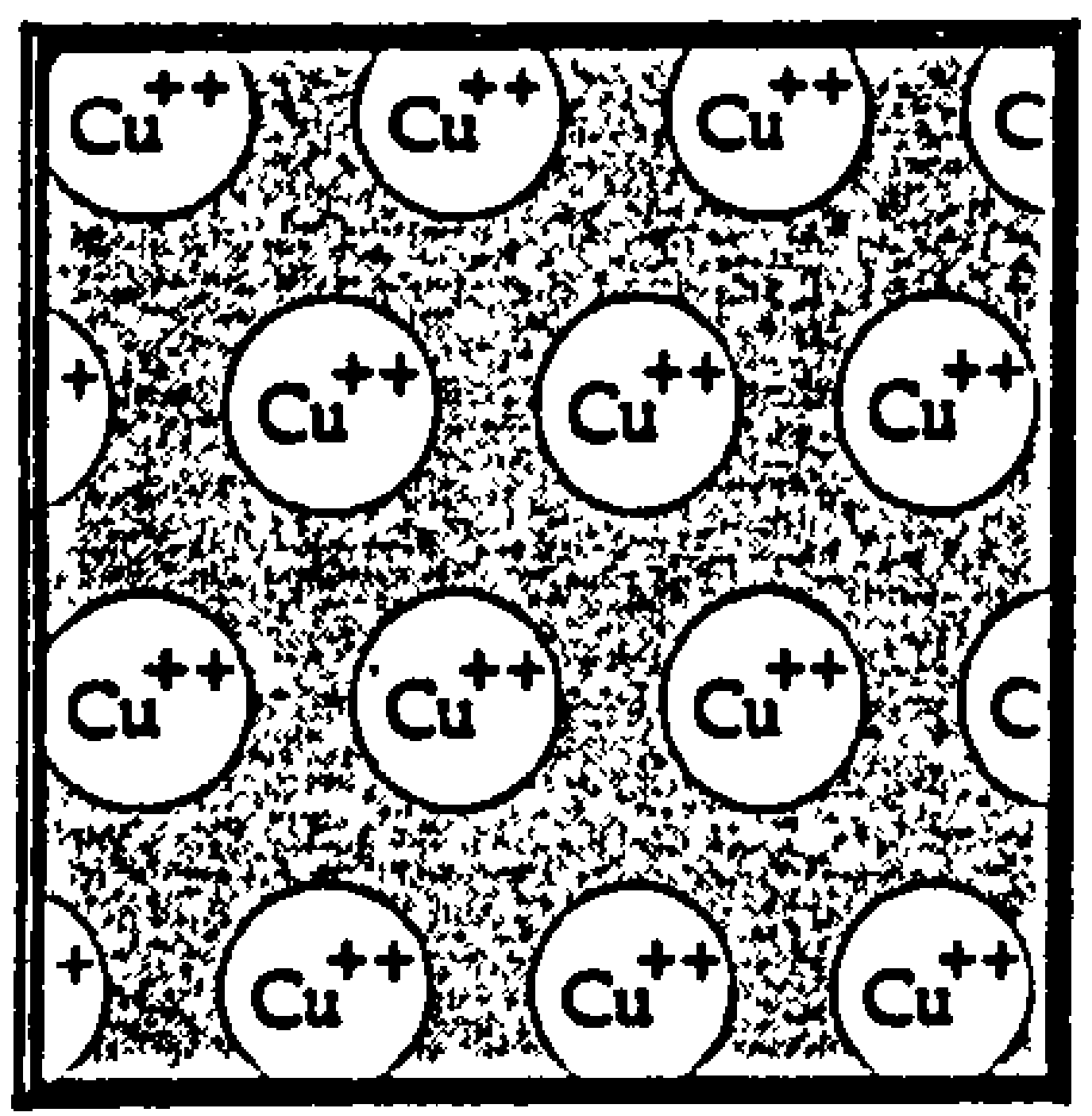
diamond lattice

2.



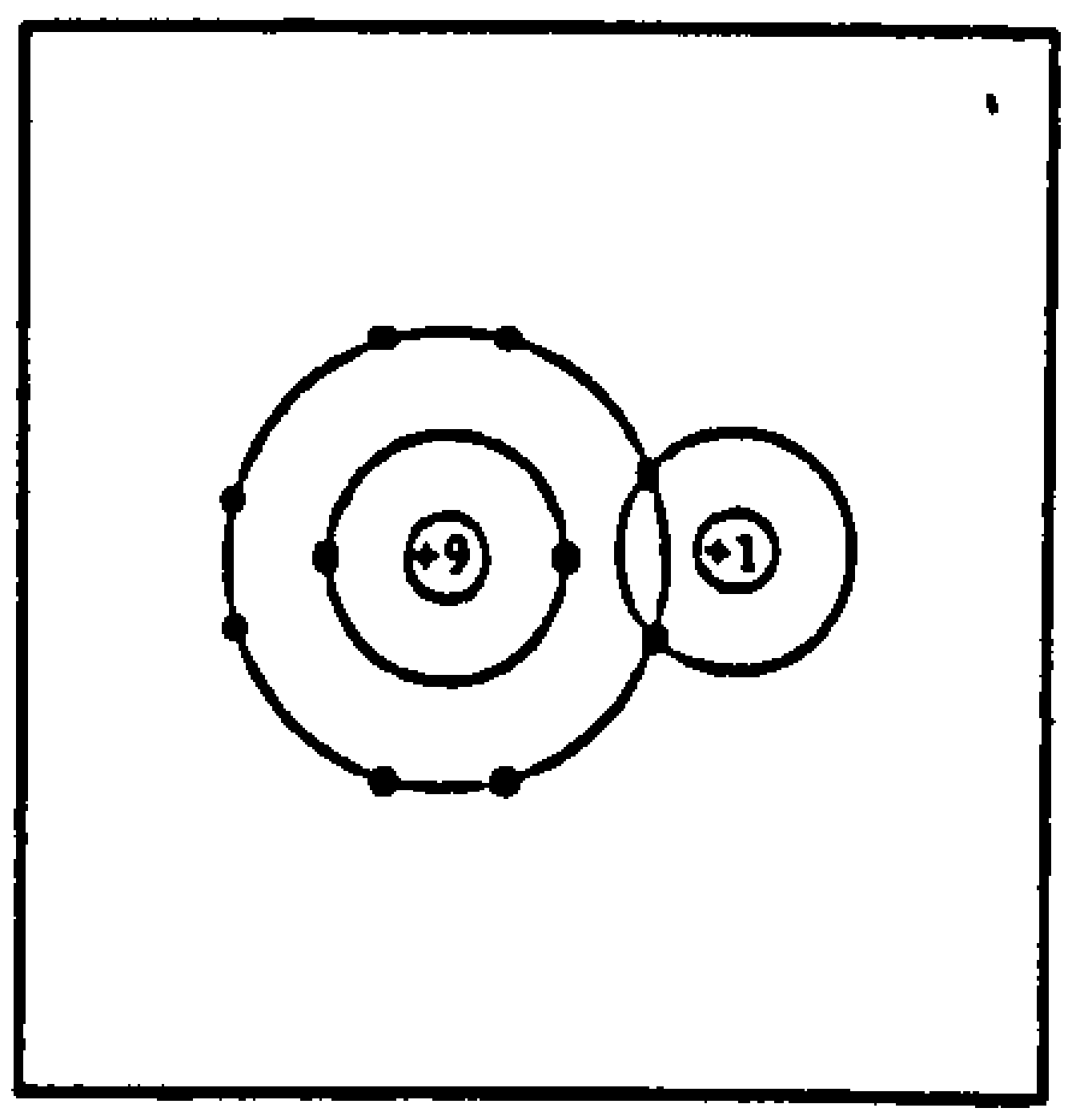
benzene molecule

3.



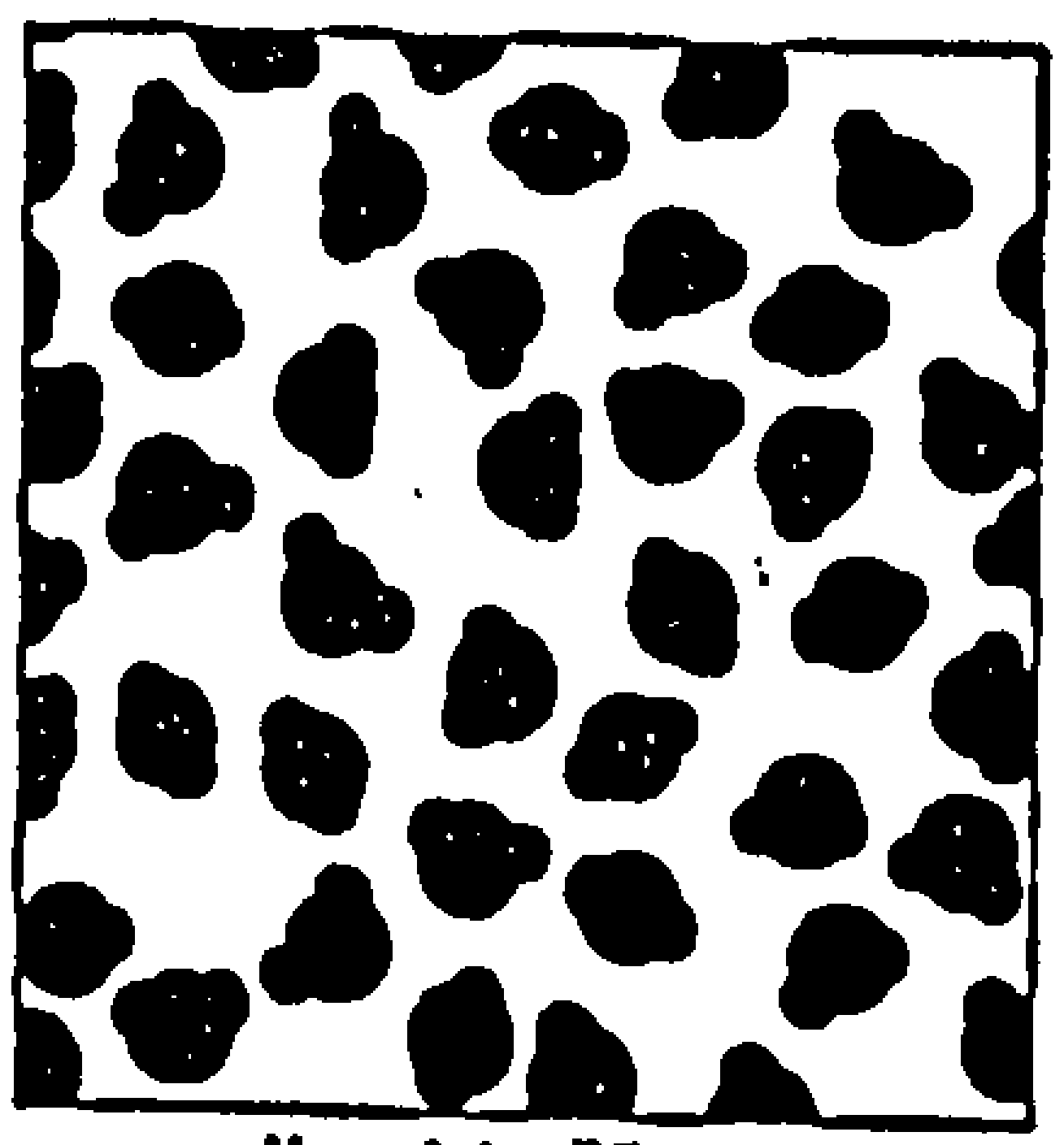
copper lattice

4.



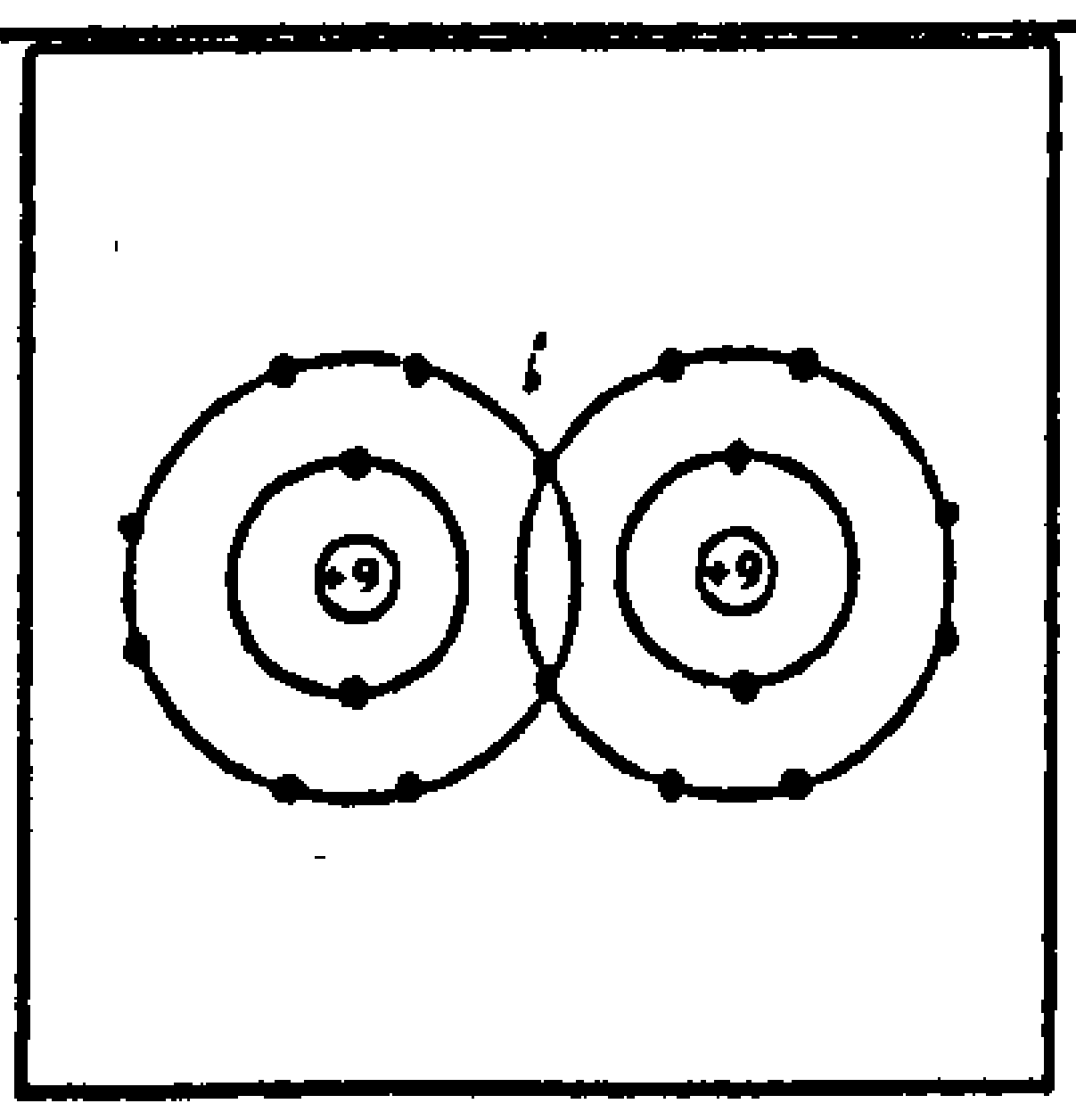
hydrogen fluoride molecule

5.



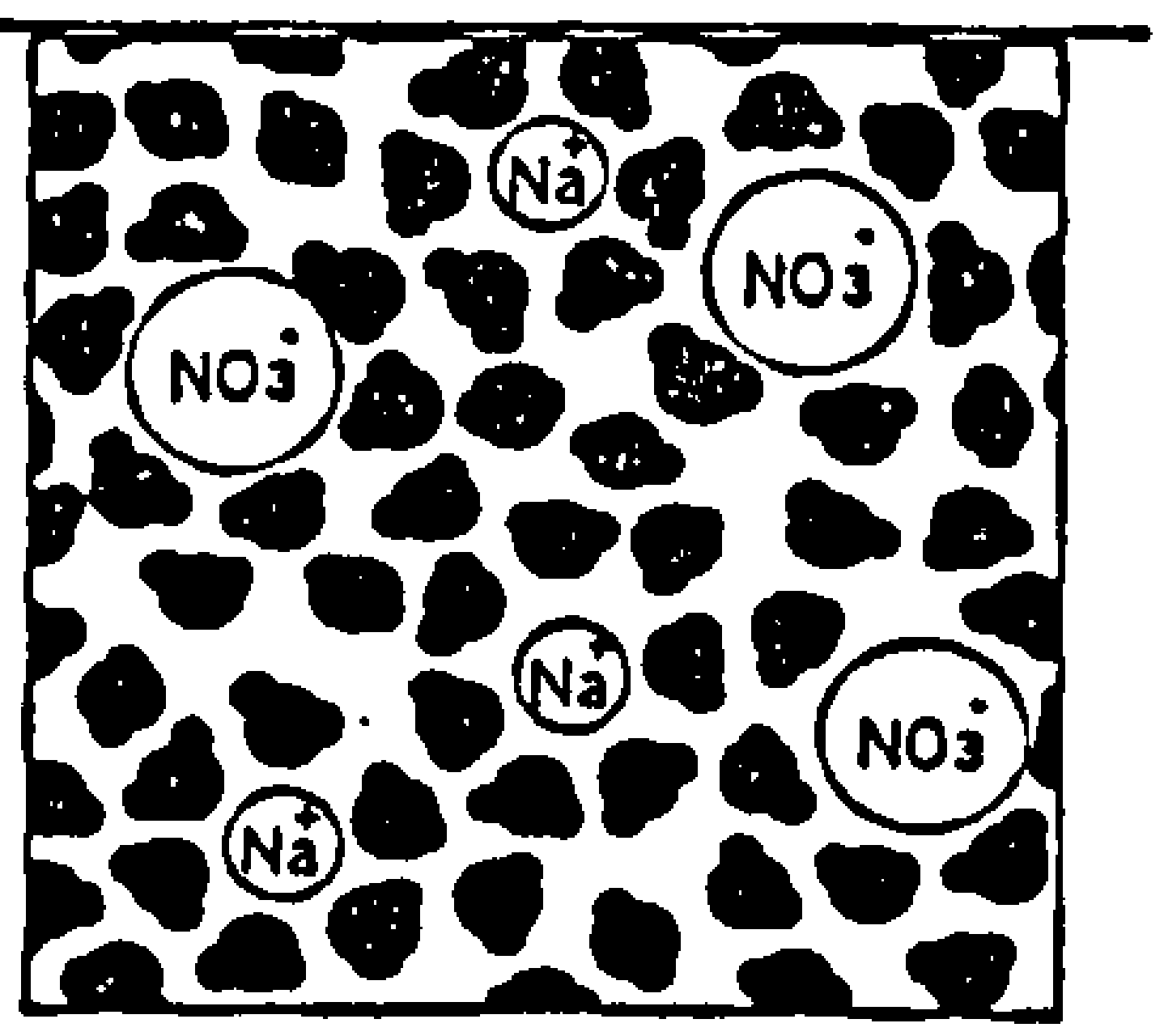
liquid water

6.



