AN EXPLORATION OF PRESERVICE TEACHERS' EXPERIENCES OF THE HIGHER DIPLOMA IN EDUCATION AND ASPECTS OF THEIR SUBJECT MATTER KNOWLEDGE

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PREFACE

"Never forget that in your reporting regardless of how faithful you attempt to be in describing what you observed, you are creating something that has never existed before. At best it can be similar, never exactly the same as what you observed. And at worst ......" (Wolcott, 1994:15)

ABSTRACT.

Three case studies were conducted involving Andrew, Ferrial and Mary. A number of aspects relating to their experiences were explored and are described in this report. In addition to their personal accounts, their views about the nature of science, science teaching and learning were sought. The study also surveyed HDE students' knowledge of certain concepts related to chemical bonding and acids and bases. The case studies were observed during their teaching practice to establish how the aspects mentioned above relate to their practices in the classroom. Data was collected through interviews, journals, classroom observation both in their science methodology classes and during teaching practice and diagnostic tests. It was found that school backgrounds influenced Ferrial's and Mary's perceptions of the HDE programme. They both appreciated those aspects of the metholodologies that were directly linked to preparation for teaching, such as the mini lessons, test design, the practical work, and enriching their knowledge of science concepts through discussing science content. Both were very anxious about their competence in teaching science. They considered the assignment work excessive, irrelevant, and frustrating and were sometimes not sure what was expected. Ferrial felt they were given too much work. Andrew, on the other hand did not seem to find any problems. He liked the practical approach followed in the classes and appreciated the suggestions made. His experiences were more of a personal nature and related to the fact that he was engaged in part time teaching.

Their conceptions of science, teaching and learning were modified rather than changed during the year of study. They were not always successful in trying out their theories of teaching and learning and applying the suggestions made in the HDE courses because such moves were sometimes unacceptable to their students or cooperating teachers. In Andrew's situation implementation of suggestions were impeded by lack of appropriate facilities.

It was also found from this study that student teachers had several erroneous ideas about chemical bonding and acids and bases irrespective of the depth of their chemical background. It was further found that discussing chemical bonding helped the students change some of their ideas to more acceptable ones.

DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other institution.

V. L. Kelly

DEDICATION:

In memory of my grandmother Ntfombitodvwa Magagula and my brother Boy-Masaka Ivan Kelly.

ACKNOWLEDGEMENTS:

I would like to thank Dr M. S. Rollnick for her invaluable assistance in many aspects of this study. I am grateful to the many suggestions she made towards improving the study and its reporting.

I would also like to extend my gratitude to the following people without whose contributions this research would not have been successful.

The three student teachers who accepted my request to be candidates for the case studies. Thank you for your commitment and dedication.

Mrs. M. Brand, Mr. M. Stanton, Mrs. L. Harris and Dr. P. Huddle.

The principals of schools where the subjects conducted their teaching practice.

Mr. K. Dlamini for providing transport to the schools during teaching practice and his untiring support through my period of study.

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EXPLANATION OF TERMS, ABBREVIATIONS AND NOTATIONS USED

Names:

All the names used in this report including those in the excerpts and the appendices are fictitious to protect the identity of those involved.

Andrew, Ferrial and Mary are the three student teachers participating in the case studies.

The numbers 4 to 11 used in Chapter 4 are arbitrary and are used for discussion purposes.

M1 and M3 refer to the physical science methodologists.
M2 and M4 refer to the biology methodologists
M5 refers to the additional studies lecturer
M6 refers the teacher educator who led discussion on chemical bonding

School R is the school where Ferrial was not keen on doing her teaching.
School P is the school where Ferrial conducted her teaching practice
School Q is the school where Mary conducted her teaching practice.

Excerpts:

[I1:1] refers to excerpts taken from the initial interview (interview 1) on page 1 in data source (interview transcript) or in the appendix as the case may be as shown in the example below. (NB! Only a few data sources serving as examples are included in the appendices of this report.)

[I1:239a], [I1:239b], [I1:239c] means several excerpts taken from the initial interview on page 239 in the appendix. Not necessarily chronological.

[CD1:268] refers to except taken from the first class discussion in methodology classes taken from page 268 in the appendix. Quotes taken from pages beyond 272 are not inluded in the appendix.

[MJ:1] refers to except taken from methodology journal on page 1 of the journal.

[TPJ:5] refers to except taken from teaching practice journal on page 5 of the journal.

[science] or *science:* These words are added or used in excerpts for purposes of clarity.

[...] at beginning or within and excerpt denote deliberate exclusion of text which does not help illustrate the point under discussion.

..... means that what was said is inaudible.

hydrogen bonding.... means an interruption by the next speaker

Others:

std 6, std 7, std 8, etc mean standard 6, standard 7, standard 8, etc.

TED means Transvaal Education Department.

DET means Department of Education and Training.

HDE means Higher Diploma in Education.

UNISWA means University of Swaziland

CHAPTER 1

INTRODUCTION

CONTENTS CHAPTER 1 PAGE

1.0 Introduction.

Research in science education has focused mainly on the learners as the ones who construct knowledge in a teaching learning situation. While outside the classroom the learners' construction of knowledge is influenced by factors other than the teacher. The major determining factor in the classroom is most likely to be the teacher. The kind and nature of information and the ways in which the teacher makes it available to the learner will contribute to the constructions learners make. Therefore it is important to pursue studies on teachers' conceptual frameworks.

Just as learners actively construct knowledge on the basis of their experiences and existing knowledge, so teachers also develop their conceptual frameworks about science and science education on the foundation of their existing knowledge and experiences of being students themselves (Hewson and Hewson 1988; Brickhouse and Bodner 1992). Teachers construct knowledge about science, their students and the science classroom, that fits their experiences to the satisfaction of the goals they set for themselves and their students. Some of this learning takes place in teacher education courses, but most in school. The constructivists view of learning science places the learner at the centre of the teaching learning situation. This view which dominates research in science education should therefore recognise that science instruction depends upon the individual teachers perceptions and conceptions of teaching, learners and learning and knowledge of science (Aguirre et al. 1990; Brickhouse and Bodner 1992).

This study focuses on three case studies of students in the higher diploma in education (HDE) programme at the University of the Witwatersrand (Wits):

- Andrew, a male with some teaching experience and who holds a BSc degree with chemistry III major.
- Ferrial and Mary, young females without any teaching experience, and who hold BSc degrees in biological sciences and chemistry I.

It also explores content knowledge of the student teachers in the HDE in selected topics.

1.1 Subject matter

In Swaziland

In the short time I spent understudying the chemistry curriculum studies within the Department of Curriculum and Teaching at the University of Swaziland (UNISWA), I observed that subject matter does not form part of the teacher education programme for post-graduate studies, while half the curriculum of the under-graduate Bachelor of Education (science) consists of university level content. As in many other countries it is assumed that the under-graduate degree provides the student teachers with adequate content knowledge. Thus in many post-graduate teacher education courses the assumption is that prospective teachers have the necessary subject matter knowledge and should be able to teach it provided they acquire the necessary skills. Further research into aspects of subject matter preparation offered by specialist academic departments in university teacher training programmes is necessary (Ferguson and Womack, 1993) as well as that obtained prior to entry into teacher training.

The possible existence of a deficit in content knowledge in science teachers in Swaziland was highlighted by the activities of the In-School Maths and Science Teaching Improvement Programme (IMSTIP) which started in 1986 (Williams and Brophy 1989). IMSTIP was set up within the in-service structures of UNISWA to improve the quality of teaching of mathematics and science in high schools. It was also anticipated that by improving mathematics and science teaching in the schools, the number of candidates qualifying for the Bachelor of Science degree at UNISWA would increase. This focus on content during the IMSTIP activities continued in spite of the fact that by 1988 about 46% of the teachers were graduates, 34% of them trained teachers (Williams and Brophy 1989). Evaluation of IMSTIP revealed that teachers appreciated the seminars and workshops offered because they found them to be directly related to their needs at school and upgraded their skills relevant to the teaching situation. The teaching materials produced from these workshops were rich in content. They included notes for teachers, background materials, worksheets, details of experiments, booklets of model answers to previous exams and examiners' reports. All were reported to be extremely valuable to the teachers.

1.2 Motivation for the study

Observations of both the preservice and inservice activities of science teachers regarding subject matter generated my interest in exploring content knowledge of post graduate preservice students. Further interest on subject matter developed because of the general assumption that post graduate preservice teachers have mastered the content in the subject area and all they need are pedagogical skills.

I was further motivated to take up this study by the HDE science methodology course at Wits. This programme was within my area of interest - teacher education. As a teacher training programme, it provided an opportunity for me to attend methodology lectures and interact with the students while exploring the experiences and conceptions of those selected case studies during the course. I also hoped to become exposed to possible and different approaches to teacher training through attending these courses. For purposes of the study focus was, however, only on the parts of the course dealing with chemistry related topics viz acids and bases, chemical bonding and the nature of science.

1.3 Purpose of the study

The aim of the study was to explore and describe the experiences of four Higher Diploma in Education students as they progressed through the programme, as well as their conceptions of science, teaching and learning, and some aspects of their subject matter knowledge and that of their colleagues.

1.4 Research Questions

From the study possible answers to the following questions were sought.

1. What is the experience of preservice teacher education like for the participants involved?
2. What are the participants' conceptions of science?
3. What are the participants' conceptions of science teaching and learning?
4. What is the status of HDE students subject matter knowledge of chemical bonding and acids and bases?
5. What is the relationship (if any) between what preservice teachers learn in the HDE classes, their claims (with respect to 1, 2 and 3 above) and their

classroom behaviour during teaching practice?

1.5 Rationale

Preservice students' motives for entering the profession (Steinberg 1985) and their experiences of professional training are a valuable subject of research. Such research has direct implication for preservice teachers' professional socialisation and subsequent career attitudes (Book, Byers and Freeman, 1983). Reasons for the choice of teaching as a profession is the result of various factors and therefore more complex than it appears to be (Steinberg, 1985). It is therefore reasonable to expect teacher trainers to be aware and understand student teachers experiences, expectations and their perceptions of the relevance of their professional training (Book, et al. 1983).

This study was inspired by a special interest in teacher education. Encouragement came from "A Case Study Exploration of Development in Preservice science teacher", a paper by Gunstone, Slattery, Baird and Northfield (1993). The paper reports on a part of a broader study conducted in Australia involving science teachers in secondary schools and science graduates in a one year preservice teacher education programme. The part reported concerns the preservice teacher. The study looked into issues of understanding better the complexities of teaching and learning science, the processes of change in individual teacher trainees and to develop an understanding of research methodologies appropriate for reaching these goals. This report inspired my interest for two reasons. The first reason was that conducting a study along the same lines could provide the opportunity for me to understudy a teacher training programme, such as the Higher Diploma in Education (HDE) at the University of the Witwatersrand (Wits). The other reason was that I could fulfil my research report requirements for the pursued degree. This study also formed the foundation for the methodology in this study.

As an employee of the University of Swaziland (UNISWA), the post I will resume on returning to Swaziland will entail the training of secondary and high school science teachers. Naturally my interest was in getting to know more about the transition of the preservice teachers during professional preparation for teaching science, gain insight into aspects of the science content, of these teacher trainees, relevant for teaching science at the secondary level.