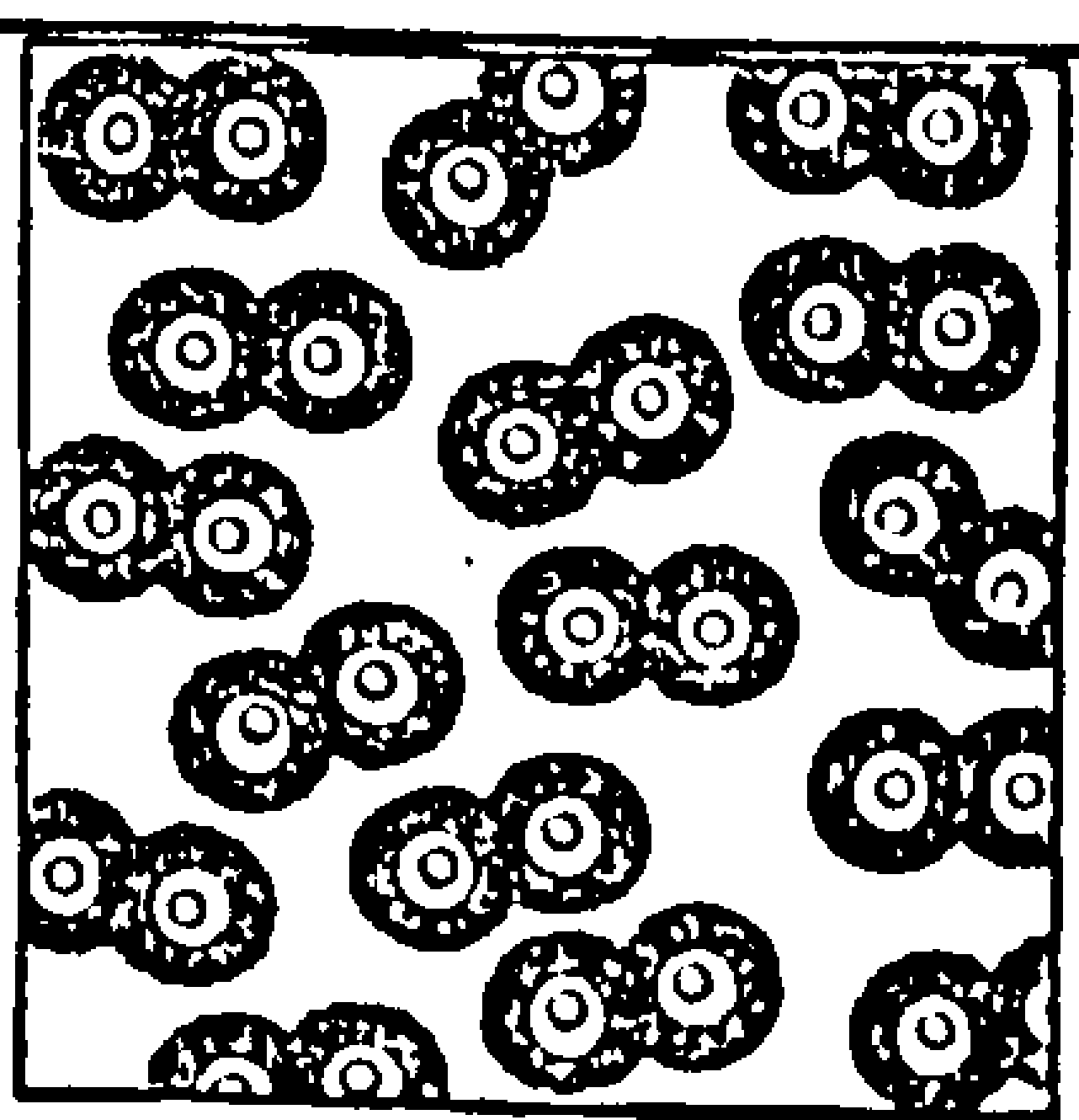
fluorine molecule

7.



sodium nitrate solution

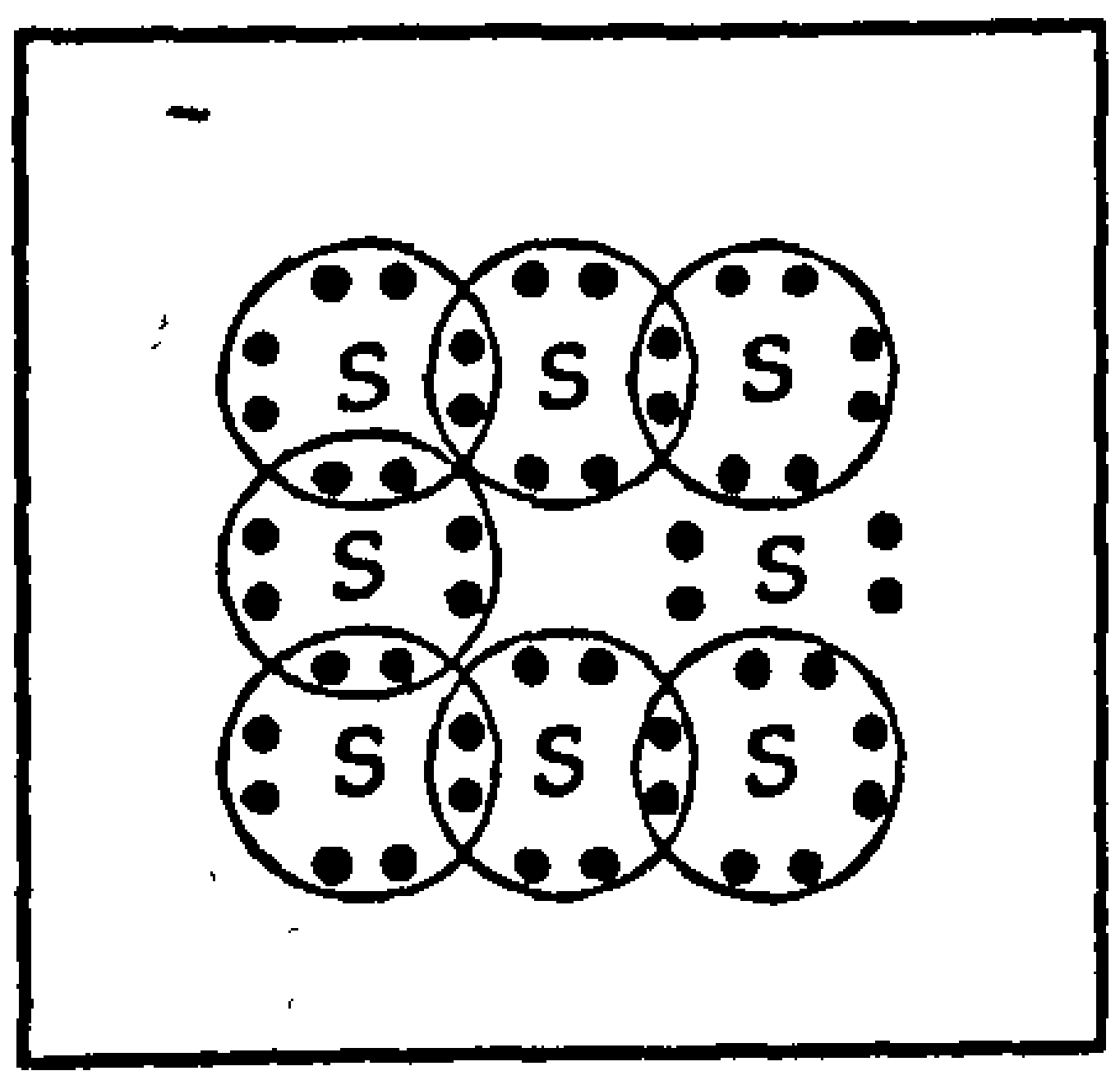
8.



liquid oxygen

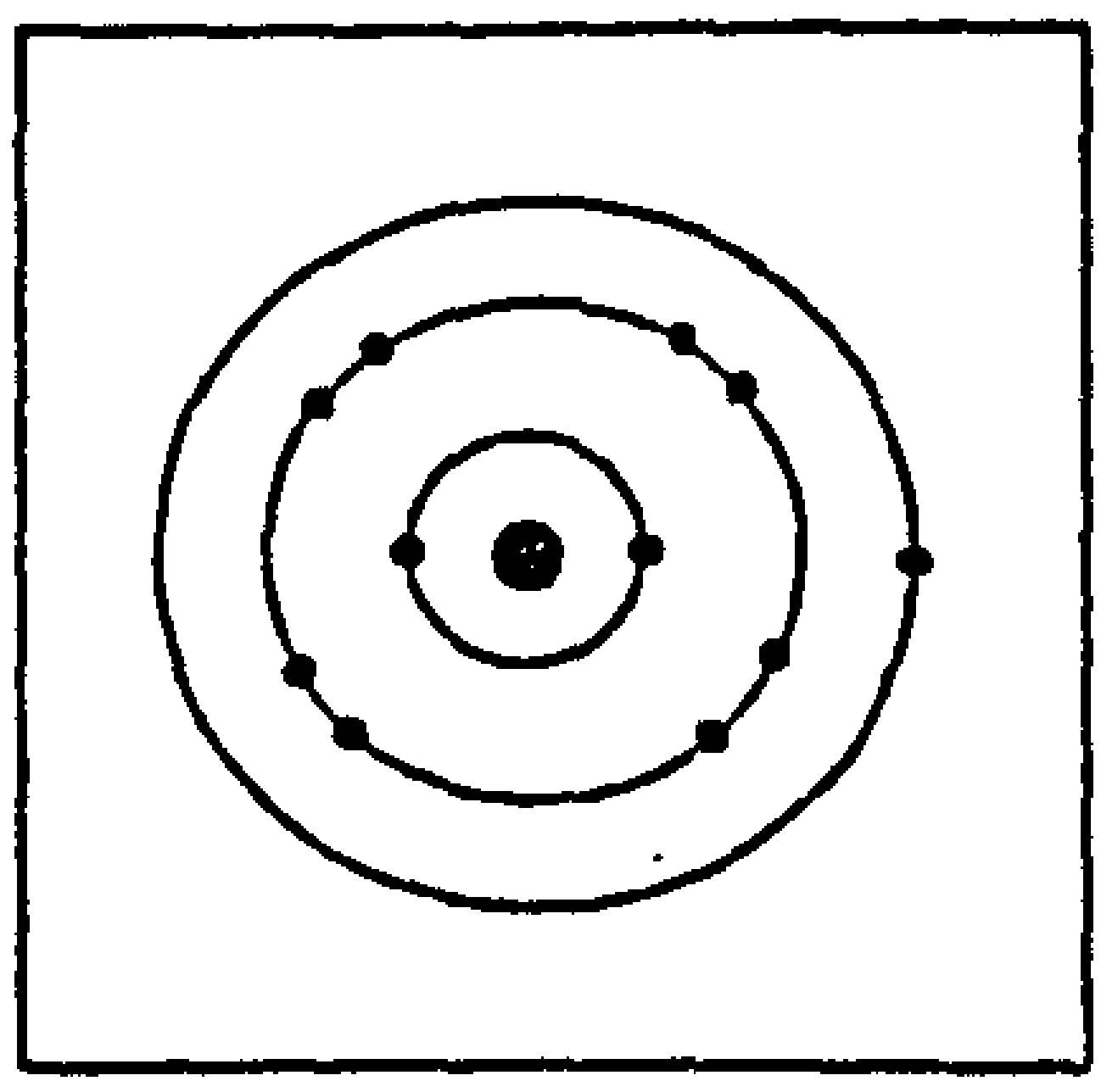
9.

Spot the bonding



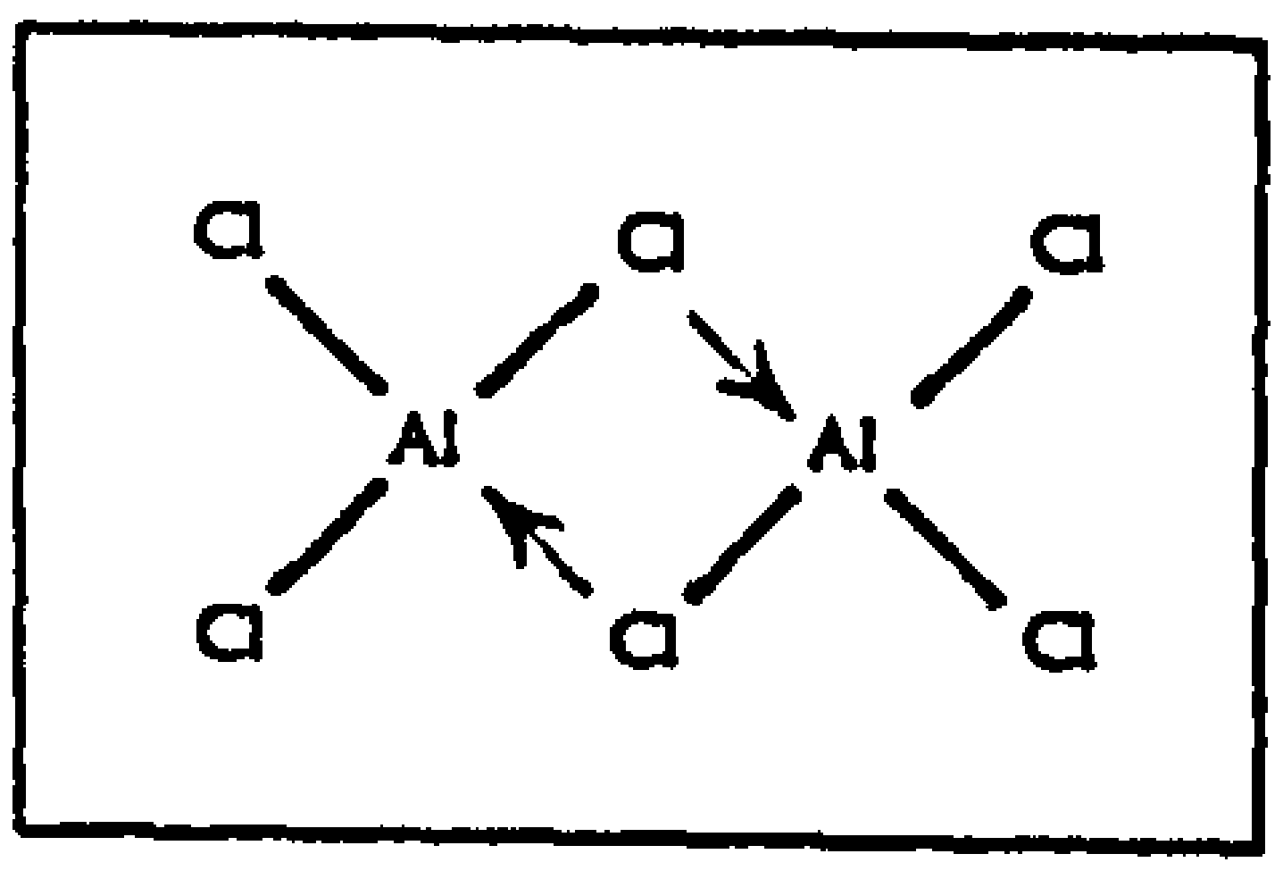
sulphur molecule

10.



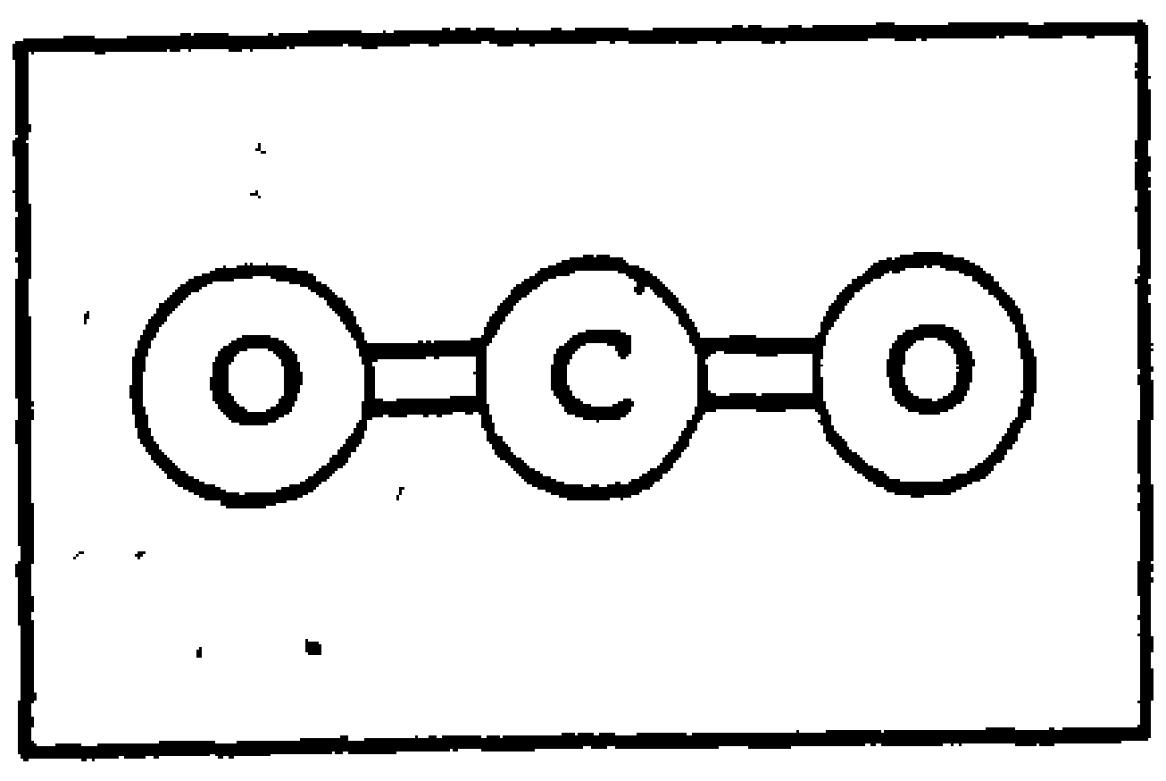
sodium atom

11.



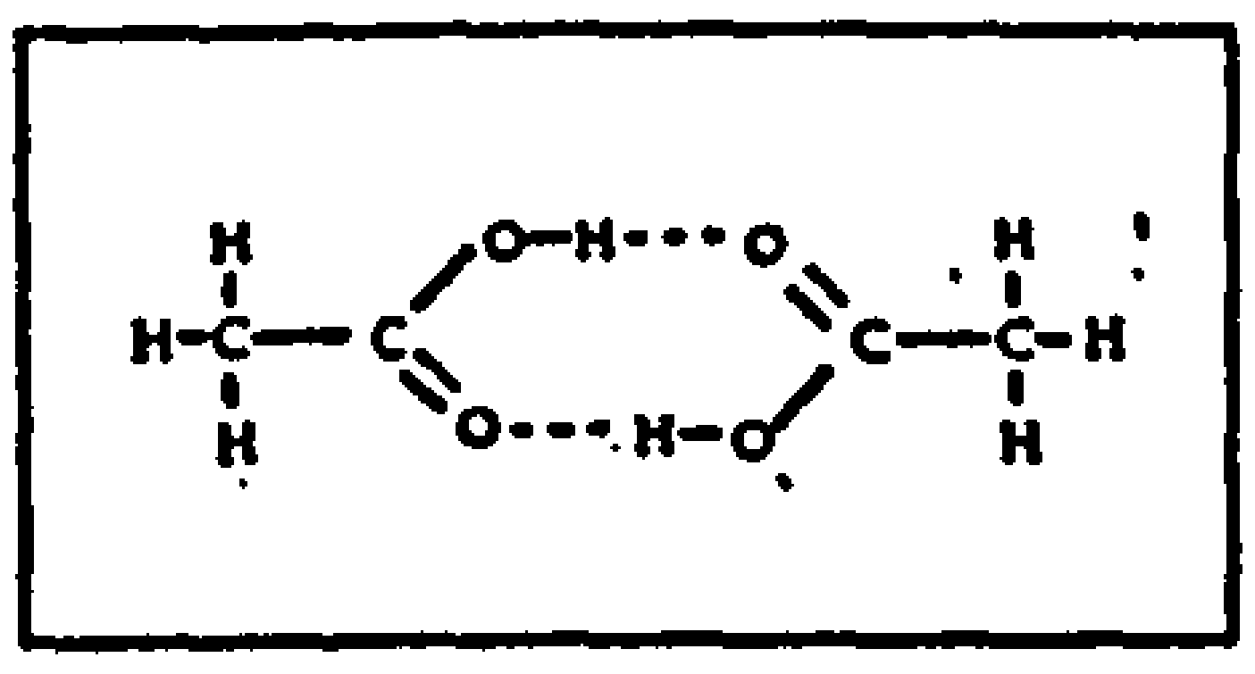
aluminium chloride dimer

12.



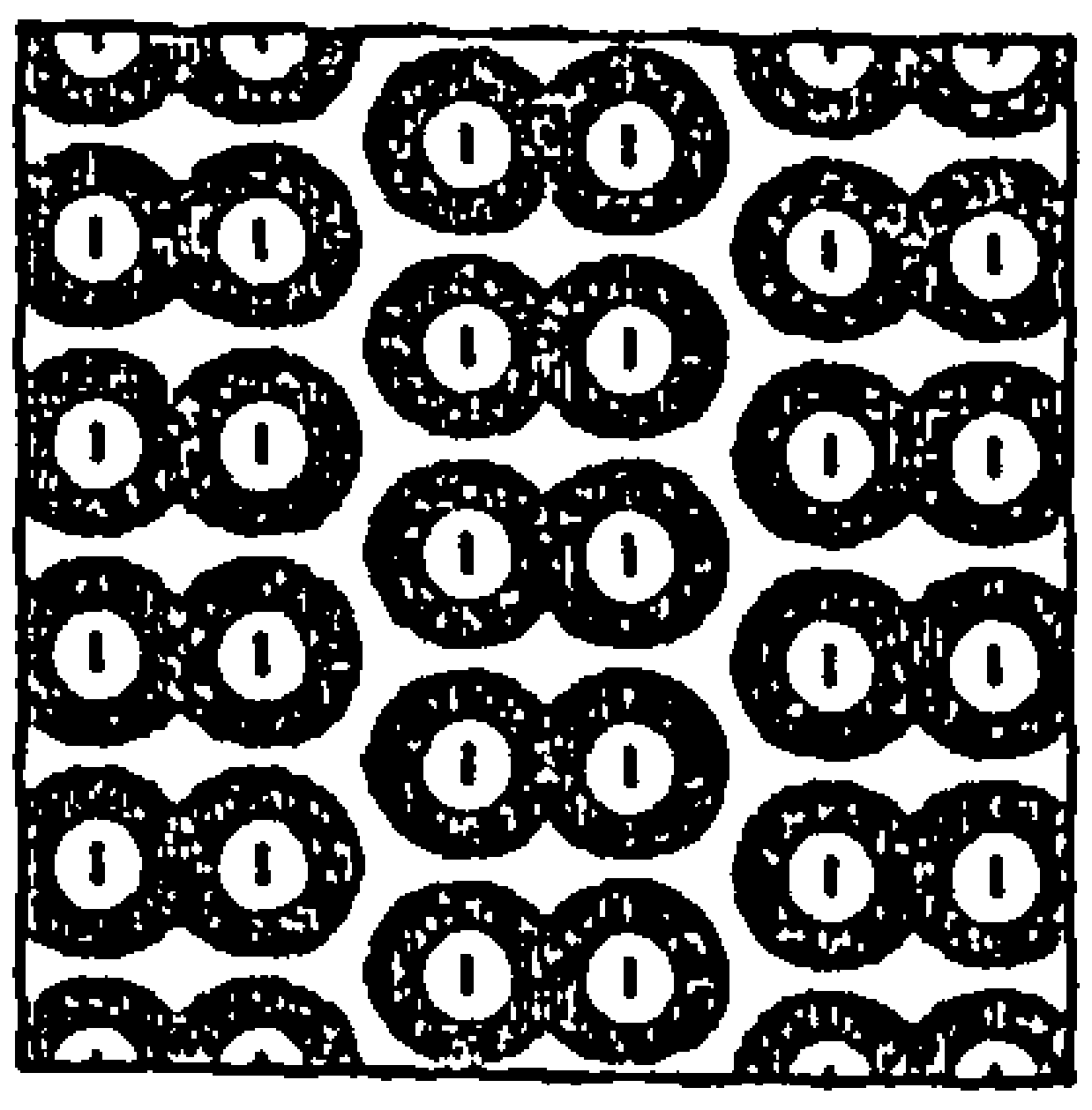
carbon dioxide molecule

13.



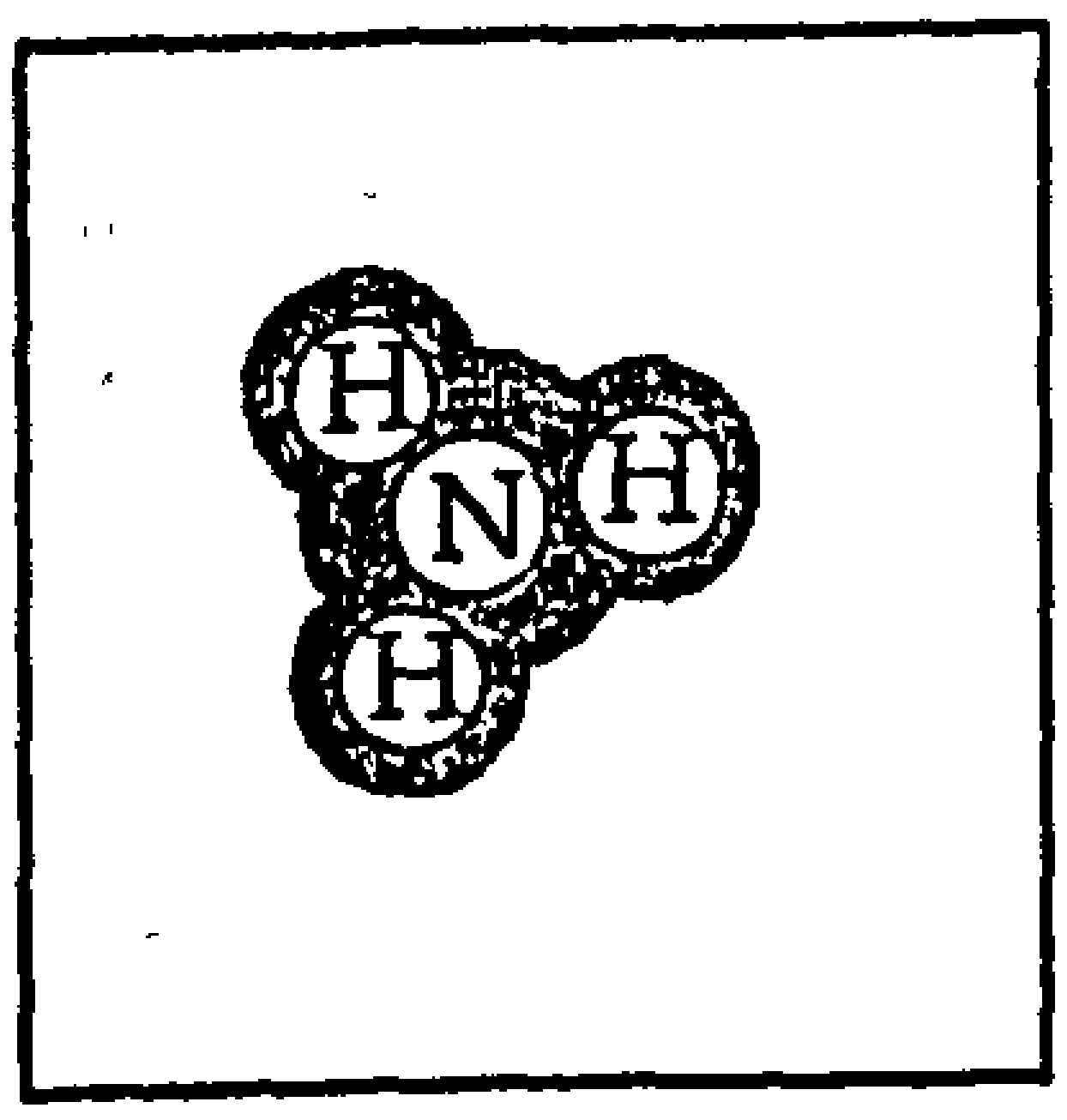
ethanoic acid dimer

14.



iodine lattice

15.

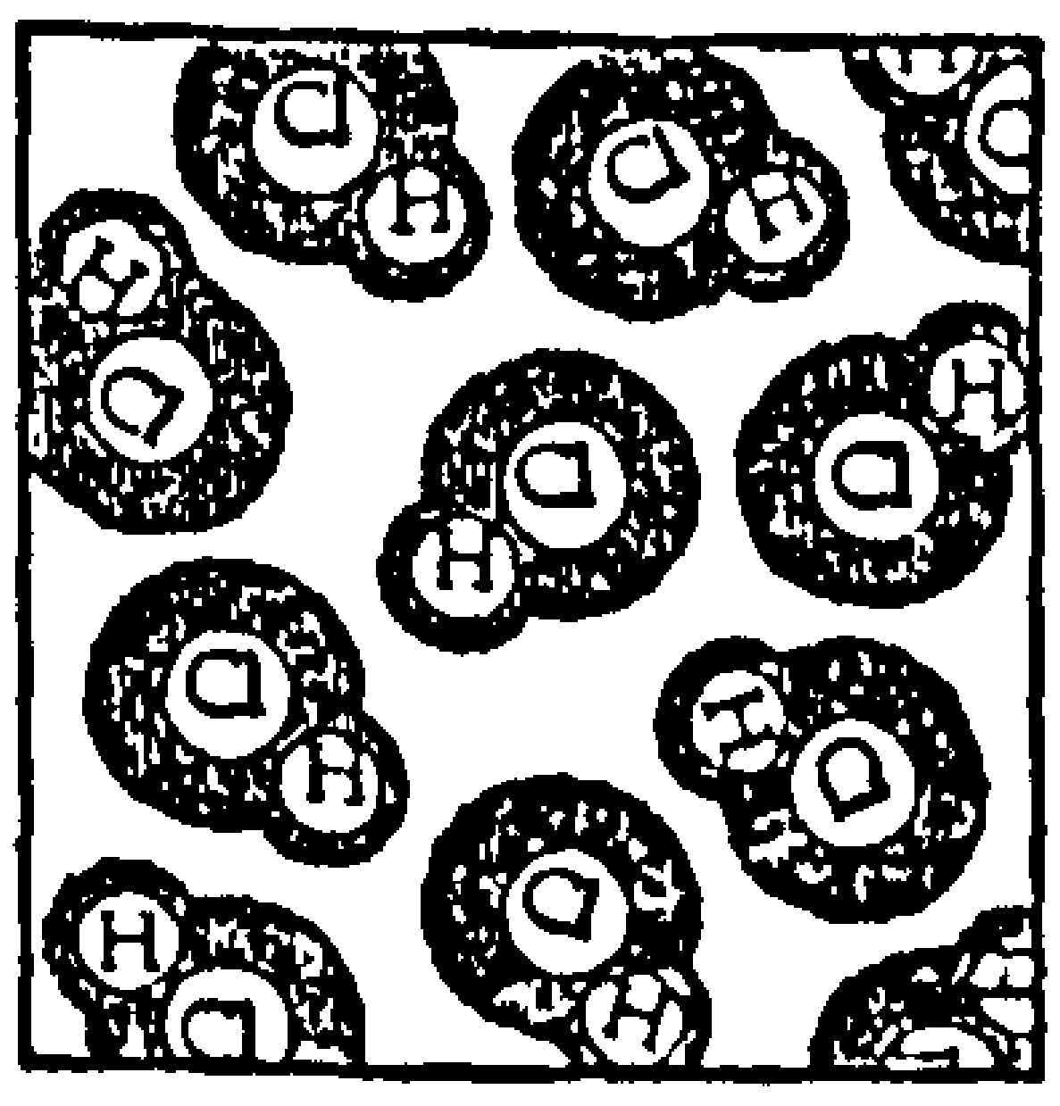


ammonia molecule

16.

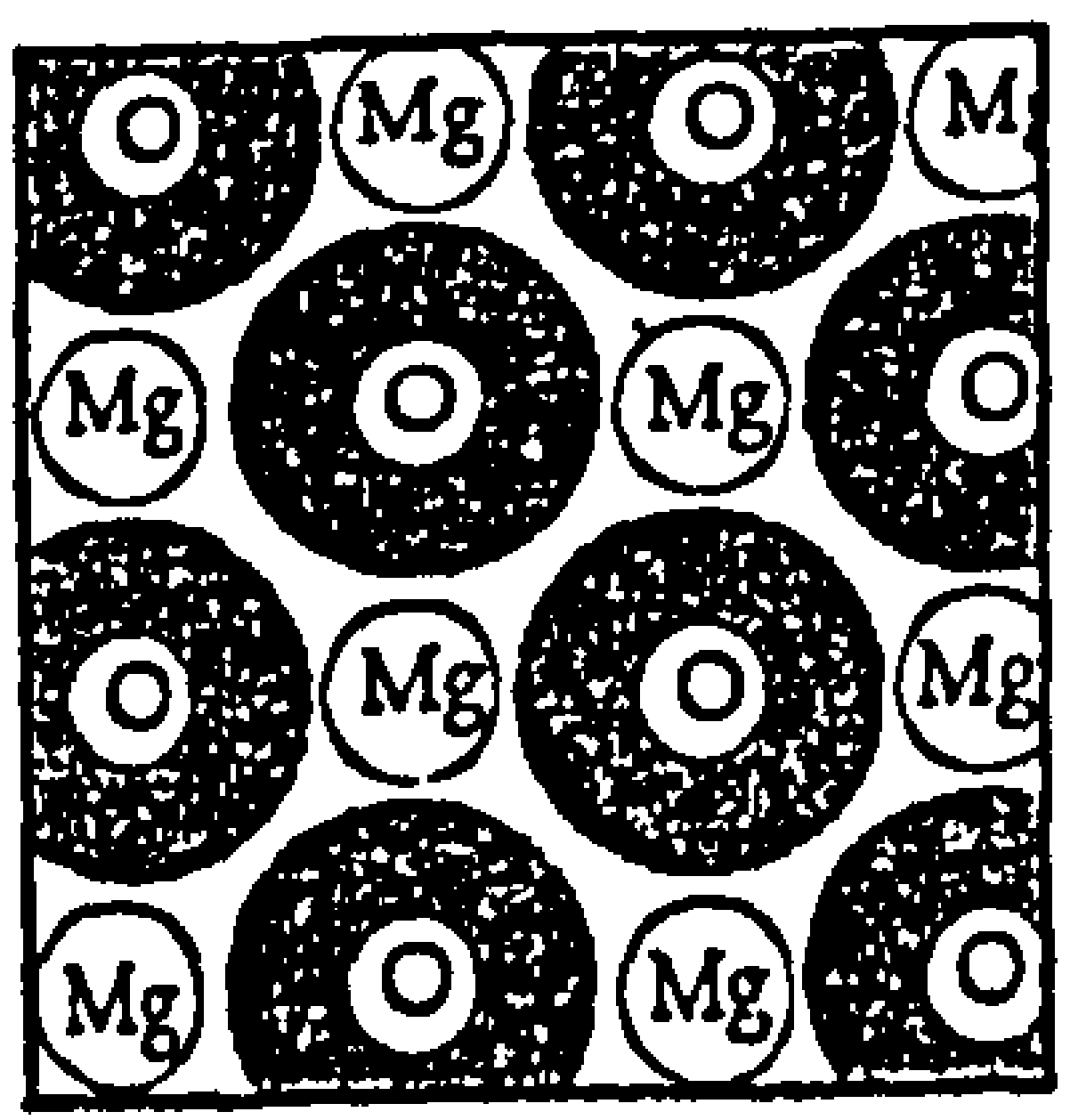
magnesium oxide lattice

17.



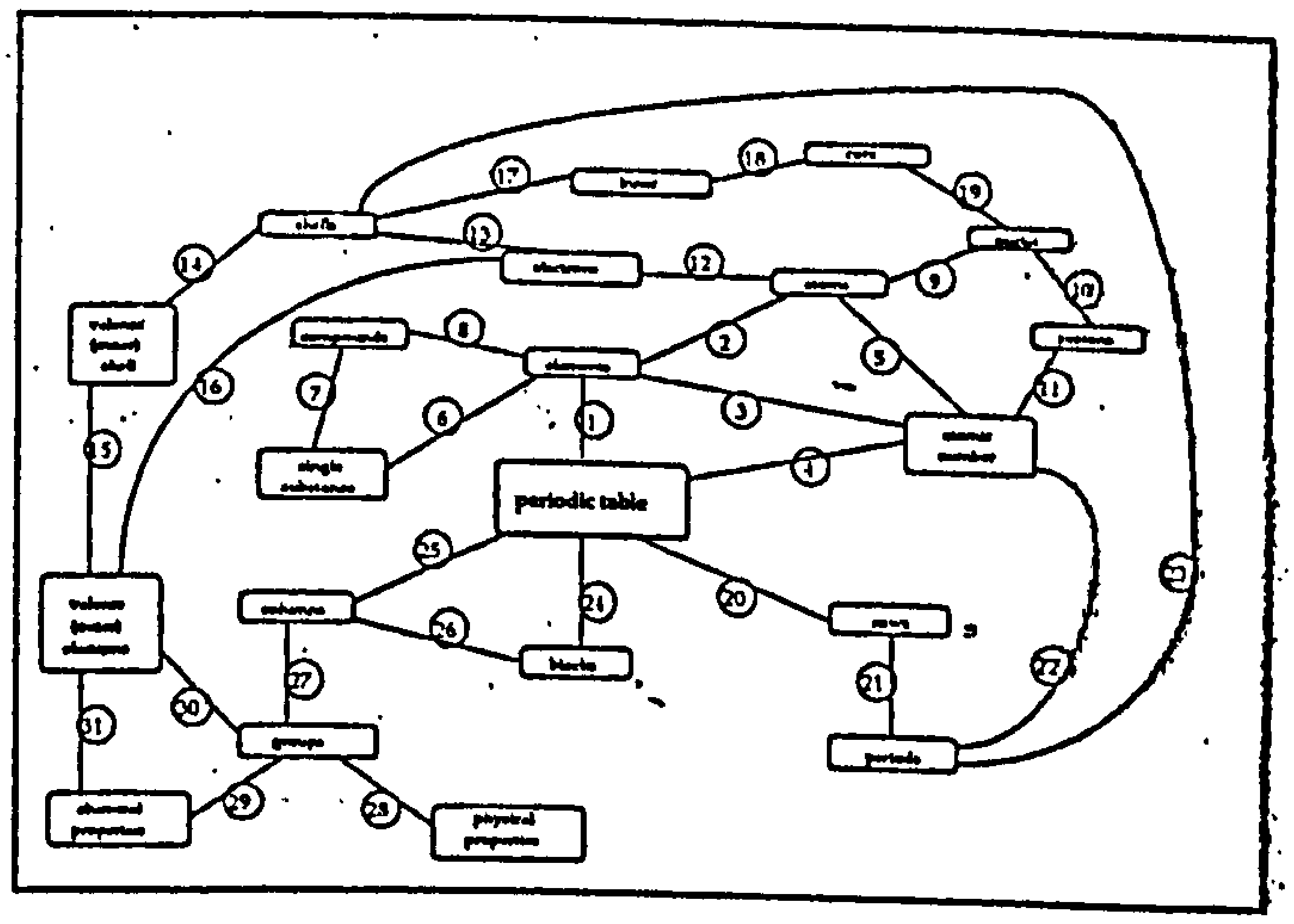
liquid hydrogen chloride

18.



The periodic table

You have been given a copy of a revision 'map' for the topic of the periodic table. The map is a diagram with boxes labelled with some words we use in chemistry, joined by numbered lines. Each of the lines suggests a relationship which could be described in a sentence.



You are asked to think up sentences to show how the different words in the boxes are related. Try and be as accurate and precise as you can. Make sure you put each sentence next to the correct number in the spaces below. *One of the sentences has been suggested for you, to get you started.*

Fill in as many of the spaces as you can, but do not worry if you can not complete them all.