It is assumed that knowing more about the processes by which individuals change with experience in teacher training programme can be advantageous in the structuring of teacher training courses to cater for prospective teachers concerns. The study focuses on cases and cannot on its own lead to suggestions of ways of changing the HDE programme but will show in chapters 5, 6 and 7 that in certain cases students teachers' needs can be ignored and thus lead to their frustration and depression. The present study concentrates on areas that were thought could develop an awareness about the professional changes individual trainees undergo include their experiences, their views about science, teaching and learning.

1.6 Background to the Higher Diploma in Education Programme

Informal interviews with two of the tutors, M1 and M5, revealed that the HDE programme offered in the Faculty of Education at Wits is a one year full time teacher certification programme for graduates who wish to qualify in the teaching profession. Compulsory subjects for the HDE students are Theory of Education, Subject Methodology I and Subject Methodology II. The subject methodologies are done in two approved teaching subjects. In addition to these three subjects they have to do additional studies (not offered in biology) in one of the two teaching subjects. In the case of science graduates the subject methodologies and additional studies are offered in physical sciences and mathematics. The additional studies may contain direct discussion of content as in discussing misconceptions in selected topics but focus is mainly on discussing the history and philosophy of physics, chemistry and mathematics concepts. Research (Mahaffy 1992; Solomon et al. 1992; Wandersee 1986; Sherratt 1982) has shown that studying the history of science concepts enhances the understanding of those concepts. The additional studies can be seen as an indirect way of addressing the content and are expected to enhance student teachers' competence in the classroom. The student teachers would thus be in a better position to understand how school students develop their scientific concepts, predict students' misconceptions and help the students acquire appropriate science concepts. The better understanding of classroom expectations by student teachers is further achieved because the additional studies curriculum is very flexible to allow for the discussion of other issues raised by the students.

Other HDE course requirements are religious studies and computer literacy. Competence in the use of English or any other language as a medium of instruction, recognised by the Criteria for Evaluation of the South African Qualification for Employment in Education, is signified as a language endorsement on the certificate.

In addition to the theoretical work, the students have to do two weeks of unsupervised school observation at the beginning of the school year and eight weeks of supervised teaching practice later on during the course of the year. The two weeks observation is aimed at recapturing the students' experiences of school teaching and providing experience from the teachers' viewpoint. The teaching practice which comes later in the year provides real hands on school teaching experience and an opportunity to implement the theories and skill acquired in the campus based HDE courses.

After the methodologist's observations of student teachers' difficulty with subject matter during teaching practice and research studies (Bradley, Gerrans and Matthee, 1985), the physical/general science methodology course was modified to include certain content related topics. For the 1994 chemistry methodology course these topics were 'symbols and representations', 'chemical bonding', and 'acids and bases'. The intention varied from discussions to assist student teachers on how to cope with teaching the topics to showing how they could relate to the school syllabus.

CHAPTER 2

REVIEW OF THE LITERATURE

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2.0 Introduction

This chapter focuses on the literature surveyed for this study. It is divided into three main sections, namely

- the importance of teachers' beliefs
- conceptions of science, science teaching and science learning
- subject matter knowledge

2.1 Importance of teacher beliefs

The central role of teachers is almost universally accepted in school systems yet science teacher education is still one of the least popular aspect of research in science education. It is also surprising that research in science teacher education is so limited yet it is an immediate area of study (Fensham and Northfield 1993). The fact that many researchers in science education are science teacher educators should promote more research in the area. The inadequate attention received by research on science teachers has been regarded as the main factor contributing failure of innovations and reforms in science curricula in Europe (Fensham and Northfield 1993).

Recent studies on student teachers' conceptions of the nature of science, teaching and learning suggest routes towards change in teacher education. As such a large body of research directed at the study of teachers' conceptions of science and science teaching and their implications for teacher education has been established. Brickhouse (1990) shows that teachers views of the nature of science can be expressed in classroom instruction and that these views are important for a better understanding of science by the pupils taught. Teachers' notions about the nature of science, teaching and learning can influence students' and their understanding of science (Hewson and Hewson 1987, 1988; Cobern 1989; Cronin-Jones, 1991) because these beliefs determine the way teachers interpret and implement the curriculum (Cronin-Jones 1991). There is thus a perceived link between what teachers think (beliefs, views, theories, planning, decisions) and what they do (classroom behaviour, students' classroom behaviour and achievement) (Aguirre, Haggerty and Linder 1990; Hewson and Hewson 1987; Brickhouse 1990). While teachers' views of the nature of science can influence their students' conceptions of science they can also limit the kinds of science that children do in the classroom (Abell and Smith 1994).

Hewson and Hewson (1987, 1989) also noted that answers given by different students at school level tend to show a regular and consistent pattern. They also believe that these answers are not random, isolated pieces of information but reflect the way the students have been taught science, further demonstrating the influence of teachers' ideas on student understanding of science concepts. The possibility of teachers being sources of erroneous concepts in science was also investigated by Sanders (1993). On the same note Mosimege (1995) states that results from various studies on misconceptions indicate that irrespective of the amount of training and experience in teaching most science educators experience misconceptions in one form or another and pass these on to students. A similar view is held by Fensham and Northfield (1993). Fensham and Northfield (1993) believe that science teachers also hold the many conceptions (they refer to as "Teachers' Science") found in their students and which may vary from the normally accepted scientists science.

Student teachers bring to training programme a range of beliefs formulated during their years of schooling about the kind of teacher they want to be. It is important that these beliefs are assessed. If they do affect classroom behaviour, then students teachers must be made aware of the relationship and be provided with opportunities to reflect and examine their beliefs and practice critically because without this they will adopt practices they remember from their own schooling and reinforce the status quo (Bramald, Hardman, and Leat 1995).