1

2

3

4

5

6 An element is a single chemical substance.

7

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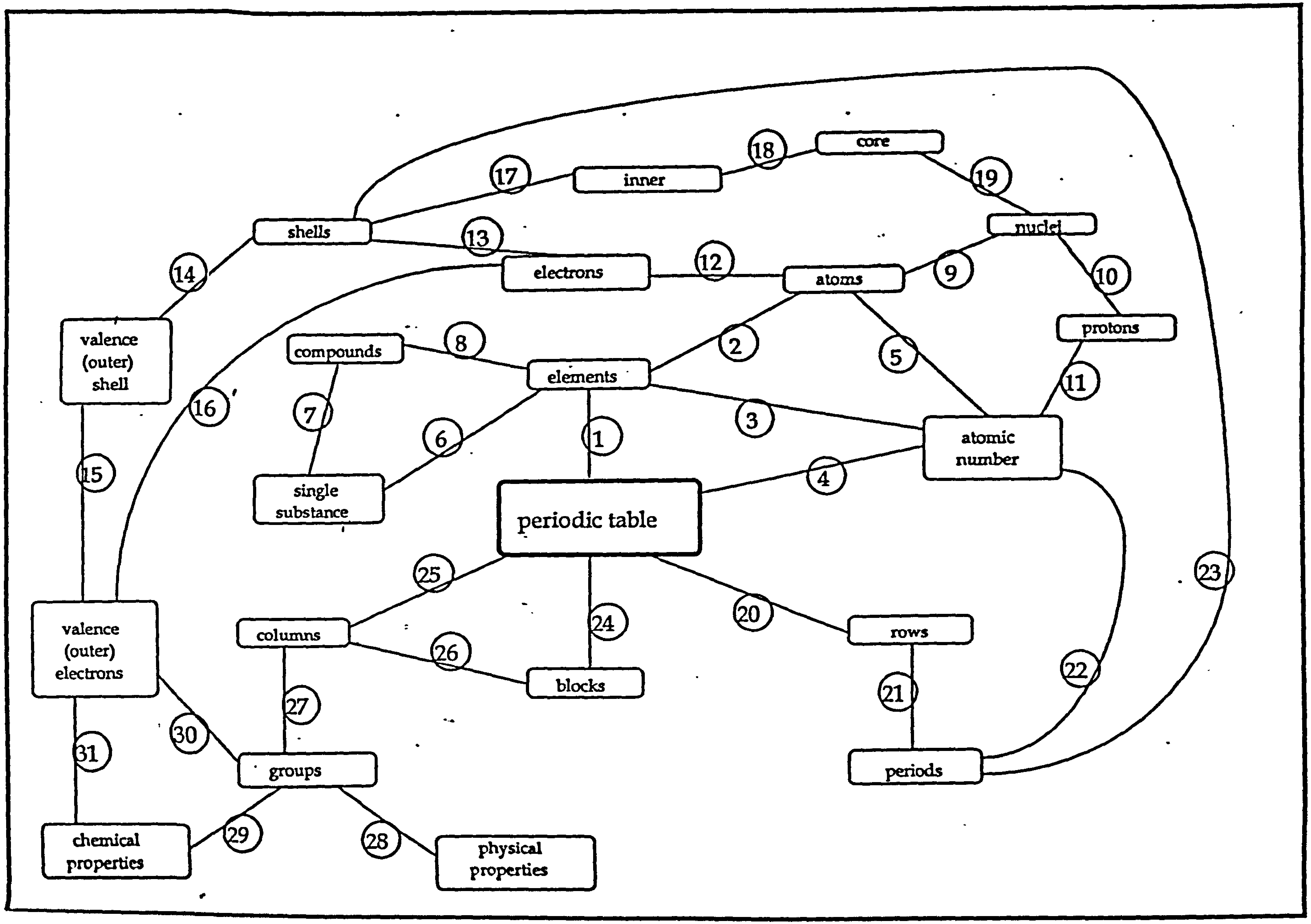
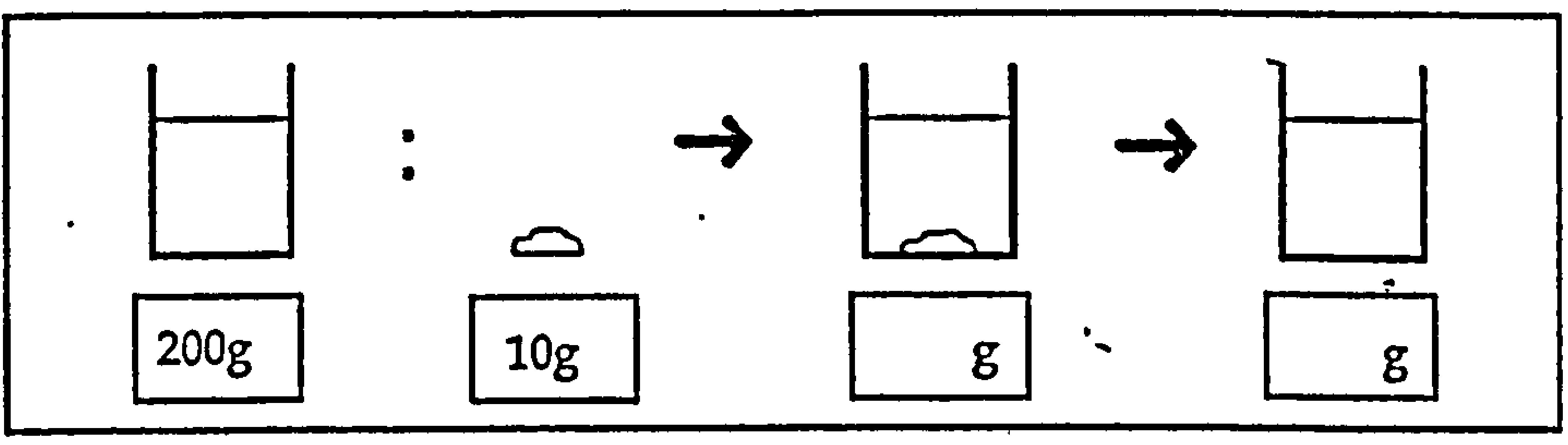
Revision map for the periodic table



Mass and dissolving

This exercise is about what happens when solids dissolve in liquids.

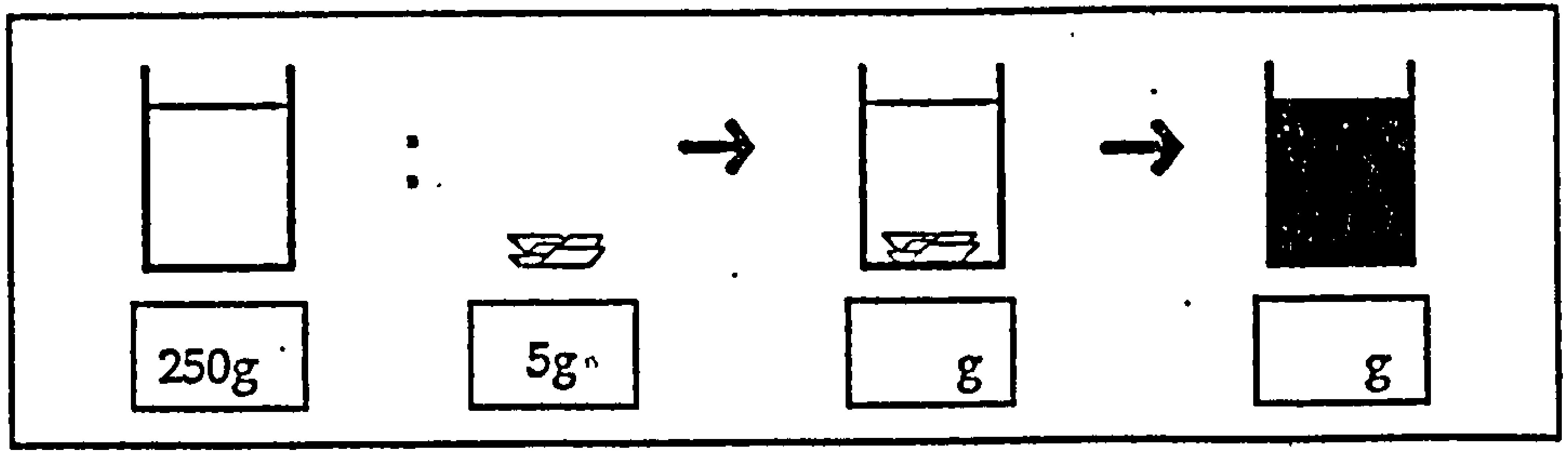
1. Sugar and water. Some water was placed in a beaker, and its mass was measured using a balance. The mass of beaker and water was 200g. Then 10g of *sugar* was weighed out. The sugar was added to the water, and sank to the bottom. 10 minutes later the sugar could not be seen.



Fill in the boxes to show what you think the mass of the beaker and its contents would be when the sugar was first added, and then after it could no longer be seen.

Where did the sugar go?

2. Copper sulfate and water. Some water was placed in a beaker, and its mass was measured using a balance. The mass of beaker and water was 250g. Then 5g of blue crystals of *copper sulfate* was weighed out. The copper sulfate was added to the water, and sank to the bottom. 20 minutes later the copper sulfate could not be seen, but the liquid had turned blue.



Fill in the boxes to show what you think the mass of the beaker and its contents would be when the copper sulfate was first added, and when it could no longer be seen.

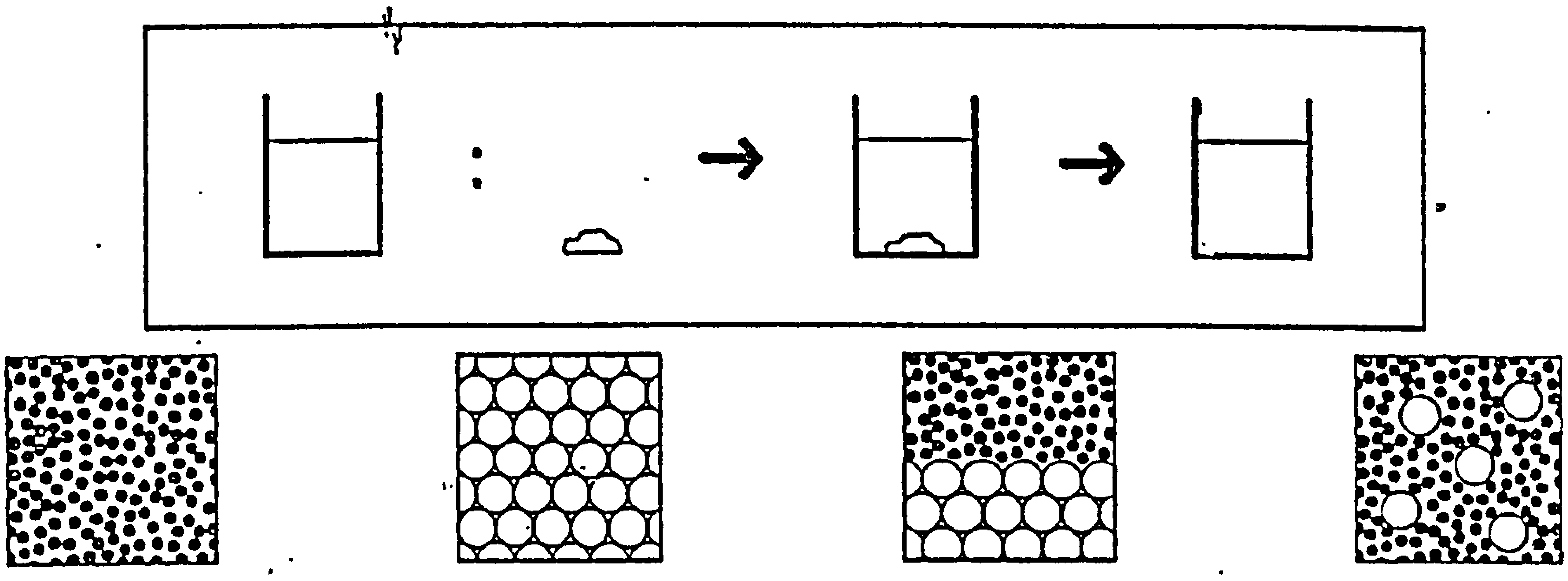
Why did the water turn blue?

Where did the copper sulfate go?

name:

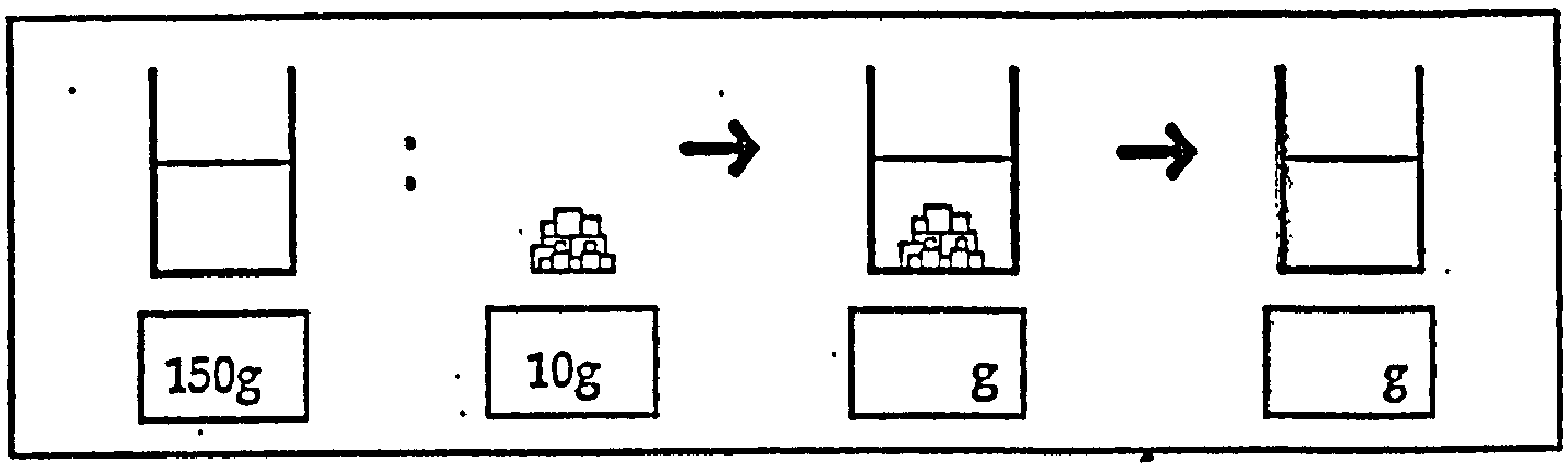
Mass and dissolving

3. Particles in sugar and water. The diagrams below show the particles present at the different stages when sugar is dissolved in water.



Why does the liquid taste sweet when sugar is added to water?

4. Salt and water. Some water was placed in a beaker, and its mass was measured using a balance. The mass of beaker and water was 150g. Then 10g of *salt* was weighed out. The salt was added to the water, and sank to the bottom. 10 minutes later the salt could not be seen.



Fill in the boxes to show what you think the mass of the beaker and its contents would be when the salt was first added, and then after the salt could no longer be seen.

Where did the salt go?

name:

elements, compounds or mixtures? (1)

In science, it is important to know the difference between elements, compounds, and mixtures. Try to explain what you think each of these words means:

An element is ______________________________

____

____

____

A compound is ______________________________

____

____

____

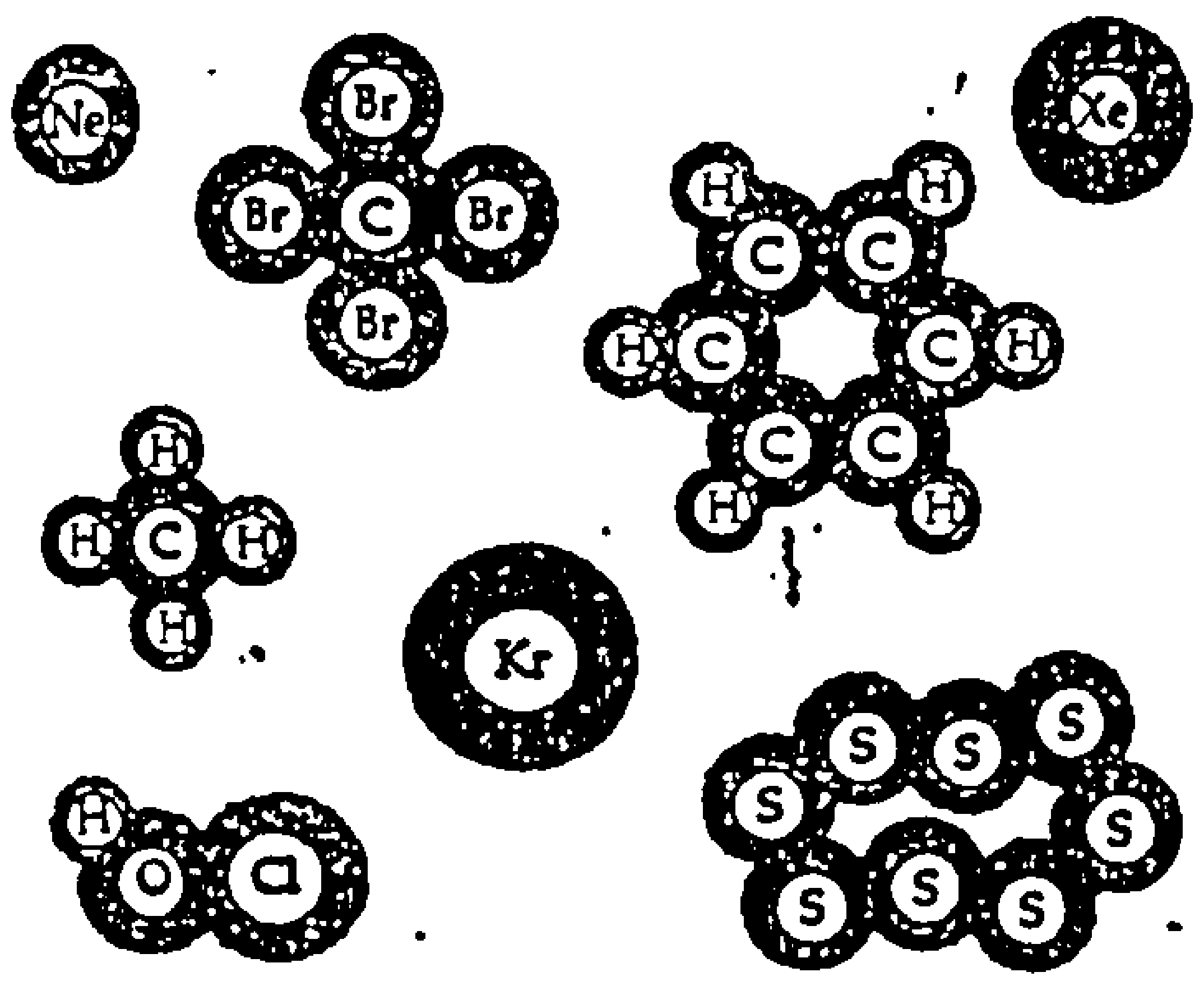
A mixture is ______________________________

____

____

____

On the second sheet you will find six diagrams showing the particles in some samples of materials. The different particles are shown as:

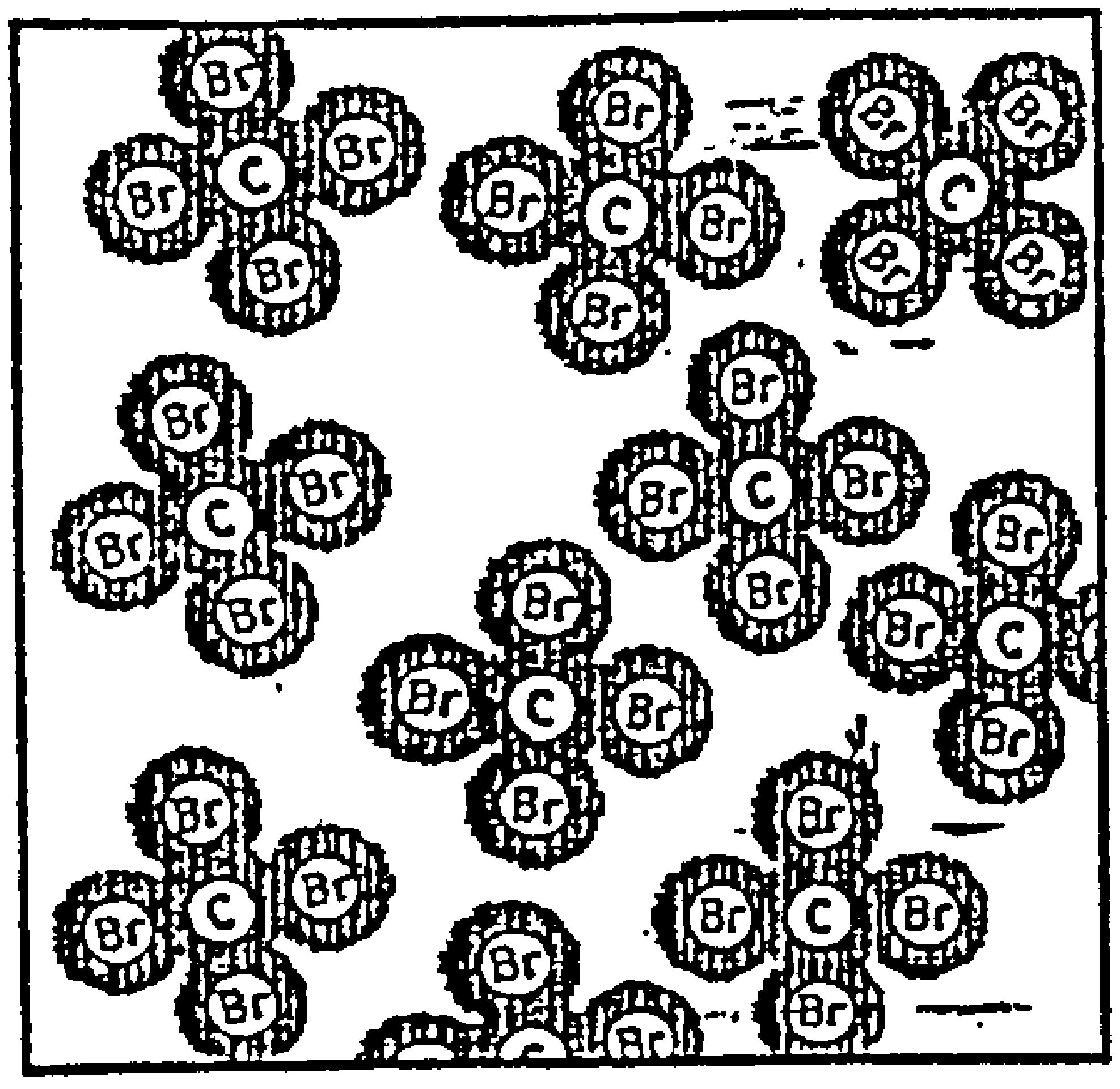


Each diagram is meant to show either an element, a compound or a mixture.

Decide whether each diagram on the other sheet represents an **element**, a compound, or a **mixture**, and try to explain your reasons.

name: ______________________________ class:

elements, compounds or mixtures? (1)



This diagram shows particles in:

____

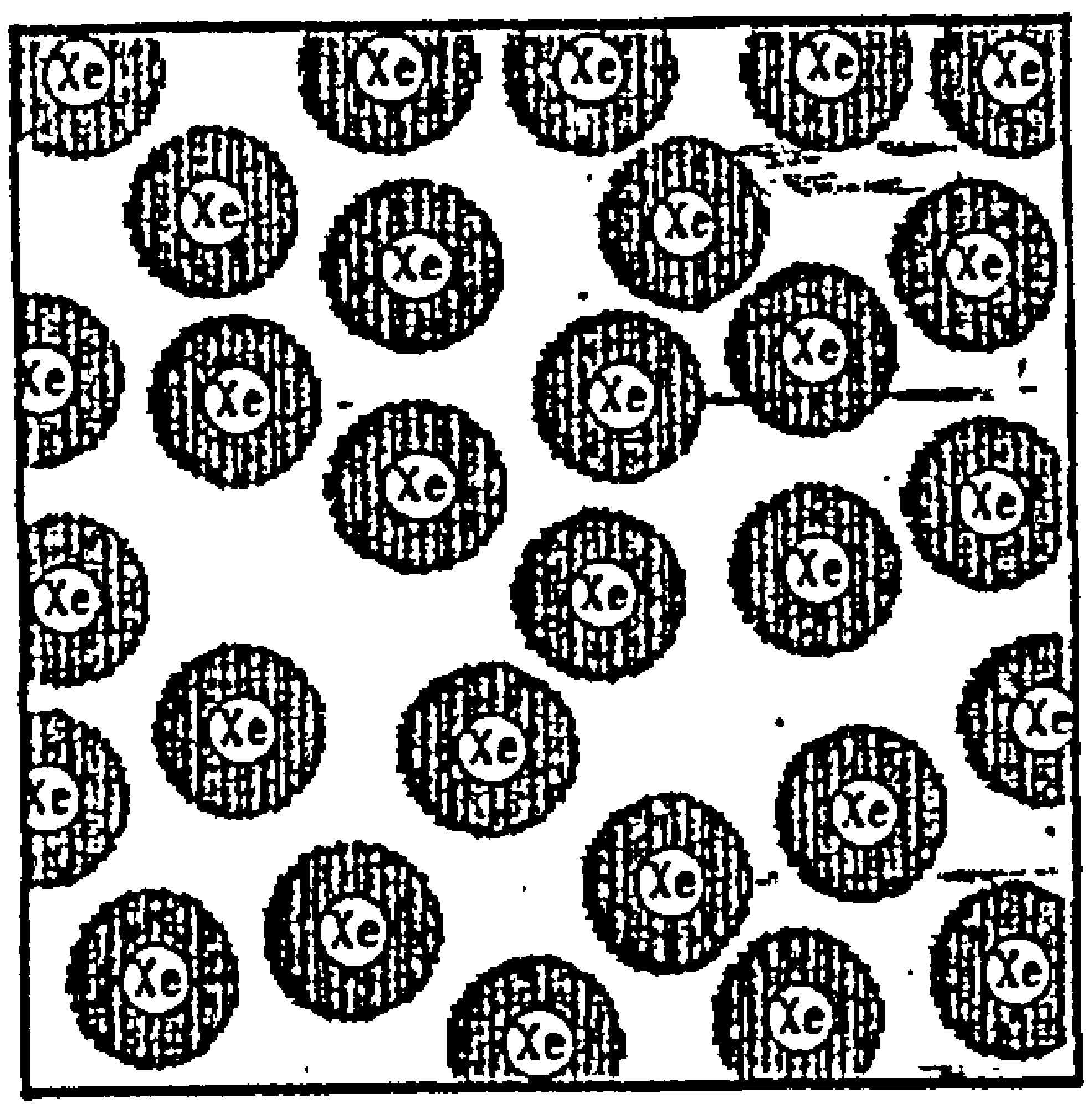
I think this because:

____

____

____

____



This diagram shows particles in:

____

I think this because:

____

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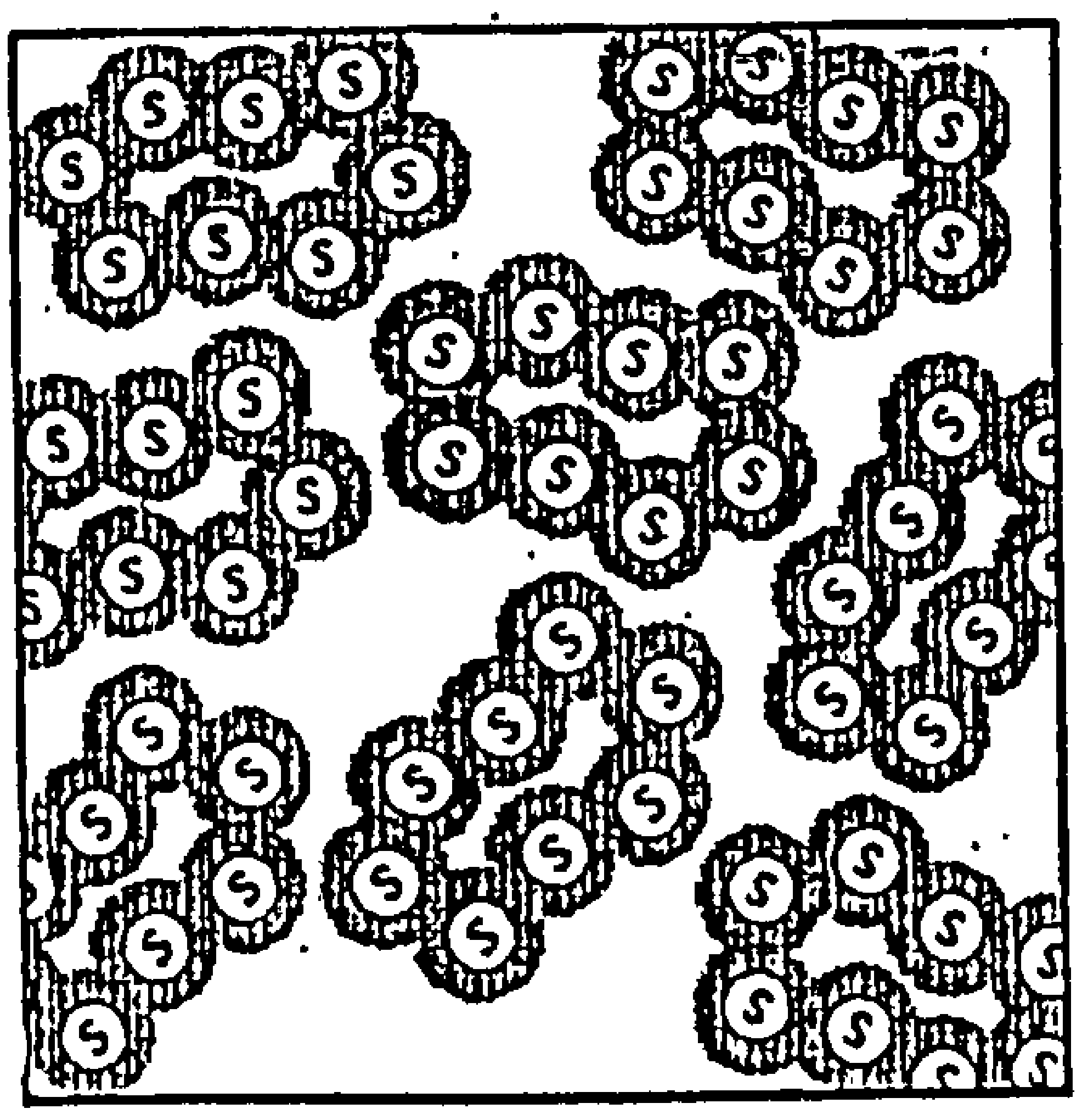


now please turn over

This diagram shows particles in:

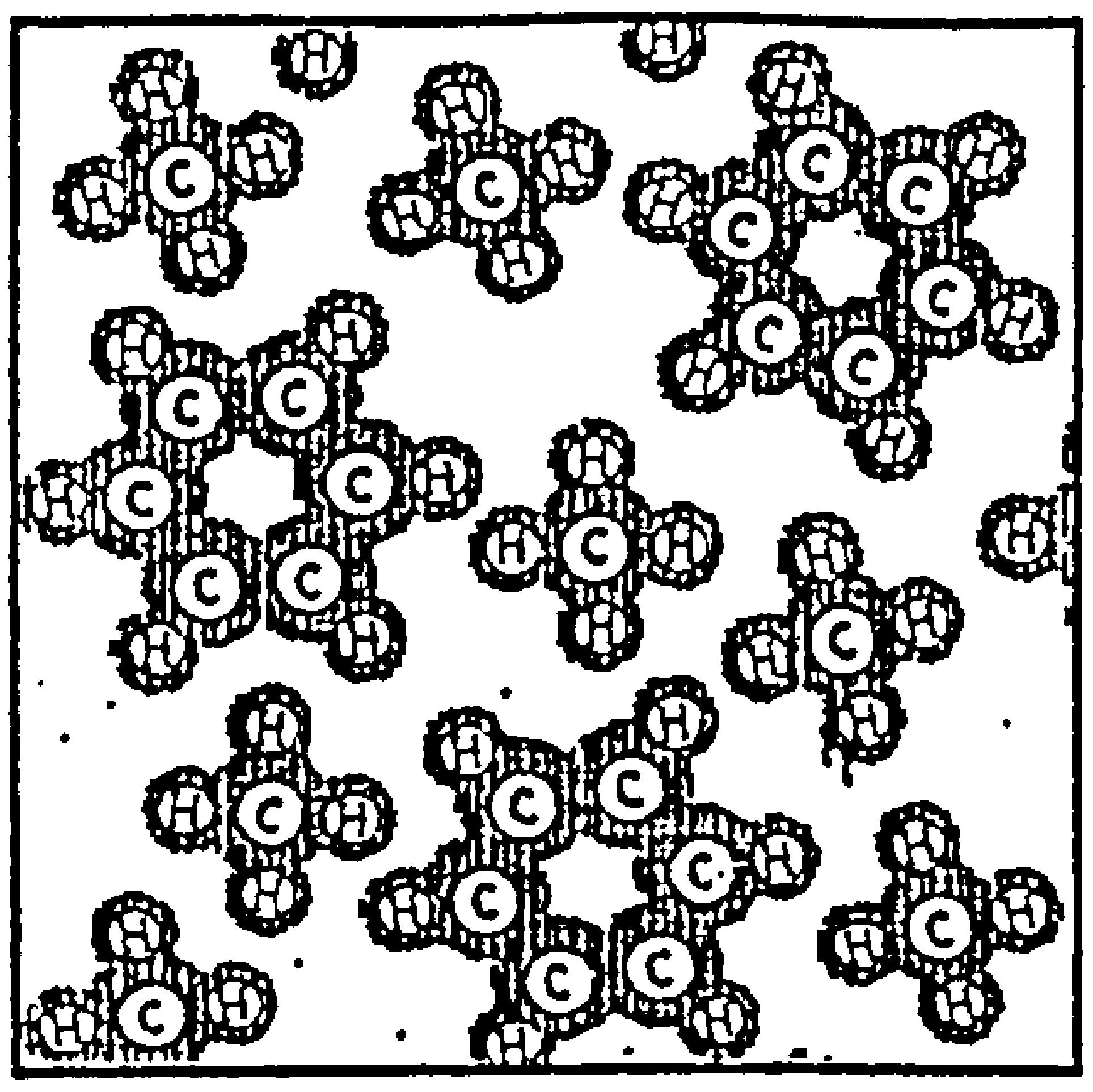
____

I think this because:

____

name: ______________________________ class:

elements, compounds or mixtures? (1)



This diagram shows particles in:

____

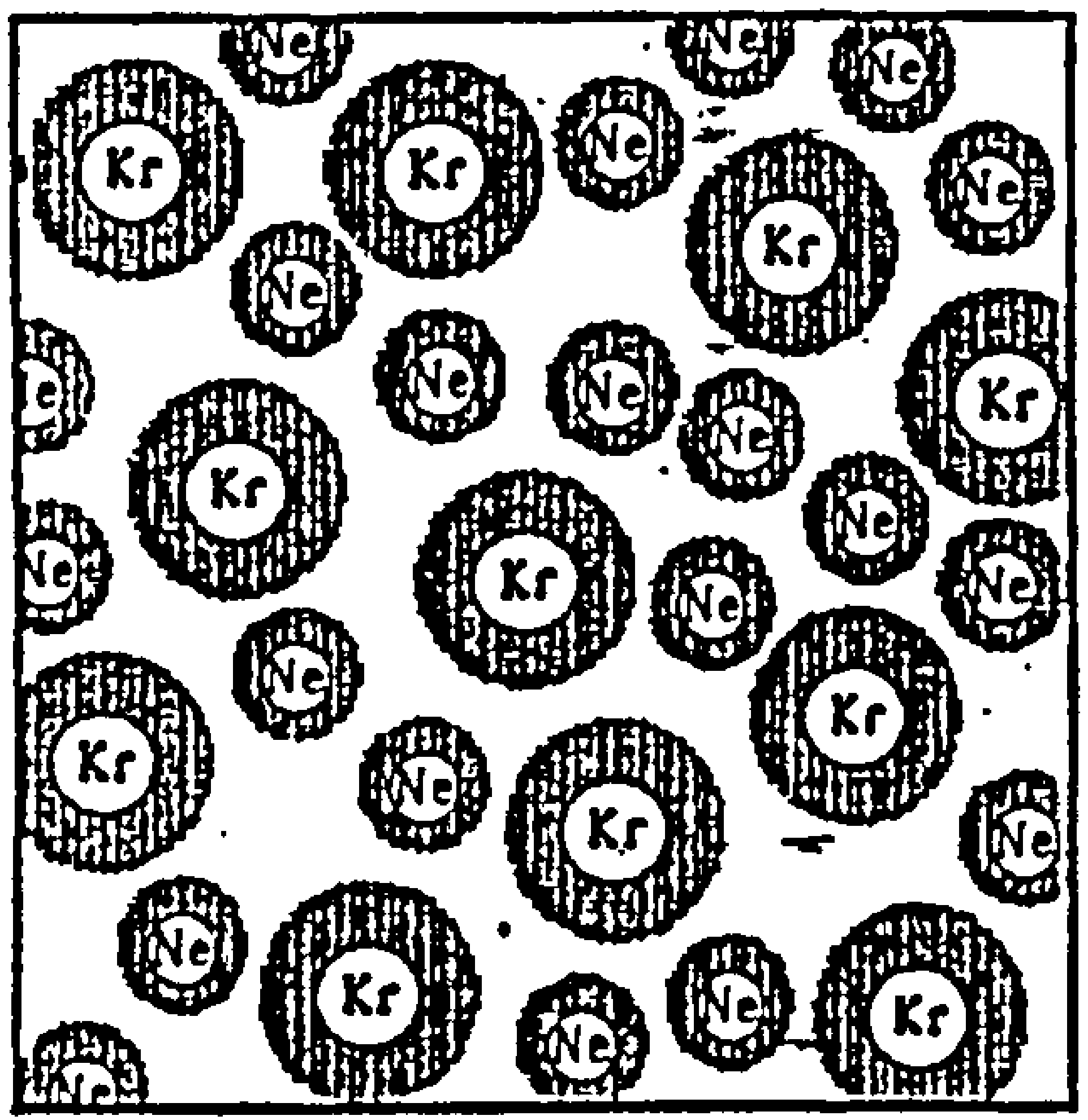
I think this because:

____

____

____

____



This diagram shows particles in:

____

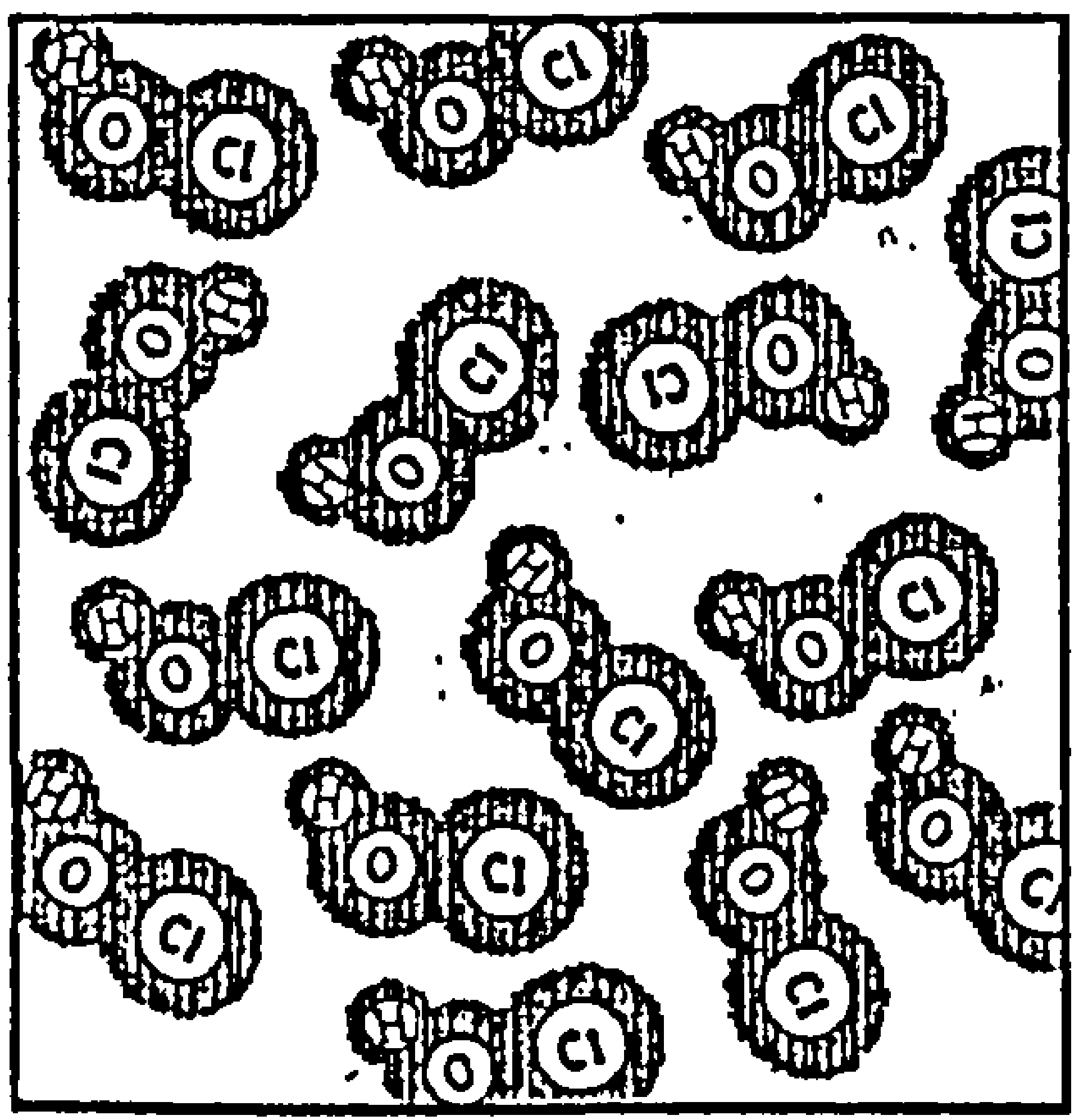
I think this because:

____

____

____

____



This diagram shows particles in:

____

I think this because:

____

____

____

____

name: ______________________________ class:

Appendix XVI Example of extract of observation data
Record of lesson observed

Code: BL/V/07 Date: 11/1/'01

Student: Marie School: School F

Time (mins)	*Video record*	*Notes from observation*
1	Pupils arrive, settle down.	
2		
3		
4	Recap on previous lesson dealing with matter.	Teacher talks. Points out examples of matter around room.
5		
6	Recap on concept of atom and terms proton, neutron, electron.	Asks questions of class. Good response to questions about orbit and shell.
7		
8	Teacher tells class that structure of atom going to be discussed today.	Asks for volunteers, three girls, label on each – proton, neutron and electron. Two girls together, one moving around outside.
9		
10		
11	Tells class that over 100 different types of atoms. An element is where only one type of atom. Various examples of elements discussed.	Teacher exposition followed by showing aluminium kitchen foil to class. Also shows can of *Coke*, a tin can, a thermometer and matches to class. Refers to sodium street lamps.
12		
13		
14		
15	All elements have different structures and are listed in the Periodic Table.	Small Periodic Table pinned to blackboard. Symbols pointed out. Poster of some chemical symbols also pinned to blackboard.
16		
17	Origin of symbols explained.	

18	Teacher tells class we are now going to learn how to draw what an atom of an element looks like	Tells class to take out a ruler, tells them that atoms are 1 million times smaller than 1 mm on ruler.
19		
20	Tells pupils that scientists have discovered what an atom looks like.	Teacher exposition. Puts poster of nuclear formula of helium on blackboard. Refers to helium in balloon made up of atoms.
21		
22		
23	To draw an atom you need to know how many protons, neutrons and electrons it has.	Points to nuclear formula, top number called atomic number. Writes “2 protons” on board. The 4 is the mass number. Writes “no of protons + no of neutrons” on board.
24		
25	Emphasises need to subtract atomic number from mass number to find the number of neutrons.	
26	Tells class how to find number of electrons.	Writes “2 electrons” on board.
27	Asks class “What element would you like to know the structure of?”	No response from class.
28	Takes carbon as an example.	Writes nuclear formula of carbon on board. Asks questions about significance of each number. Good response. No questions.
29		
30		
31	Tells class to attempt questions in worksheet on atomic structure of elements.	Gives out worksheet. Corrects mistake in worksheet. Pupils work at filling in blanks. Teacher walks around room giving assistance.
32		
33		
34		
35	Calls class to attention. Tells class now going to recap on lesson.	Asks for definition of element. Asks for examples of elements, meaning of nuclear formula, how to calculate number of neutrons, etc. In general, good response from class.
36		
37		
38		
39	Tells class to open up text books.	Points out pages to be studied. Tells class to underline certain key points and learn these points.
40	Bell sounds. End of class.	

Appendix XVII Extract of framework used in analysis of baseline data

The factors that influence decisions student teachers make about what to do in science lessons (baseline data)

Factor	*As exemplified by ...*	*Evidence from baseline questionnaire data N = 24*	*Evidence from baseline observation data N = 12*	*Evidence from baseline interview data N = 12*	*Evidence from baseline lesson plans data N = 12*
3. View of teaching.	Nature of presentation Classroom climate Links to everyday life	AV aids (50%) Vary teaching methods (50%) Vary topic (42%) Projects (33%) Group work (25%) Role play (9.7%) Teacher enthusiasm (33%) Encourage pupil opinion (50%) Strict but fair discipline (25%) Learning should be fun (16.7%) Give everyday examples (83%)	AV aids used (83%) 91.67% use limited teaching methods. Simulations and models (16.6%) Analogies (25%) No discipline problems observed in most classes (91.67%). Encourage pupil opinion (8.3%) Used everyday examples in teaching (66.6%)	AV aids and artefacts (66.7%) Resources – textbook reliance (100%) Simulations and models (16.6%) Terminology problem (66.7%) Importance of good teaching strategies (33.3%) Concern with discipline not major (33.3%) Importance of everyday examples stressed (66.6%)	AV aids (83.3%) Limited teaching strategies (83.3%). Simulations and models (16.6%) All reflections on lessons show general satisfaction with classroom climate. Everyday examples used (66.6%)

Note: Percentages are used to enable ease of comparison but note the small sample size.

Appendix XVIII Extract from Baseline Interview Data

View of Teaching: Nature of Presentation (Audio Visual Aids)

TEXT: Baseline Data. Áine.txt (35/42)
CODE: Nature presentation - AV aids (G:100)
At the beginning of the lesson, I see that you used flash cards, why did you use those?

I find that when writing on the blackboard it works well for me but at other times you can put things everywhere. I used flash cards so that it was neat and concise and they can read it. It keeps the amount of written material to a minimum.

TEXT: Baseline Data. Gerard.txt (117/120)
CODE: Nature presentation - AV aids (G:100)
I tried to make the overhead transparencies as clear as possible, not make the language too complicated and to include some pictures in the transparencies.

TEXT: Baseline Data. Majella.txt (94/101)
CODE: Nature presentation - AV aids (G:100)
Maybe as well the arrangement of the particles, that could be hard enough as well so I brought in the visual examples of the plastic model plasticine and things like that, how they're arranged and when you're heating them, they move apart and I was trying to bring in that in the classroom that they're stuck together , they're sitting down and then they get up, they're moving around and they're more like a gas, things like that.

TEXT: Baseline Data. Margaret.txt (111/112)
CODE: Nature presentation - AV aids (G:100)
We had these cards on the board and we put the different things under the different headings.

TEXT: Baseline Data. Maura.txt (110/114)
CODE: Nature presentation - AV aids (G:100)
I think if you've got as much visual content as possible instead of just saying, "This is the way it is and deal with it", I had the polystyrene model for the solids, liquids and gases and they could see the whole idea of the space between the particles and stuff.

TEXT: Baseline Data. Susan.txt (74/78)
CODE: Nature presentation - AV aids (G:100)
I had a poster with one big example on it and I said we'd refer to that one all the time and I had the flashcards to highlight and help them focus on the new words and I hoped that the two of those would gel together and make it fall into place.

TEXT: Baseline Data. Sadie.txt (82/87)
CODE: Nature presentation - AV aids (G:100)
I was delighted with all the props I had collected to bring in. I thought that was good and they were real-life examples and I think atoms are a very difficult thing to explain and to pin down and I was trying to show how useful they were which was a hard thing to do. I thought that was good.

Appendix XIX: Sample data obtained from baseline questionnaire asking student teachers what they think teachers need to do to bring about effective learning in science.

Genevieve, Judith

1) Better knowledge of experimental procedures and easier methods of doing the different experiments to create effective learning.
2) Relating science to everyday life to generate more interest.
3) Student teachers should be given a crash course on the science syllabus and the experiments before entering the classroom.
4) Students may become more enthusiastic about practical work and write-ups if they were examined. In turn more experiments would be carried out instead of theory.
5) Students asked to do more projects through teaching with the aid of the Internet. Teachers should be given computer courses.
6) Teachers should explain difficult science words in simple language. No student should have the perception that "science is difficult".
7) Different types of tests should be given as opposed to strictly written examinations.

Eamonn, Tom

1) Increased use of visual aids, in order to abstain from over talking/monologue.
2) With regards to mixed ability teaching, remember to pace the lesson allowing for the weaker students to keep in contact with the stronger ones.
3) Demonstration of experiments, other than those on the syllabus to teach specific topics, e.g. Velocity/acceleration use trolleys etc.
4) Class participation with regards to experiments, and avoid over demonstration, as students love to participate in the experiments (where possible).
5) Relating science to real life, where the pupils can associate with it.
6) Be prepared – don't allow yourself become over dependent on the text!

Liz, Maura, Brian

1) Get class involved in experiments as much as possible. Allow use of equipment.
2) Get students to bring in stuff, which they would be interested in talking about.
3) Class project.
4) School excursions (field trips).
5) Varied homework.
6) Group work.
7) Try to relate topics to everyday life.
8) Encourage students to put forward their opinions on a topic before you tell them about it.
9) Introduce a topic through its history.

Karen, Susan

1) Relate topic to everyday life. (Why they are learning the topic.)
2) Student input. (Students come up with ideas.)
3) Tell students exactly what you expect of them for whole year and even write-ups.
4) Use everyday props.
5) Get students into groups to do experiments themselves and help out those who don't understand.
6) Have variety in teaching styles. E.g. show video, slides, blackboard, worksheets etc.
7) Show enthusiasm yourself and this will motivate students.
8) Arouse students interest especially experiments by asking them what they would expect to happen.
9) Asking more experienced teachers for advice.

Eimear, Aileen

1) Relevant practical work.
2) Student involvement.
3) Start with simple ideas that can be related to by students (if possible).
4) Importance in everyday life.
5) Go slowly, step by step.
6) Create fun where possible.
7) Encourage student's views.

Bridget, Majella

1) Pupils undertake more practical work.
2) Demonstrations by the teacher to effectively demonstrate a definition not just simply theory.
3) More use of charts and videos. Get students to relate back on what they saw.
4) Active student participation i.e. mini role-plays.
5) Use everyday examples from world around us.
6) When beginning a new topic ask them what they know already on it.
7) Incorporation of general teacher enthusiasm into the topic.
8) Brief recapitulation at the beginning.
9) Use flow diagrams.
10) Project and presentation to the class.

Lisa, Paul

1) Experimental work, both demonstration and participation.
2) Summarise chapter in hardback copy.
3) Introduce topic by general conversation about everyday events that arise and are similar to the topic.
4) Word space or crossword type worksheet.
5) Use models where possible.
6) Vary teaching methods i.e. blackboard, O.H.P., CD-ROM's (interactive learning)
7) Rotation of topic at regular intervals or when students appear bored with a topic.

Appendix XX ***Example of chart used to help identify changes in post intervention data (relative to baseline data) and to compare lesson plan data with observation data (post-intervention data)***

Factor	*As exemplified by ...*	*Evidence from post intervention observation data N = 16*	*Lesson plan data*
3. View of teaching.	Nature of presentation Links to everyday life	AC used flash cards, OHP, CD ROM and Powerpoint. DC used OHP, flash cards, models , conceot cartoon and apparatus. MC OHP, flash cards, posters, apparatus. PC used OHP, flash card, poster. MD used OHP, data projector, CD ROMS, internet, apparatus, flash cards. PD used Concept Cartoon, flash cards, OHP, posters. KG – used concept cartoons, flash cards, posters, OHP. Ch Used concept cartoons, flash cards, posters, OHP. PK – Powerpoint, OHP, Periodic Table. SK – OHP, flash cards, practical demonstrations, GM – powerpoint, concept cartoon, role play, CD ROM, OM – overhead projector, practical demonstrations, pupil practical work. AMM – used OHP, flash cards, demo expts, Concept Cartoon, worksheets. DC- Used coke to show volume same in other container, MC – huge number of everyday substances. PC – none PD – lots or practical examples. KG – used lots of everyday examples, chocolate melting, vinegar and washing soda, CH – very poor attempt, dilute and conc.- took copper sulfate as example PK – very little. SK – use in electroplating, extraction of metals, GM – used some everyday examples for matter. OM – did give everyday examples, fire burning, petrol in car, etc. AMM – huge number of everyday examples, ice cream melting, banana in blender, frying stteak, etc. AOD – none	AC used flash cards, OHP, CD ROM and Powerpoint MC – good use of AV aids listed. PC – OHPs, flash cards, posters. PD – overhead, posters, flash cards. KG – posters, overhead, flash cards, demonstration expts, pupil practical work. CH - posters, overhead, flash cards, demonstration expts, pupil role play PK – Powerpoint presentation essentially. GM – mainly didactic lesson plan OM – lesson plan didactic. AMM – lesson plan excellent, well though out with all points included. AOD – didactic points in lesson plan. JOS – lesson plan variety – Powerpoint, flash cards, blackboard, worksheet. EW – lesson plan had posters, blackboard, handouts, experiments. DC – worksheet with lots of everyday examples. MC – loads of examples in everyday life. PD – lots of everyday examples. KG – used some everyday examples but not enough. CH – hopeless, very little evidence of this. PK – no evidence of this in lesson plan. SK – shows cutlery, jewellery as examples of electroplated objects. Tin plating and chromium plating in lesson plan but not covered in lesson itself. GM – poor effort at links with everyday life. Had some. OM – does use lots of everyday examples, fire burning , match burning, petrol burning, mentions copper foil increasing in mass but not done in lesson. AOD – none. JOS – none in lesson plan. EW – preparation of hydrogen, plating of cutlery and jewellery.

REFERENCES

Abd-El-Khalick, F. and Lederman, N. G. (2000) Improving science teachers' conceptions of nature of science: a critical review of the literature, *International Journal of Science Education,* 22 (7), 665-701.

Abour, C. et. al. (1997) Non-conventional Methods in Teaching Matter, Atoms, Molecules and the Periodic Table for Non-major Students. *The American Biology Teacher,* 59 (7), 428-439.

Abraham, M.R. et. al. (1992) Understandings and Misunderstandings of Eight Graders of Five Chemistry Concepts Found in Textbooks. *Journal of Research in Science Teaching,* 29 (2), 105-120.

Adelman, C., Kemmis, S. and Jenkins, D. (1980) Rethinking case study: notes from the Second Cambridge Conference. In H. Simons (ed.) *Towards a Science of the* Singular. Centre for Applied Research in Education. East Anglia: University of East Anglia.

Adey, P. (1989) Cognitive Acceleration Through Science Education. In: Maclure, S. and Davies, P. (Eds.), *Learning to Think: Thinking to Learn.* Oxford: Pergamon Press.

Adey, P. and Shayer, M. (1993) *Really Raising Standards.* London: Routledge.

Adey, P., Shayer M. and Yates, C. (1995) Thinking Science: The materials of the CASE Project. Surrey: Nelson

Anderson, G. (1999) *Fundamentals of Educational Research.* London: Falmer Press.

Anderson, R.C. (1984) Some reflections on the acquisition of knowledge. *Educational Researcher*, 13 (10), pp. 5 – 10.

Andersson, B. (1986) Pupils' explanations of some aspects of chemical reactions. *Science Education,* 70, 549-563.

Andersson, B. (1990) Pupils' Conceptions of Matter and its Transformations (age 12-16). *Studies in Science Education,* 18, 53-85.

Anderson, M. (1992) *Intelligence and Development: A Cognitive Theory.* London: Blackwell.

Andersson, B. and Renstrom, L. (1981) *Oxidation of steel-wool* (Report Elevperspektiv No. 7). Goteborg: Department of Educational Research, University of Goteborg.

Andersson, B. and Renstrom, L. (1983) How Swedish pupils, age 12-15, explain the copper pipe problem. EKNA-group, Department of Education and Educational Research, University of Goteborg, Box 1010, S-431 26 Molndal, Sweden.

Bannister, D. and Mair, J. (1968) *The evaluation of personal constructs*. London: Academic Press.

Barker, V. (1994) A longitudinal study of 16 – 18 year old students' understanding of basic chemical ideas. Unpublished DPhil thesis, University of York.

Barnett, J. (2003) Examining pedagogical content knowledge: The construct and its implications for Science Education, *Science Education,* 87 (4), 615-618

Barral, F. L. et. al. (1992) Secondary Schools Interpretations of the Process Occurring in an Electrochemical Cell. *Journal of Chemical Education,* 69 (8), 655-657..

Batten, M. (1990) The identification, development and sharing of professional craft knowledge. In C. Day and J. Calderhead (eds.), *Research on Teacher Thinking: Understanding Professional Development.* (pp. 177 – 184). London: Falmer Press.

Bell, J. (2000) *Doing Your Research Project*, 3rd edn. Buckingham: Open University Press

Bell, R. L., Blair, L. M., Crawford, B. A. and Lederman, N. G. (2003) Just do it? Impact of a science apprenticeship program on high school students' understandings of the nature of science and scientific inquiry, *Journal of Research in Science Teaching,* 40 (5), 487-509.

Benner, P. (1984), *From novice to expert: Excellence and power in clinical nursing Practice.* Menlo Park: Addison-Wesley.

Bennett, J. (2003), *Evaluation Methods in Research.* London: Continuum.

Berliner, D. (1987) Ways of thinking about students and classrooms by more and less experienced teachers. In: Calderhead J. (Ed.), *Exploring Teachers Thinking (pp. 60 – 83). London:* Cassell.

Bianchini, J. A., Johnston, C.C., Oram, S. Y. and Cavazos, L. M. (2003) Learning to teach science in contemporary and equitable ways: The successes and struggles of First-Year Science Teachers, *Science Education,* 87 (3), 419-443.

Black, P. and Lucas, A. (1993) *Children's informal ideas in science.* New York: Routledge.

Blanco, A. and Prieto, T. (1997) Pupils' Views on How Stirring and Temperature Affect the Dissolution of a Solid in a Liquid : a Cross-age Study (12-18). *International Journal of Science Education,* 19 (3), 303-315.

Boo, H. K. (1998) Students Understandings' *of Chemical Bonds and the* Energies of Chemical Reactions. *Journal of Research in Science Teaching, 35 (5), 569-581.*

Borko, H., and Livingston, C. (1989) Expert and novice teachers' mathematics instructions: Planning, teaching and post-lesson reflections. *American Educational Research Journal,* 26, p, 473 – 498.

Borko, H., Bellamy, M. and Saunders, L. (1992) A cognitive analysis of patterns in science instruction by expert and novice teachers. In: Russell T and Munby H. (Eds.), *Teachers and Teaching: From Classroom to Reflection* (pp. 49 – 70). London: Falmer Press.

Botton, C. (1995) Collaborative Concept Mapping and Formative Assessment Key Stage 3: Understanding of Acids and Bases. *School Science Review,* 77 (279), 124-130.

BouJaoude, S. (1991) A Study of the Nature of Students' Understandings About the Concept of Burning. *Journal of Research in Science Teaching,* 28 (8), 689-704.