Hewson and Hewson (1987) further concluded from their study of science teachers' conceptions of teaching, that preservice and inservice teachers are likely to hold conceptions of teaching which are in conflict with the idea of teaching for conceptual change. These alternative conceptions can be expected from teachers because as mentioned earlier they were taught for some time before deciding to become teachers and will have given these conceptions considerable thought. They challenge teacher education programmes to address these alternative conceptions during training.

The importance of knowing more about student teachers preconceptions is receiving recognition from researchers because they show remarkable resistance against attempts to change them. Teacher educators want student teachers to change their conceptions of teaching as explaining concepts through teacher talk to realising that teaching aims at student learning and understanding. But they seem to be unsuccessful in the end to influence student teachers' conceptions brought to training classes. This results in poor transfer of the theory taught and skills trained on campus to the classroom during teaching practice because teacher education programmes fail to influence student teachers' preconceptions (Wubbels 1992).

In a study assessing preservice teachers' attitudes and beliefs towards science and mathematics, McDevitt et al. (1993) found that different students had different conceptions of teaching and learning. They also conclude that these beliefs develop over years of being students and from other experiences and that they may not be consistent with those expected by teacher trainers.

The idea that basic knowledge and beliefs about teachers, teaching and learning accumulate early and are modified during preparation programmes as well as informal experiences also receives support from researchers like Carter (1994), Cole and Knowles (1993); Calderhead and Robson (1991); Abell and Smith (1994); and Hodson (1988). Very little is known about what teachers perceive about teaching processes despite general agreements that teachers' understandings are of fundamental importance to teaching. While much research has gone into novice teachers' behaviours, attitudes and dispositions towards the field experiences little research has been directed at what student teachers learn about teaching during their initial preparation. (Carter 1994).

Exposing, discussing and critically analysing teachers' conceptions of science, teaching and learning is important in informing teacher educators about providing prospective teachers with other views in these phenomena. Teacher educators could also find ways of encouraging preservice teachers to reflect on alternative views and their implications for instruction in science. (Aguirre et al. 1990; Aguirre and Haggerty 1995).

There seems to be no consensus regarding an apparent link exists between teachers views and beliefs about science and their classroom practice. While some researchers, as mentioned above, have suggested a link between teachers' views of science and classroom practice, others have been unable to demonstrate this link which exists. A review by Lederman (1992) suggests that attempts to address students' lack of understanding of science through the curriculum were inadequate. Furthermore these studies failed to show a significant relationship between teachers' understanding of the nature of science and classroom practice. Though teachers may possess appropriate conceptions of science, this is no guarantee that these may be imparted to the students they teach.

In an earlier study to identify classroom variables which are related to changes in high school students conceptions of the nature of science, Lederman (1986) found a positive relationship between student outcome and both teacher behaviour and classroom climate

> Although it is easy to see how a warm and supportive atmosphere would be desirable in any classroom, such an atmosphere does not necessarily contribute to learning. Students must become excited about the material being presented. Their interest and curiosity must be piqued, for a warm and supportive climate might simply represent a non-threatening environment in which the student feels no need to expend any effort. The dynamic nature of the teachers' presentation and the use of a variety of instructional media appeared to have accomplished this task (13).

Discouragingly, later studies were not convincing about the link between conceptions of the nature of science and the "transfer" of these to students. The assumption that preservice programmes can improve teachers' conceptions of the nature of science by providing teacher trainees with suitable strategies for effective transfer of these conceptions has no empirical foundation (Zeidler and Lederman, 1989; Lederman, 1992). From a study to test the validity of the assumptions that teachers' conceptions of the nature of science directly influences classroom behaviour, Zeidler and Lederman (1989) reported that teachers' conceptions may not necessarily affect the teachers' classroom behaviour. Possession of a valid conception of the nature of science will not necessarily guarantee that the teacher will perform teaching behaviours that are dedicated to improving students' conception of science. They do not, however, comment on the counter case - the influence of a negative attitude toward science on classroom behaviour or the link between the lack of an appropriate conception of the nature of science and classroom behaviour. Teachers tend to focus their teaching on handing over conceptual facts with very little attention, if any, to the objectives concerned with attitudes and values of teaching science (Lederman, 1992). In fact, an ASE report (1979) states that science teachers who are products of science education that places emphasis of content have a scant understanding of the nature of science knowledge (Hodson 1988). Also teachers' classroom behaviour tends to be modelled around what they remember from their own experiences of what was used on themselves when they were taught (McDevitt et al. 1993 and Bramald et al. 1995) .

Lee (1993) cites previous studies that teachers who have positive attitudes towards science like to teach the subject and that their students, too, will have a positive attitude towards it. For teachers with negative attitudes, the students they teach tend also to have negative attitudes. Lee conducted a comparative study of students with different majors in a Junior Training College and a Training College. Lee found that for individual students there was significant correlation of cognitive development, science process skills and attitude towards science and that students with science and maths majors were more positive towards science. This observation indicates the relationship that can exist between attitude towards a subject and choice of the subject. Lampert (1988 quoting Horn and Walberg) feels that science education research has not yet reached a stage where the relationship between understanding and interest in a subject is known. Whatever the case may be, teacher trainers are faced with the challenge of improving teachers' understanding of the nature of science and scientific knowledge. Exploration of teachers' views of science (knowledge, method, theories) during training could inform planning by methodologist to address inconsistencies in the conceptions of science, teaching and learning held by preservice teachers.

The paragraphs below highlight some of the research studies that have been conducted around teachers' conceptions of the nature of science, science teaching and subject matter knowledge. A review of studies on chemical bonding and acids and bases is also included later in the chapter.

2.2 Conceptions of science, teaching of science and learning:

From the literature surveyed there was a lot of overlap between science and science teaching, and teaching and learning within each of the research studies. Attempts are only made here to distinguish between conceptions of science and conceptions of science teaching/teaching and learning. Conceptions of teaching and learning are discussed simultaneously because the two processes are interdependent.

2.2.1 Conceptions of science

Promoting an appropriate conception of science is an important goal of science education (Lederman 1986). Science students' conceptions of science reflect the way science is taught, so it is important to understand the relationship between teachers' thinking and actions in class. Teachers' conceptions about the nature of science, science teaching and science learning may invariably be imparted to the learners in a variety of ways, including ways that the teacher was taught when a student (McDevitt et al. 1993). Whether intentionally or not, teachers convey to students what a subject is about, the nature of the subjects in their field and the meaning of teaching and learning a subject. All these observations demonstrate the connection between what teachers think and what they do (McDiarmid 1990).

Science as a body of knowledge is man-made and there is a general consensus about this knowledge that everyone adheres to. Achieving appropriate conceptions of science has been a prolific area of research in science education. Numerous arguments have been presented in literature regarding science, scientific method, scientific knowledge, science teaching. According to Hodson (1988) no general consensus has been reached on what constitutes the scientific method. Cobern (1989) asserts that numerous instruments for assessing teachers and students knowledge of nature of science have been produced and used and that the theoretical basis for the nature of science is well laid out in published studies, but it remains difficult to speak of the nature of science in common terms. Despite the observation that there is no unifying method of science, science is not a jumble of irrational happenings Hodson (1988). A few science educators like Driver et al. (1994) and Hodson (1988) also acknowledge that sometimes there is no single view which can adequately explain what is meant by the concepts science or scientific method. So each science educator presents a slightly different view from the other.

Earlier views of science were that science is an interconnection of concepts and conceptual schemes that developed as a result of experimentation and observation. Science was not viewed as a quest for certainty but a quest which was successful only to the degree that it was successful. Science was thus a speculative enterprise, an imaginative and explorative activity where intuition and imagination were the mainspring of advances in learning (Jenkins and Whitfield 1975).

Hodson (1981) described the views of science and scientific knowledge as multifaceted. In the subjectivist view, science resides in the minds of individuals as a set of beliefs justified by observation or reasoning. The objectivist view considers science knowledge to be man-made but independent of its makers once established. The consensus view of scientific knowledge is that it consist of facts, concepts and theories which are accepted by a community of scientists. Scientific knowledge is thus recorded for a community of scientists in a style and language approved by them and to which all practitioners and learners are expected to adhere. I feel it is this latter view that gave rise to the much researched and controversial area of misconceptions in science education.

Aguirre et al. (1990) agree with the view that scientific knowledge is a human construction and also advocate the idea that science is a process of constructing broader models for characterising and predicting natural phenomena. While Driver et al. (1994) assert that scientific knowledge in many domains consists of formally specified entities and the relationships existing between them. The concepts used to describe and explain phenomena are human constructions invented and imposed on phenomena in an attempt to explain or interpret them. Driver et al. (1994) also present the view that scientific knowledge is socially constructed, validated and communicated and that the learning of science is knowledge construction involving both individual and social processes agrees with Hodson's (1988) consensus view. Science is seen as a process of enculturation rather than discovery. Scientific knowledge cannot be discovered by empirically studying the world.

From this brief review it appears that there is some consensus underlying the tenet that science and scientific knowledge are human creations. Science is thus a culture with tools enabling its creators to understand the natural world. Science education has the responsibility of providing links between children's everyday experiences and this culture of science (Hawkins and Pea 1987, cited in Brickhouse 1990).

Aguirre, et al. (1990) conducted a study on student teachers' conceptions of science, teaching and learning. They found that students entering teacher education programmes possess a variety of views about science, teaching and learning. Their participants portrayed the conception that:

> ..... science is a body of knowledge comprising a collection of observations and explanations of how and why certain phenomena function in the universe; science consists of propositions which have been proven to be correct or which could not be falsified; science is an activity directed at technological advancement to improve lifestyles; scientific knowledge develops through formulation, testing then acceptance of theories; (384-5)

According to the authors, none of the students' responses displayed the idea that science constructs models for explaining and predicting natural phenomena. Another conclusion they drew from their study was that the views teachers hold at the start of their teacher training need to be exposed, discussed, analysed and modified to suitable conceptions which can be safely imparted to school children. They further recommended that preservice training include different strategies to develop skills in student teachers for interpreting and addressing children's prior knowledge.

While exploring the effect of beliefs of two experienced teachers and one beginner teacher about the nature of science on classroom practice, Brickhouse (1990) found though interviews and observations that the beliefs of the two experienced teachers of how scientists construct knowledge were consistent with their beliefs about how students should learn. However, this was not the case with the beginner teacher. She further recommended that preparation of prospective teachers should occur concurrently with their study of subject matter to enable them to see the connection between their views about the nature of science, nature of science learning and classroom practice.

Bloom (1989) assessed the understanding of science (knowledge science and theories, evolution) among preservice elementary teachers. He found that subjects in the study had strong anthropomorphic beliefs which strongly influenced their understanding of science, theory of evolution and how to teach this concept. This indicated that beliefs held by student teachers can influence their understanding of science. He concluded that mere exposure to accurate readings or instruction will not necessarily bring about an appropriate understanding of science. It seems that it requires purposeful efforts to expose inappropriate beliefs held by individual student teachers during training.

Abell and Smith (1994) analysed preservice elementary teachers' definitions of science and conceptions of the nature of science. Their results showed that the student teachers held naive realist conceptions of science (science discovers what is out there, scientists learn from observing the world, knowledge comes directly from observable facts). These researchers also found that the student teachers' ideas were very similar to those of grade 7 pupils. This observation led to the conclusion that the conceptions of science exhibited by the students were based on the science teaching they witnessed over years of schooling. They too, suggested that teacher training programmes should help prospective teachers understand how scientific knowledge is derived and how children learn.