BouJaoude, S. and Barakat, H. (2000) Secondary school students' difficulties with stoichiometry, *School Science Review,* 81 (296), 91.

BouJaoude, S. and Tamim, R. (2000) Analogies generated by middle-school science students – types and usefulness, *School Science Review,* 82 (299), 57.

Boyles, E., Stanisstreet, M. (1990) Misunderstandings of 'Law' and 'Conservation': a study of pupils' meanings for these terms. *School Science Review,* 72 (258), 51-57.

Brenner, M., Brown J. and Canter, D. (Eds.) (1985) *The Research Interview: Uses and Approaches.* London: Academic Press.

Briggs, H. and Holding, B. (1986) Childrens Learning in Science Project. *Aspects of Secondary Students' Understanding of Elementary Ideas in Chemistry*: Full Report. HMSO.

Brook, A., Briggs, H. and Driver, R. (1984) *Aspects of Secondary Students' Understandings of Particulate Nature of Matter.* (Leeds: Children's Learning in

Science Project, University of Leeds, Centre for studies in Science and Mathematics Education).

Brown, D. and Clement, J. (1991) Classroom teaching experiments in mechanics. In: R. Duit, F. Goldberg and H. Niedderer (Eds.), *Research in Physics Learning: Theoretical and Empirical Studies*. Kiel, Germany: IPN.

Brown, S. and McIntyre, D. (1993) *Making Sense of Teaching*. Buckingham: Open University Press.

Calderhead, J. (1984) *Teachers' Classroom Decision Making*. London: Holt, Rinehart and Winston.

Calderhead, J. and Shorrock, S. (1997) *Understanding Teacher Education.* London:Falmer.

Carr, W. and Kemmis, S. (1986) *Becoming Critical.* Lewes: Falmer.

Carter, K. and Doyle, W. (1984) Variations in academic tasks in high and average ability classes. In: L. Lomes (Ed.), *Classroom Research*. Victoria, Australia: Deakin University Press.

Cavallo, A. M., McNeely, J. C. and Marek, E. A. (2003) Eliciting students' understandings of chemical reactions using two forms of essay questions during a learning cycle, *International Journal of Science Education,* 25 (5), 583-603.

Chi, M.T.H., Slotta, J.D. and de Leeuw, N. (1994) From things to processes: a theory of conceptual change for science learning. *Learning and Instruction,* 4, 27-43.

Clarke, D. and Thompson, R. (1989) Acid Rain pH and Acidity: A Common Misinterpretation. *The American Biology Teacher* 51 (1), 11-13.

Claxon, G. (1983) *School Science: Falling on stoney ground or choked by thorns?* Centre for Science and Mathematics Education, University of London: Chelsea College.

Clerk, D. and Rutherford, M. (2000) Language as a confounding variable in the diagnosis of misconceptions, *International Journal of Science Education,* 22 (7), 703-717.

Cohen, L. and Manion, L. (1997) *Research Methods in Education.* London: Routledge.

Cohen, L., Manion, L. and Morrisson, K. (2000) *Research Methods in Education,* 5th edn. London: Routledge.

Coll, R. K. and Treagust, D. F. (2003) Investigation of secondary school, undergraduate, an graduate learners' mental models of ionic bonding, *Journal of Research in Science Teaching,* 40 (5), 464-486.

Cosgrove, M. and Osborne, R. (1981) *Physical change: a working paper on learning in science project.* University of Waikato, New Zealand.

Cosgrove, M. and Osborne, R. (1981) *Physical change* (Working Paper No. 26). Learning in Science Project, University of Waikato, Hamiltion, New Zealand.
de Posada, (1997). Conceptions of High School Students Concerning the Internal Structure of Metals and Their Electric Conduction: Structure and Evolution. *Journal of Science Education,* 81,. 445-467.

Craven III, J. A., Hand, B. and Prain, V. (2002) Assessing explicit and tacit conceptions of the nature of science among preservice elementary teachers, *International Journal of Science Education,* 24 (8), 785-802.

Day, C. (1999) *Developing Teachers: The Challenge of Lifelong Learning.* London: Falmer Press.

Department of Education and Science (1998) *Task force on the physical sciences: Report and Recommendations.* Dublin: Government Publications.

De Vos, W. and Verdonk, A. (1987) A New Road to Reactions. *Journal of Chemical Education,* 64 (8), 692-694.

Dewey, J. (1916) *Democracy and Education.* New York: Macmillan.

Dori, Y. (1997) In-Service Chemistry Teachers' Training: The Impact of Introducing Computer Technology on Teachers' Attitudes and Classroom Implementation. *International Journal of Science Education*, 19 (5), 577-592.

Donnelly, J. (2001) Contested terrain or unified project? 'The nature of science' in the National Curriculum for England and Wales, *International Journal of Science Education,* 23 (2), 181-195.

Drefus, H.L. and Dreyfus, S.E. (1977) *Uses and abuses of multi-attribute and multi-aspect model of decision making.* Unpublished manuscript, Department of Industrial Engineering and Operations Research, Berkeley, University of California.

Drefus, H.L. and Dreyfus, S.E. (1986) *Mind Over Machine: The Power of Human Intuition and Expertise in the Era of the Computer.* New York: The Free Press.

Drever, E. (1995) *Using semi-structured interviews in small scale research.* Edinburgh: The Scottish Council for Research in Education.

Driver, R. (1985) Beyond appearances: The Conservation of Matter under Physical and Chemical Transformations. *International Journal of Science Education,* 11 (Special Edition), 481 – 490.

Driver, R. (1989) Students' conceptions and the learning of science. *International Journal of Science Education,* 11, 481-490.

Driver, R. and Bell, B. (1986) Students' thinking and the learning of science: a constructivist view. *School Science Review,* 67 (240), 443 – 456.

Driver, R. and Easley, J. (1978) Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education,* 5, 61-84.

Driver, R. and Oldham, V. (1986) A constructivist approach to curriculum development in science. *Studies in Science Education,* 13, 105-122.

Driver, R., Guesne, E. and Tiberghien, A. (Eds.) (1986) *Children's Ideas in Science.* Milton Keynes: Open University Press.

Driver, R., Squires, A., Rushworth, P. and Wood-Robinson, V. (1994) *Making Sense of secondary science.* London: Routledge.

Driver, R., Asoko, H., Leach, J., Mortimer, M. and Scott, P. (1994) Constructing Scientific Knowledge in the Classroom. *Educational Researcher,* 23 (7), 5 - 12.

Driver, R., Leach, J., Millar, R. and Scott, P. (1997) *Young people's images of s science.* Buckingham: Open University.

Driver, R., Asoko, H., Leach, J., Mortimer, M. and Scott, P. (2004) Constructing Scientific Knowledge in the Classroom. In Scanlon, E, Murphy P, Thomas J and Whitelegg, E (eds) *Reconsidering Science Education* (pp. 58 – 73). London: Routledge Falmer.

Duit, R. (1991) Students' conceptual frameworks: consequences for learning *science. In* S.M. Glynn, R.H. Yeany and B.K. Britton (Eds.), *The Psychology of Learning Science* (Hillsdale: Erlbaum), *65-85.*

Duke, B. J. (1978) Stability of Electron Pairs – a Myth. *Education in Chemistry,* 15 (8), 186-188.

Erduran, S. (2003) Examining the mismatch between pupil and teacher knowledge in acid-base chemistry, *School Science Review,* 84 (308), 81.

Ebenezer, J. and Gaskell, P. (1995) Relational Conceptual Change in Solution Chemistry. *Science Education.* 79 (1), 1-17.

Ebenezer, J. and Erickson, G. (1996) Chemistry Students' Conceptions of Solubility: A Phenomenography. *Science Education,* 80 (2), 181-201.

Elliott, J. (1991) *Action Research for Educational Change*. Buckingham: Open University Press.

Eraut, M.E. (1994) *Developing Professional Knowledge and Competence.* London: Falmer Press.

Eraut, M.E. (1995) Developing Professional Knowledge and Competence. In: Guskey, T.R and Huberman, M. (Eds.) *Professional Development in Education: New Paradigms and Practices*, Columbia University, Teachers College Press.

Eraut, M.E. (1996) *Professional knowledge in teacher education.* In: Nuutinen P (Ed.), University of Joensu, Bulletin of the Faculty of Education, No. 64, p. 1 – 27.

Eylon, b. Ben-Zvi, R. Silberstein, (1982) J. NARST.

Farin, Susan (1997) Acting Atoms. *Science Scope*, 97 (21) PT 3, 46-47.

Feiman-Nemser, S and Buchmann. M. (1986) The first year of teacher preparation: Transition to pedagogical thinking? *Journal of Curriculum Studies*, 18, p. 239 - 256.

Feiman-Nemser, S. and Buchmann. M. (1987) When is student teaching teacher education? *Teaching and Teacher Education*, 3, p255 – 273.

Ferk, V., Vrtacnik, M., Blejec, A. and Gril, A. (2003) Students' understanding of molecular structure representations, *International Journal of Science Education,* 25 (10), 1227-1247.

Fernelius, W. C. (1982) Confusion in the Periodic Table of the Elements. *Journal of Chemical Education,* 59 (6), 504-508.

Fensham, P. J. and Lui, J (2001) What makes a chemical equation an equation?, *School Science Review,* 83 (302), 57.

Fischler, H. (1999) The impact of Teaching Experiences on Student-teachers' and Beginning Teachers' Conceptions of Teaching and Learning Science. In: Loughlin J., *Researching Teaching.* (pp172-198) London: Falmer Press.

Fransella, F. and Bannister, D. (1977) *A manual for repertory grid technique.* London: Academic Press.

Fullan, M. (1982) *The meaning of educational change.* Toronto: OISE Press.

Fullan, M. (1991) *The new meaning of educational change.* 2nd edition. London: Cassell.

Fullan, M. (2001) *The new meaning of educational change.* 3rd edition. London: Cassell.

Furio, C., Azcona, R., Guisasola, J. and Ratcliffe, M. (2000) Difficulties in teaching the concepts of 'amount of substance' and 'mole', *International Journal of Science* Education, 22 (12), 1285-1304.

Gabel, D., Samuel, K. and Hunn, D. (1987) Understanding the Particulate Nature of Matter. *Journal of Chemical Education,* 64 (8), (695-697).

Gardner, H. (1993) Lost youth. *The Guardian (Education),* 12 October 1993 p. 6.

Garnett, P. J., Garnett, J. P. and Hackling, M. W. (1995) Students' Alternative Conceptions in Chemistry: A Review of Research and Implications for Teaching and Learning. *Studies in Science Education,* 25, 69-95.

Gayle, N. (2001) A report of undergraduates' bonding misconceptions, *International Journal of Science Education,* 23 (7), 707-730.

Gernett, P.J. and Treagust, D. F. (1992) Conceptual Difficulties Experienced by High School Students of Electrochemistry: Electric Circuits and Oxidation-Reduction Equations. *Journal of Research in Science Teaching,* 29 (2), 121-142.

Gilbert, J.K. (Ed.) (1993) *Models and Modelling in Science Education.* Hatfield, ASE.

Gilbert, J.K., Osborne, R.J., Fensham, P.J. (1982) Science Education 66 623 (to be checked).

Gilbert, J.K. and Swift, D.J. (1985) Towards a Lakatosian analysis of the Piagetian and alternative conceptions research programs. *Science Education,* 69, 681-696.

Glynn, S., Yeany and Britton, B. (1991) A constructive view of learning science. In: Glynn, S., Yeany and Britton, B. (Eds.), *The Psychology of Learning Science* (pp.5-19). Hillsdale, NJ: Erlbaum.

Goodman, J. (1984) Reflection and teacher education. *Interchange,* 15 (3), 9 – 26.

Goodwin, A. (2003) Evaporation and boiling – trainee science teachers' understanding, *School Science Review,* 84 (309), 131.

Gould, C (1995) *Quality in Science Teaching*, Education in Science, 1995 p. 8 – 10.

Griffiths, A. and Preston, K. (1992) Grade-12 Students' Misconceptions Relating to Fundamental Characteristics of Atoms and Molecules. *Journal of Research in Science Teaching,* 29 (6), 611-628.

Grosslight, L., Under, C., Jay, E. and Smith, C. (1991) Understanding Models and their Use in Science: Conceptions of Middle and High School Pupils and Experts. *Journal of Research in Science Teaching,* No 29, pp 799-822.

Haggarty, L. (1995) The use of Content Analysis to Explore Conversations Between School Teacher Mentors and Student Teachers. *British Educational Research Journal*, 21 (2),183-197.

Haidar, A. and Abraham, M. (1991) A comparison of applied and theoretical knowledge of concepts based on the particulate nature of matter. *Journal of research in Science Teaching,* 28 (10), 919-938.

Hall, G., Wallace, R. and Dossett, W. (1973) *A developmental conceptualisation of the adoption process within educational institutions.* Austin, Texas: Research and Development Center for Teacher Education, The University of Texas at Austin.

Hall, G.E. and Loucks, S.F. (1981) Program definition and adaptation: Implications for inservice. *Journal of Research and Development in Education*, 14(2), 46 –58.

Haney, J. J. and McArthur, J. (2002) Four case studies of prospective science teachers' beliefs concerning constructivist teaching practices, *Science Education,* 86 (6), 783-802.

Hapkiewicz, A. (1991) Clarifying Chemical Bonding. *The Science Teacher,* 58 (3), 24-27.

Harland, J. and Kinder, K. (1997) Teachers' continuing professional development: framing a model of outcomes. *British Journal of In-service Education*, 23 (1), 71-84.

Harrison, A. and Treagust, D. (1996) Secondary Students' Mental Models of Atoms and Molecules: Implications for Teaching Chemistry. *Science Education,* 80 (5), 509-534.

Hawkes, S. J. (1996) Salts are Mostly Not Ionised. *Journal of Chemical Education,* 73 (5), 421-423.

Hebrank, M. (1997) Reduce Confusion About Diffusion. *The American Biology Teacher,* 59 (3), 160-163.

Hess, J. J. (1987) *Students conceptions of chemical change.* Unpublished doctoral dissertation, Michigan State University, E. Lansing.

Hesse, J.J. (1992) Students' Conceptions of Chemical Change. *Journal of Research in Science Teaching,* 29 (30), 277-299. CHECK (30)

Hewson, P.W. (1981) European Journal of Science Education. 1981, 48 (55), 363. CHECK (55)

Hewson, P.W. and Hewson, M.G. (1988) An appropriate conception of teaching science: A view from studies of science learning. *Science Education,* 72, 597-614.

Hitchcock, G. and Hughes, D. (1989) *Research and the Teacher*. 2nd edition. London: Routledge.

Hopkins, D. (1985) *A teachers guide to classroom research.* Buckingham: Open University Press.

Hord, S. (1987) Evaluating educational innovation. London: Croom Helm.

Ireson, G. and Twidle, J. (2004) Increasing the subject knowledge of trainee teachers, *School Science Review,* 85 (313), 51.

Jackson, P.W. (1968) *Life in Classrooms.* New York: Holt, Rinehart and Winston.

Johnson, K. (1988) Changing teacher's conceptions of teaching and learning. In: Calderhead, J. (Ed.), *Teachers Professional Learning.* Lewes: Falmer Press.

Johnson, P. (2000) Children's understanding of substances, part 1: recognizing chemical change, International Journal of Science Education, 22 (7), 719-737.

Johnson, P. (2002) Children's understanding of substances, Part 2: explaining chemical change, *International Journal of Science Education,* 24 (10), 1037-1054.

Johnstone, A.H. (1984) New stars for the teacher to steer by? *Journal of Chemical Education,* 61, 847-849.

Johnstone, A.H. (1991) Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning,* 7, 75-83.

Johnstone, A. H. (2000) Teaching chemistry – logical or psychological?, *Chemistry Education: Research and Practice in Europe,* 1 (1), 9-15.

Johnstone, K. (1992) Students' responses to the active learning approach to teaching the particulate nature of matter. In P.L. Lijnse, P. Licht, W. de Vos and

A.J. Waarlo (Eds.), *Reading Macroscopic Phenomena to Microtopic Particles. A Central Problem in Secondary Science Education.* (Netherlands: University of Utrecht).

Johnston, K. and Driver, R. (1990) *A case study of teaching and learning about plant nutrition.* Leeds: Centre for Studies in Science and Mathematics Education.

Joyce, B. and Showers, B. (1980) Improving in-service training: the messages of research. *Educational Leadership*, 37, 379-385.

Joyce, B. and Showers, B. (1995) *Student achievement though staff development.* White Plains, New York: Longman.

Keith, S. et. al. (1998) An Alternative Conceptual Framework from Chemistry Education. *International Journal of Science Education*, 20 (5), 597-608.

Kelly (1971) Ontological acceleration. In: B. Maher (Ed.). *The selected papers of George Kelly.* London: Wiley.

Kemmis, S. and McTaggart, R. (Eds.) (1992) *The Action Research Planner.* Victoria, Australia: Deakin University Press.

Kerlinger, F. N. (1970) *Foundations of Behavioural Research.* New York: Holt, Rinehart and Winston.

Kikas, E. (2004) Teachers' conceptions and misconceptions concerning three natural phenomena, *Journal of Research in Science Teaching*, 41 (5), 432-448.

Kim-Chwee, Tan, D. and Treagust, D. (1999) Evaluating Students' Understandings of Chemical Bonding. *School Science Review*, 81 (294), 75-81.

Koballa, T., Graber, W., Coleman, D. C. and Kemp, A. C. (2000) Prospective *gymnasium* teachers' conceptions of chemistry learning and teaching, *International Journal of Science Education*, 22 (2), 209-224.

Kokkotas, P. and Vlachos, I. (1998) Teaching the topic of the particulate nature of matter in prospective teachers' training courses. *International Journal of Science Education* 20 (3), 291-303.

Kolb, D. (1978) The Chemical Equation Part II: Oxidation-Reduction Reactions. *Journal of Chemical Education*. 55 (5), 326-331.

Kmel, D., Glazar, S. S. and Watson, R. (2003) The development of the concept of "Matter": A cross-study of how children classify materials, *Science Education*, 87 (5), 621-639.

Kuhn, D., Amsel, E. and O'Loughlin, M. (1988) *The Development of Scientific Thinking Skills.* London: Academic Press.

Kyle, W. C. (1995) Editorial, *Journal of Research in Science Teaching,* 32 (9).

Kyriacou, C. and Stephens, P. (1999) Student Teacher' Concerns During Teaching Practice. *Evaluation and Research in Science Education,* 13 (1), 18-31.

Lawson, A. and Renner, J. (1978) Relationships of science subject matter and developmental levels of learners: *Journal of Research in Science Teaching,* (15), 465 –478.

Leach, J. and Scott, P. (1995) The demands of learning science concepts: issues of theory and practice. *School Science Review,* 76 (277), 47-51.

Leach, J. and Scott, P (2000) Children's thinking, learning, teaching and constructivism. In: M. Monk and J. Osborne (Eds.), *Good practice in science teaching.* (pp. 41 – 56), Buckingham: Open University Press.

Leach, J. and Scott, P. (2002) Designing and Evaluating Science Teaching Sequences: An approach drawing upon the concept of learning and a social constructivist perspective on learning, *Studies in Science Education,* 38, 115-142.

Lee, O. et. al. (1993) Changing Middle School Student's Conceptions of Matter and Molecules. *Journal of Research in Science Teaching,* 30 (3), 249-270 .
Leeds: Centre for Studies in Science and Mathematics Education, University of Leeds.

Lenton, G. and Turner, G. (1999) Student-teachers' grasp of science concepts, *School Science Review,* 81 (295), 67.

Linder, C.J. (1993) A challenge to conceptual change. *Science Education* 77 (3), 293-300.

Linn, M.C., Layman, J., and Nachmias, R. (1987) Cognitive consequences of microcomputer-based laboratories: Graphing skills development. *Journal of Contemporary Educational Psychology,* 12, 244-253.