2.2.2 Conceptions of teaching and learning

Having been learners themselves and having observed teachers at work for long periods of time, preservice teachers are likely to have already developed some views about teaching and learning, even though such views may not be acceptable to science teacher educators (Abell and Smith 1994; Carter 1994; Aguirre and Haggerty 1995). Also a large proportion of prospective teachers enter formal teacher education institutions in possession of many beliefs and perspectives regarding the roles and practices of teachers in classrooms and schools (Cole and Knowles 1993; Calderhead and Robson 1991; McDiarmid 1990; Bramald et al. 1995; Weinstein 1989).

The act of teaching is conscious and purposeful and ideally every teacher should have adequate and appropriate knowledge to communicate to the those being taught (Lederman 1992). The same view is echoed by Hewson and Hewson (1988) who advocate that the logical truth of teaching is that one necessarily teaches somebody something. Teaching is also a specialist profession, not just anybody can teach. Teachers possess a specialised body of knowledge acquire through training. (Hewson and Hewson 1989). Teachers have a goal-orientation in relation to it's clients - the students. Teaching is a professional thinking activity. The teacher must posses a body of specialised knowledge. (Calderhead and Robson 1991; Hewson and Hewson 1989). Unfortunately, the profession does not receive the professional status it deserves.

Science teaching is constrained by the presence of activities and tasks which are intended to help the learners learn particular content, knowledge, skills, attitudes and the activities should relate to content the to be learned (Hewson and Hewson, 1989). The content should also be within the competence of the pupils (Head 1982; Strike and Posner 1982) and presented in such a way that it is possible for the learner to learn it (Hewson and Hewson 1988). Teaching is an active process which depends the knowledge and skill of the teacher, the ability of the teacher to transform content by adapting it to suit the learning capability of the learners (Hewson and Hewson 1988). Thus the central role of teaching science is to enable the student to reach a state of mind in which they can understand phenomena and perform the task of learning (Hodson 1985; Hewson and Hewson 1988). However, there is no requirement that learning occurs simultaneously with teaching though the two can be closely linked (Hewson and Hewson 1988). For teaching to result in learning, the learner must have the intent and motivation to learn. The teacher cannot do more than facilitating the learning process. It is practically impossible to teach anyone who is not willing to learn or who will not learn. (Jeffreys 1971).

Teaching and learning are complex processes which occur under a variety of conditions (Head 1982). In an earlier paper "What is teaching?" Hirst (1971) demonstrates the polymorphous nature of both teaching and learning and the dependence of teaching on learning. As a result of the many different forms that teaching can take, he believes that many activities can be interpreted as teaching activities. But he further argues that teaching can be used to label those activities of a person (the teacher), the intention of which is to bring about in another person (the learner) deliberate learning of something. From this statement it is obvious that teaching cannot be separated from learning (see below).

> The intention of all teaching activities is that of bringing about learning. [...] the concept of teaching is totally unintelligible without a grasp of the intention of learning. [...] there is no such thing as teaching without the intention to bring about learning and therefore one cannot characterise teaching independently of characterising learning. Until, therefore we know what learning is, it is impossible for us to know what teaching is. The one concept is totally dependent on the other. Because of the tightest conceptual connection then the characterisation and *raison d'etre* of teaching rests on that of learning". (Hirst 1971:9)

Learning and the growth of scientific knowledge is not a matter of adding to one's store of concepts or the accumulation facts (Strike and Posner 1982). Nor is it a matter of acquiring "nuggets of truth" (Lakin and Wellington 1994). Learning is the alteration of prior conceptions (Brickhouse 1990) and the transformation of current knowledge. Learning can be better understood if conceptual change is understood. The process of teaching involves "clarifying content presented in texts, explaining solutions to problem, demonstrating principles, providing laboratory exercises, testing for recall of facts, ability to apply knowledge to problems". Teachers should be able to diagnose, analyse and correct errors in students thinking. (Lakin and Wellington 1994).

It is important for teachers to have both subject matter knowledge and the skill of translating that knowledge to the students they teach (Hollingsworth 1989). On investigating changes in elementary and secondary preservice teachers' knowledge and beliefs about reading instruction, she drew conclusions similar to Aguirre et al. (1990), that student teachers have definite prior conceptions about teaching and learning, though these may not be coherently expressed. Preservice programmes therefore need to understand these prior conceptions to appreciate student teachers' learning and inform their supervision.

Aguirre et al. (1990) also found that the student teachers regarded

> ..... the teacher is a source of knowledge which is transferred though the process of teaching; the teacher is a guide who mediates understanding through teaching; learning is intake of knowledge; learning attempts to make sense of new information in light of existing knowledge, learning will occur as a result of motivation.(Summarised from several pages)

Aguirre and Haggerty (1995) further note that few investigations examined concepts about teaching brought by preservice teachers to teacher education programmes. They argue that teacher educators concentrate on teaching aspects with the hope that improved learning will follow from improved teaching, instead of focusing on both teaching and learning. They advance that developing an awareness of other features of learning, the individual's learning proficiency may improve. Aguirre and Haggerty (1995) seemed to follow up on their 1990 suggestion. They investigated preservice teachers' (with pure or applied science background) understanding of learning through interviews on three occasions throughout the year of study. The results again showed that the group of student teachers held diverse conceptions and ideas about learning and teaching, with some indicators that some did not seem to have a clear view of what learning concerns. They also found that the students had not changed their views substantially across the three interviews. They concluded that the theories identified by the study must have been developed informally and were atheoretical and were likely to influence their first few years of teaching. This study confirmed that these prior conceptions are tenacious as numerous studies have shown.

2.3 Review related to subject matter knowledge

2.3.1 Subject matter knowledge and teaching

Research on teaching effectiveness has consistently neglected the importance of subject matter yet it is the central aspect of classroom life. Very little research seems to have focused on subject matter in teaching studies, on how it is transformed from the knowledge of the teacher into content of instructions (Shulman 1986). Of all the literature on alternative conceptions in science sampled from ERIC 1982-March 1993 only five references on teacher misconceptions in science are provided (Goodwin 1995). The status of subject matter knowledge of preservice teachers has not been extensively researched either. Research on practising teachers' concepts, theories and pedagogical beliefs regarding content and subject matter is also a recent event (Baird 1988). He calls for much more research to be done on teachers' conceptions and in particular on certain specific content topics, like energy. This will result in a better understanding of the ways teachers' understanding of content influences their intellectual performance.

As mentioned earlier, the idea that teachers can be responsible for many of the errors that students may display has also been explored by Sanders (1993). She examined South African biology teachers' ideas about respiration and related concepts as a possible source of errors for students' conceptions in this topic. The results of her study suggested that pupils were in actual fact taught erroneous ideas because a large proportion of the teachers involved in the study appeared to have erroneous ideas about the process of respiration. She also proposes that if the problem of teachers being responsible for erroneous ideas is to be corrected or alleviated preservice and inservice courses have to be used. For example, by informing both preservice and inservice teachers of possible erroneous ideas that may be held by pupils about biological concepts *(and possibly chemical concepts)*, current research findings on misconceptions, factors that cause and exacerbate misconceptions like the dynamic nature of scientific knowledge, and the need for them to keep abreast. Student teachers' own erroneous ideas should be exposed and corrected.

There appears to be serious debates in research on the subject matter knowledge of teachers. Different people place different emphasis on the kind of knowledge teachers must have in order to be effective teachers. While acknowledging that teachers' subject matter knowledge may be inadequate, some still believe that helping teachers acquire better ways of presenting material will make them more effective. Others believe that in the teaching process techniques are more important than subject matter knowledge. Others still feel that subject matter knowledge is more important as can be seen from the research reported below.

Amongst the issues which emerge are

- the assumption that teachers know the subject matter they are to teach and all that they require is learning different ways to teach it (Mosenthal and Ball 1972).
- subject matter knowledge is a central aspect to classroom life (Shulman 1986)
- subject matter alone is inadequate for classroom instruction (Ferguson and Womack 1993)
- effective teaching requires both subject matter knowledge and pedagogical skills

From an analysis of how teachers interpreted and assigned roles to subject matter in an inservice programme Mosenthal and Ball (1972) concluded that teachers' subject matter knowledge is crucial for good teaching but does not necessarily guarantee effective teaching. A directly conflicting view is presented by Buchmann (1984) in her paper "The Priority of Knowledge and Understanding in Teaching". Here she strongly argues in favour of teachers being knowledgeable about subject matter over pedagogy skills. She points out that all professions use knowledge and in the teaching profession knowledge is what teaching is about. On the basis of this argument she criticises emphasis placed on teaching and skills in preservice work. She believes that no matter how useful these may be they do not add to the content knowledge that is required for teaching. She asserts that

> [...] while no degree of mastery of teaching skills can overcome lack of content knowledge, given content knowledge, we have something to teach. [...] The teacher's experience thoughtfully explored, can yield knowledge and insight that can help in teaching and understanding of children's thinking. However, no amount of reflection, observation of students, general information and personal experience can overcome lack of knowledge in areas such as mathematics and chemistry. On the other hand, content knowledge delimits the significance of management concerns and affects the very occurrence of management problems.
> (Buchmann 1984:30, 37-8)

Her strong convictions about this view are further demonstrated in her summary to her paper:

> Content knowledge is a logical precondition for the activities of teaching: without it, teacher activities such as asking question on planning lessons cannot proceed. This reminder about the meaning of the term teaching does not set minimal or desirable levels of content knowledge. It simply means the intrinsic connection between content knowledge and teaching as a distinctive form of professional work.
> (Buchmann 1984:45)

While Buchmann's argument is logical, her rejection of teaching skills is challenged by other science educators. The knowledge of science concepts does not necessarily imply that the persons' understanding of the nature of science and the scientific enterprise is as good. It also says very little about being able to communicate it. (Yager, Hidayat and Penick 1988). Their support comes from the abundant complaints about the teaching of university professors who are known to be well versed in science content. They agree with many other researchers (quoted below) that content preparation is necessary but insufficient for effective teaching. They strongly believe that preservice teachers be taught the history, philosophy and applications of science.

In another study exploring the subject matter knowledge of maths graduates who were placed in schools to teach, McDiarmid and Wilson (1991) noted that to expect teachers to know everything about the subject matter they might be teaching is to expect what is highly unlikely as shown by the extract below:

> It is assumed that teachers with bachelor's degrees know enough about the subjects they are going to teach before they enter the programmes and consequently little attempt is made to teach these teachers about subject matter. [...] it appears that many of these new teachers, however lack the fundamental knowledge of mathematics. (McDiarmid and Wilson 1991: 94)

Though their findings cannot be generalised beyond the sample used in the study, some questions could be asked of the assumptions made in other post graduate teacher training programmes:- Can it really be assumed that graduate students entering teacher training programmes know their subject matter and only need help in techniques of delivering it to the students they will be teaching?