Linn, M.C., Songer, N.B., Lewis, E.L., and Stern, J. (1993) Using technology to teach thermodynamics: Achieving integrated understanding. In: Ferguson, D.L. (Ed.), *Advanced technologies in the teaching of mathematics and science* (Vol. 107, pp. 5-60). Berlin: Springer-Verlag.

Llorens, J. (1987) Proppuesta y aplicatiốn de una methodologia para analizar la adquisiciốn de los conceptos quĺmicos necesarios en la introducciốn a la teoria atốmico-molecular. Doctoral Thesis, University of Valencia.

Longden, K. (1984) Understanding of Dissolving Shown by 11-12 year old children, unpublished M.Sc. thesis, University of Oxford.

Longden, K. (1991) Children's Interpretation of Dissolving. *International Journal of Science Education,* 13 (1), 59-68.

Loucks-Horsley, S., Love, N., Stiles, K.E., Mundry, S. and Hewson, P. (2003). *Designing Professional Development for Teachers of Science and Mathematics.* 2nd edition. Thousand Oaks, CA: Corwin Press.

Loughran, J., Mulhall, P. and Berry, A. (2004) In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice, *Journal of Research in Science Teaching,* 41 (4), 370-391.

Macintyre, C. (2000) *The Art of Action Research in the Classroom.* London: David Fulton Publishers.

Mackinnon, A. (1987) Detecting reflection-in-action among pre-service teachers. *Teacher and Teacher Education*, 3, (2), 135 – 145.

Mariana, P. et. al. (1991) Pupils' Representations of Models of Water. *International Journal of Science Education,* 13 (3), 313-319.

Mas, C., Perez, J. and Harris, H. (1987) Parallels between Adolescents' Conceptions of Gases and the History of Chemistry. *Journal of Chemical Education*, 64 (7), 616 – 618.

Matthews, M. (1994*) Science Teaching. The Role of History and Philosophy of Science.* London: Routledge.

McNamara, D.R. (1980) The outsider's arrogance: the failure of participant observers to understand classroom events. *British Educational Research Journal*, 6: 113 – 125.

Meheut, M. et. al. (1983) Pupils' (11-12 Year Olds) Conceptions of Combustion. *European Journal of Science Education,* 7 (1), 83-93.

Mercer, N. (1992) Culture, context and the construction of knowledge in the classroom. Light P. & Butterworth, G. *Context and cognition: Ways of learning and knowing.* London: Simon and Schuster.

Miles, M. B and Huberman, A (1994) *Qualitative Data Analysis: An Expanded Sourcebook (2nd edition).* London: Sage

Millar, R. (1989) Constructive criticisms. *International Journal of Science Education*, 11 (5), 587 – 596.

Millar, R. (2002) Evaluating educational programmes: Issues and perspectives. Unpublished paper.

Mirzalar-Kabapinar, F. (1999) *Teaching for conceptual understanding: Developing and evaluating Turkish students' understanding of the solubility concept through a specific teaching intervention.* Unpublished PhD, School of Education, The University of Leeds.

Mirzalar-Kabapinar, F., Leach, J. and Scott, P. (2004) The design and evaluation of a teaching-learning sequence addressing the solubility concept with Turkish secondary school students, *International Journal of Science Education,* 26 (5), 635-652.

Monk, M. (2003) Discussing the nature of science teaching refraction or reflection, *School Science Review,* 85 (310), 91.

Moran, J. and Vaughan, S. (2000) Introducing CASE methodology at Key Stage 4: an example of bridging, *School Science Review,* 82 (299), 47.

Morrison, J. A. and Lederman, N. G. (2003) Science Teachers' diagnosis and understanding of students' preconceptions, *Science Education,* 87 (6), 849-867.

Moss, D. M., Abrams, E. D. and Robb, J. (2001) Examining student conceptions of the nature of science, *International Journal of Science Education,* 23 (8), 771-790.

Munn, P. and Drever, G. (1996) *Using questionnaires in small scale research.* Edinburgh: Scottish Council for Research in Education.

Nakhleh, M. (1992) Why Some Students Don't Learn Chemistry. *Journal of Chemical Education*, 69 (3), 191-197.

Nakhleh, M. (1999) Elementary School Children's Beliefs About Matter. *Journal of Research in Science Teaching*, 36 (7), 777-805.

Nakhleh, M.and Krajcik, J. (1994) Influence of levels of information as presented by different technologies on Students' Understanding of Acid, Base and pH Concepts.

Naylor, S and Keogh, B (2000) *Concept Cartoons in science education.* Cheshire: Millgate House Publishers.

Nicol, W. (1883) The nature of solution. *Philosophical Magazine,* 5 (15), 91-101.

Nisbet, J. and Watt, J. (1984) Case study. In J. Bell, T. Bush, A. Fox, J. Goodey and S. Goulding (eds) *Conducting Small–scale Investigations in Educational management*. London: Harper and Row.

Novak, J. (1988) Learning science and the science of learning. *Studies in Science Education,* 15, 77-101.

Novick, S., and Nassbaum J. (1978) Junior high school pupil's understanding of the particulate nature of matter: An interview study. *Science Education,* 63 (3), 273-281.

Novick, S. and Nussbaum, J. (1981) Junior high school pupils' understanding of the particulate nature of matter: An interview study. *Science Education,* 62, 273-281.

Nussbaum, J. (1985) The particulate nature of matter in gaseous phase. In: R. Driver. et al., *Children's ideas in science.* Milton Keynes, UK: Open University Press.

Nussbaum, J. and Novick, S. (1982) Alternative frameworks, conceptual conflict and accommodation: Towards a principled teaching strategy. *Instructional Science,* 11, 183-200.

Ogborn, J. (1997) Constructivist metaphors of science learning. *Science and Education,* 6 (1-2), 121 – 133.

Open University (1988), *Open University Course E811 Study Guide*. Buckingham: Open University Press.

Osborne, R.J. and Cosgrove, M. (1983) *Journal of Research in Science Teaching* 20, 825.

Osborne, R.J. and Freyberg, P. (1996) *Learning in Science: The Implications of Children's Science.* Auckland: Heinemann.

Oversby, J. (2000) Is it a weak acid or a weakly acidic solution?, *School Science Review, 81 (297), 89-91.*

Ozmen, H. and Ayas, A. (2003) Students' difficulties in understanding of the conservation of matter in open and closed-system chemical reactions, *Chemistry Education: Research and Practice,* 4 (3), 279-290.

Paik, S., Kim, H., Cho, B. and Park, J. (2004) K-8th grade Korean students' conceptions of 'changes of state' and 'conditions of state', *International Journal of Science Education,* 26 (2), 207-224.

Panagiotis, K., Vlachos, I. (1998) Teaching the Topic of the Particulate Nature of Matter in Prospective Teachers' Training Courses. *International Journal of Science Education,* 20 (3), 291-303.

Pardhan, H. and Wheeler, A. (2000) Taking 'STOCK' of pedagogical content knowledge in science education, *School Science Review,* 82 (299), 81.

Parsons, D (1984) *Employment and Manpower Surveys: A Practitioner's Guide.* Aldershot: Gower.

Patton, M. (1990) *Qualitative Evaluation and Research Methods.* California: Sage.

Pereria, M.P. and Pestana, M.E.M. (1991) Pupils' representations of models of water. *International Journal of Science Education,* 13 (3), 313-319.

Peterson, R. and Treagust, D. (1995) Developing Preservice Teachers' Pedagogical Reasoning Ability. *Research in Science Education,* 25 (3), 291-305.

Peterson, R. F. et. al. (1989) Development and Application of a Diagnostic Instrument to Evaluate Grade 11 and 12 students' concepts of Covalent Bonding and Structure Following a Course of Instruction. *Journal of Research in Science Teaching.* 26 (4), 301-314.

Pfundt, H. (1982) Preinstructional conceptions about substances and transformations of substances. In: W. Jung, H. Pfundt and C. v Rhoneck (Eds.), Problems concerning student's representation of physics and chemistry knowledge. Proceedings of a workshop, (pp. 320-341). Ludwigsburg: Padagogische Hochschule.

Piaget, J. & Inhelder, B. (1974)*The child's construction of quantities.* London: Routledge and Keegan, Paul.

Posner, G.J., Strike, K.A., Hewson, P.W., and Gertzog, W.A. (1982) Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education,* 66 (2), 211-227.

Pozo, R. M. (2001) Prospective teachers' ideas about the relationships between concepts describing the composition of matter, *International Journal of Science Education,* 23 (4), 353-371.

Prieto, T., Blanco, A. and Rodriguez, A. (1989) The ideas of 11 to 14 year old students about the nature of solutions. *International Journal of Science Education,* 11 (4), 451-463.

Ramsden, J.M. (1997) How does a context-based approach influence understanding of key chemical ideas at 16+? *International Journal of Science Education*, 19 (6), 697- 710.

Regan, E. and Childs, P. (2003) An investigation of Irish students' attitudes to chemistry: The promotion of chemistry in schools project, *Chemistry Education: Research and Practice*, 4 (1), 45-53.

Renström, L. (1988) *Conceptions of Matter: A phenomenographic approach.* PhD dissertation Gothenburg University Press.

Reynolds, A. (1992) What is competent beginning teaching? A review of the literature. *Review of Educational Research*, 62 (1), 1 – 35.

Reynolds, Y. and Brosnan, T. (2000) Understanding physical and chemical change: the role of speculation, *School Science Review*, 81 (296), 61.

Richardson, S, Dohrenwend, B and Klein, D. (1965) *Interviewing: Its Forms and Functions.* New York: Basic Books.

Roehrig, G. H. and Luft, J. A. (2004) Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons, *International Journal of Science Education*, 26 (1), 3-24.

Ross, B. and Munby, H. (1991) Concept mapping and Misconceptions: A study of High-school Students' Understandings of Acids and Bases. *International Journal of Science Education*, 13 (1), 11-23.

Ross, K. and Law, E. (2003) Children's naïve ideas about melting and freezing, *School Science Review*, 85 (311), 99.

Rubin, H. and Rubin, I. (1995) *Qualitative Interviewing: The art of Hearing Data.* London: Sage.

Russell, T. and Bullock, S. (1999) Discovering our Professional Knowledge as Teachers: Critical Dialogues about Learning from Experience. In: Loughran, J. *Researching Teaching* (pp 132-151) London: Falmer Press.

Russell, T, and Munby, H. (1992) *Teachers and Teaching: From Classroom to Reflection.* London: Falmer Press.

Sanger, M. J. and Greenbowe, T. J. (1997) Students misconceptions in Electrochemistry: Current Flow in Electrolyte Solutions and the Salt Bridge. *Journal of Chemical Education*, 74 (7), 819-823.

Scaife, J. (2000) *Learning in Science.* In: J.J. Wellington, *Teaching and Learning Secondary Science.* (p 61 – 108). London: Routledge.

Schatzman, L and Strauss, A (1973) *Field Research: Strategies for a Natural Sociology.* New Jersey: Prentice Hall

Schmidt, H. (2000) In the maze of chemical nomenclature – how students name oxo salts, *International Journal of Science Education,* 22 (3), 253-264.

Schmidt, H., Baumgartner, T. and Eybe, H. (2003) Changing ideas about the Periodic Table of Elements and Students' alternative concepts of isotopes and allotropes, *Journal of Research in Science Teaching,* 40 (3), 257-277.

Schmidt, H. J. (1991) A label as a Hidden Persuader: Chemists' Neutralisation Concept. *International Journal of Science Education*, 13 (4), 459-471.

Schofield, B., Bell, J., Black, P., Johnston, S., Murphy, P., Qualter, A. and Russell, T. (1989). *Science at age 13: a review of APU survey findings.* London: HMSO.

Schon, D (1983) *The Reflective Practitioner.* New York: Basic Books.

Schon, D (1987) *Educating the Reflective Practitioner.* San Francisco: Jossey-Bass.

Science Task Force Report (1998) Report on the Government Task Force on Science. Dublin: Government Publications.

Scott, D. and Usher, G. (1999) *Researching Education.* London: Cassell

Shallcross, T. and Spink, E. (2002) How primary trainee teachers perceive the development of their own scientific knowledge: links between confidence, content and competence?, *International Journal of Science Education,* 24 (12), 1293-1312.

Shamos, M.H. (1995) *The Myth of Scientific Literacy.* New Jersey: Rutgers University Press.

Shayer, M. and Adey, P.S. (1981) *Towards a Science of Science Teaching.* London: Heinemann.

Shayer, M., Kuchemann, D. and Wylam, H. (1976) The distribution of Piagetian stages of thinking in British middle and secondary school children. *British Journal of Educational Psychology*, 46, p. 164 – 173.

Shepard, D. L. Renner, (1982) J.W. *School Science Math.* 82, 650.

Shulman, L. (1986) Those who understand: Knowledge growth in teaching, *Educational Researcher*, 15 (2), 4 – 14.

Shulman, L. (1987a) Knowledge and teaching: Foundations of the new reform. *Educational Researcher*, 15 (2), p. 4 – 14.

Shulman, L. (1987b) Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57 (1), p. 1 – 22.

Silverman, D. (1993) *Interpreting Qualitative Data*. London: Sage Publications.

Simon, S. (2002) The CASE approach for pupils with learning difficulties, *School Science Review,* 83 (305), 73.

Simpson, M. and Tuson, J. (1995) Using observations in small-scale research. Glasgow: The Scottish Council for Educational Research.

Smith, R. (1999) Piecing it Together: Student Teachers Building Their Repertoires in Primary Science. *Teaching and Teacher Education,* 15, 301-314.

Solomon, J. (1983) Learning about energy - How pupils think in two domains. *European Journal of Science Education, 5,* 49-59.

Solomon, J. (1983) Learning about energy- How pupils think in two domains. *European Journal of Science Education*, 5 (1), 49-59.

Solomon, J. (1994) The rise and fall of constructivism. *Studies in Science Education,* 23, 1 – 19.

Solsona, N., Izquierdo, M and de Jong, O. (2003) Exploring the development of students' conceptual profiles of chemical change, *International Journal of Science Education,* 25 (1), 3-12.

Somekh, B. (1995) The contribution of action research to development in social endeavours. *British Educational Research Journal*, 21 (3), 339 –355.

Soudani, M., Sivade, A., Cros, D. and Medimagh, M. S. (2000) Transferring knowledge from the classroom to the real world: redox concepts, *School Science Review,* 82 (298), 65.

Spradley, J.P. (1979) *The ethnographic interview.* New York: Holt, Rinehart and Winston.

Stavridou, H. and Solomonidou, C. (1989) Physical Phenomena-Chemical Phenomena: Do Pupils Make Distinctions? *International Journal of Science Education,* 11 (1), 83-92.

Stavridou, H. and Solomonidou, C. (1998) Conceptual Reorganisation and the Construction of the Chemical Reaction Concept During Secondary Education. *International Journal of Science Education,* 20 (2), 205-221.

Stenhouse, L. (1979) The problem of standards in illuminative research. *Scottish Educational Review,* 11 January 1979.

Styles, B. (2003) Analogy – constructive or confusing? A students' perspective, *School Science Review,* 85 (310), 107.

Taber, K. (2002) *Chemical misconceptions – prevention, diagnosis and cure.* Volume 2. London: Royal Society of Chemistry.

Taber, K. S. (2002a) A core concept in teaching chemistry, *School Science Review,* 84 (304), 105.

Taber, K. S. (2003) Responding to alternative conceptions in the classroom, *School Science Review,* 84 (308), 99.

Taber, K.S. and Watts, M. (1996) "The secret life of the chemical bond: Students anthropomorphic and animistic references to bonding". *International Journal of Science Education,* 18, pp.557-68.

Tan, K. D., Goh, N., Chia, L. and Treagust, D. F. (2003) Students' understanding of acid, base and salt reactions in qualitative analysis, *School Science Review,* 84 (308), 89.

Tan, K. D. and Treagust, D. F. (1999) Evaluating students' understanding of chemical bonding, *School Science Review,* 81 (294), 75.

Tann, S (1993) Eliciting Student Teachers' Personal Theories. In: J. Calderhead and P. Gates (Eds.), *Conceptualising Reflection in Teacher Development.* (pp.53 – 69). London: Falmer Press.

Thiele, R.B. and Treagust, D. (1994) The nature and extent of analogies in secondary science textbooks. *Instructional science,* 22, 61-74.

Thiele, R.B. and Treagust, D. (1994) An interpretative examination of high school chemistry teachers' analogical explanations. *Journal of Research in Science Teaching,* 31, 227-242.

Tobin, K. and Fraser, B.J. (1991) Learning from exemplary teachers in Wasman, H.C. and Walberg, H.J. (Eds.), *Effective Teaching: Current Research,* p. 217 – 36, Berkeley CA, McCutchan Publishing Corporation.

Treagust, D. F., Chittleborough, G. and Mamiala, T. L. (2002) Students' understanding of the role of scientific models in learning science, *International Journal of Science Education,* 24 (4), 357-368.

Treagust, D., Harrison, A., Venville, G. and Dagher, Z. (1996) Using an analogical teaching approach to engender conceptual change. *International Journal of Science Education,* 18, 213-219.

Treagust, D. F., Harrison, A.G. and Venville, G. (1998) "Teaching Science effectively with analogies: An approach for pre-service and in-service teacher education". *Journal of Science Teacher Education*, 9 (1), pp. 85 – 101.

Treagust, D. and Harrison, A. (1999) The Genesis of Effective Scientific Explanations for the Classroom. In: Loughran, J., *Researching Teaching* (pp 28-44). London: Falmer Press.

Turner-Bisset, R. (1999) The Knowledge Bases of the Expert Teacher. *British Educational Research Journal,* 25 (1).

Tyler, R. (1949) *The Basic Principles of Curriculum and Instruction*. Chicago: University of Chicago Press.

Tytler, R. (2000) A comparison of year 1 and year 6 students' conceptions of evaporation and condensation: dimensions of conceptual progression, *International Journal of Science Education,* 22 (5), 447-467.

van Driel, et. al. (1998) Developing Science Teachers' Pedagogical Content Knowledge. *Journal of Research in Science Teaching,* 35 (6), 673-695.

Van Driel, J. H., De Jong, O and Verloop, N. (2002) The development of preservice Chemistry Teachers' pedagogical content knowledge, *Science Education,* 86 (4), 572

Viennot, L. and Rainson. S. (1999) Design and Evaluation of a research-based teaching sequence: The superposition of electric field. *International Journal of Science Education*, 21 (1), 1 – 16.

Watson, J. et. al. (1997) Consistency of Students' Explanations about Combustion. *Journal of Science Education,* 425-441.

Webb, S. and Webb, B. (1932) *Methods of Social Study*. London: Longman, Green and Co.

Wellington, J. (2000) *Educational Research. Contemporary Issues and Practical Approaches*. London: Continuum.

Wellington, J. (2000a) Teaching and Learning Secondary Science. London: Routledge.

White, R. and Gunstone, R. (1989) Metalearning and conceptual change. *International Journal of Science Education,* 11 (5), 577 – 586.

Wilson, S. M., Shulman, L.S. and Richert, A. (1987) 150 different ways of knowing: Representations of knowledge in teaching. In: J. Calderhead (Ed.), *Exploring teacher thinking.* London: Cassell

Wollman, W.T. (1986) Pupil's Explanations of Some Aspects of Chemical Reactions. *Science Education,* 70 (5), 549-563.

Wolpert, L. (1992) *The Unnatural Nature of Science.* London: Faber and Faber.

Yarroch, W.L. (1985) Student understanding of chemical equation balancing. *Journal of Research in Science Teaching,* 22, 449 – 459.

Zahorik, D. (1975) Teachers Planning Models. *Educational Leadership,* 33, 134 – 139.

Zeichner, K.M. and Grant, C.K. (1981) Biography and social structures in the socialisation of student teachers. *Journal of Education for Teaching,* 7, 298 – 314.

Zeichner, K.M. et al (1987) Individual, institutional and cultural influences in teacher education. In: Calderhead, J. (Ed), *Exploring Teachers' Thinking,* London: Cassell.

Zeichner, K.M. and Liston, D. (1990) Reflective teaching and action research in preservice teacher education. *Journal of Education for Teachers,* 16 (3), 235 – 254.