Other science educators and researchers see the importance of subject matter knowledge in teaching and teacher education in a slightly different light. Though it is the central aspect of classroom life (Shulman 1986), knowing subject matter is more than representing and explaining concepts. It requires going beyond traditional content, knowledge of facts or concepts and their explanation. It demands an understanding of the structure of the subject and the ability to inquire within the domain (Mosenthal and Ball 1972; Shulman 1986; Yager et al. 1988). Therefore a teacher lacking in subject matter knowledge is less likely to teach effectively. Shulman also challenges the view presented by Buchmann (1984) by stating that

> Teachers must not only be capable of defining for students the accepted truths in a domain. They must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing and how it

relates to other propositions, both within the discipline and without, both in theory and in practice (Shulman 1986:9).

Ferguson and Womack (1993) also support the argument that content knowledge is insufficient for effective teaching. They contend that research studies have shown that expertise in subject matter alone does not make a person a good teacher of that subject, which implies the need for pedagogical skills. Ferguson and Womack (1993) further argue that there is very little evidence supporting the view that in depth subject matter knowledge beyond certification requirements makes teachers more effective or that increasing teacher's knowledge of their subject matter area beyond requirements will improve teaching performance. They conclude from their literature review on subject matter knowledge and how it affects performance in the classroom that there is evidence that subject matter knowledge is an important prerequisite for effective teaching, though not sufficient on its own. They also argue that acquisition of subject matter knowledge beyond requirements for the teaching certificate does not necessarily improve performance. Hauslein, Good and Cummis (1992) advocate the combination of the two views. They state that the ultimate test of understanding rests on the ability to transform one's knowledge to teaching but this can only be achieved when the teacher has a sound subject matter knowledge background and the skill to transform that knowledge. All the same increased interest in improving the quality of education has resulted in teacher education programmes requiring prospective teachers to be graduates in specific content areas before enrolling in teacher training programmes (Gess-Newsome and Lederman 1993). Understanding subject specific content and pedagogy is a necessary condition for learning to teach though not sufficient (Hollingsworth 1989).

Convictions similar to those above were also expressed by Gess-Newsome and Lederman (1993). In an assessment study of the final year of course work, they found that biology preservice teachers were unable to make appropriate links between related concepts within biology and the content they were going to teach - the students lacked the "connectedness" in explanations found in experienced teachers. Their conclusion was that these students were not being provided with a readily accessible, explicit structure (organised conception) of biology as part of their content knowledge offered by the respective academic departments. They believe that an integrated understanding of subject matter is vitally important for both students and teachers and cannot be separated from the teaching process. Teaching or thinking about how to teach the subject matter does influence the perception of the content or vice versa. They recommended hat preservice teachers be provided with opportunities to reflect on their subject matter structures to help them develop a more coherent structure of subject matter. This recommendation collaborates an earlier proposal by Hashweh (1989, cited in Hauslein et al. 1992) for the need for subject matter preparation of preservice teachers to be structured to complement the content they would be teaching in the future. This calls for a close study of the school syllabi during teacher training. Hauslein et al. (1992) also observe that teacher education programmes appear partially successful in teaching procedural knowledge (how to teach) but pays very little attention to the declarative knowledge (what to teach). There is thus a need to produce effective teachers who can integrate subject matter knowledge and pedagogy, that is teachers who posses pedagogical content knowledge. Collaborating evidence that teaching science can be challenging even for science graduates is provided by Goodwin (1995) from case studies involving graduate students halfway through their Postgraduate Certificate in Education and who had completed six weeks of teaching practice in secondary school. He also notes from his own experience that he came to understand fully certain very basic ideas in chemistry long after graduation. It also seems a fairly common occurrence that student teachers hold erroneous ideas even in areas of their own subject specialisation (Gunstone, et al. 1993)

In another study assessing the development of and changes in preservice science teachers' subject matter and pedagogy knowledge during teacher training Lederman, Gess-Newsome and Latz (1994) again found that student teachers appeared to possess a non-coherent pattern of subject matter. They were concerned that the fragmented style of presenting content possessed by these teachers may be imparted to students when they teach secondary school science.

In outlining a framework for teachers' knowledge Tamir (1988) stated that to be effective teachers must be knowledgeable in their subject matter and be capable of teaching it. But he draws attention to the obscurity of the meaning and scope of subject matter knowledge and what is involved in being capable to teach it. Lederman and Zeidler (1987) and Lambert (1988) share the opinion that teachers cannot be expected to teach what they do not fully understand. If they are intrinsically motivated enough to attempt to do so, they would not do justice to the teaching of those concepts. They feel a teacher must have at least a working framework of what s/he is expected to teach. These feelings concur with those expressed earlier by Hirst (1971) and Hewson and Hewson (1988) that in teaching somebody teachers another something. And if that something is science concepts they have to be in concordance with those generally accepted.

Teaching is a triangular interaction between students, teachers and subject matter, yet teaching studies often overlook the subject matter (Hashweh 1987; Goodwin 1995). Hashweh (1987) further supported other researchers like Lederman and Zeidler (1987) and Lampert (1988) regarding knowledge of subject matter to be taught. She studied the knowledge of specific topics in biology and physics using simulated incidents in these topics and involving experienced secondary school teachers specialising in physics and biology. She found that teachers tend to ignore details they cannot remember when they are planning to teach. Teachers not so cognizant of the topic were found to follow the textbook very closely and when no practical activities were provided in the book, only the knowledgeable teachers improvised. Knowledgeable teachers were also more likely to detect students' preconceptions more successfully, correctly interpret students comments and deal effectively with general classroom difficulties. The other teachers were more likely to reinforce preconceptions, incorrectly criticise students' correct answers or accept faulty information from students. The conclusion from the study was that teachers' prior subject matter knowledge affects different aspects of the transformation of the subject matter in textbooks while planning to teach and would affect the actual teaching process. Even though the study was not based on real classroom observations the results do demonstrate the possible shortcomings of insufficient content knowledge in a subject in classroom instruction.

2.3.2 Students' ideas on chemical bonding

Research on preservice teachers' understanding of specific science concepts seems very sparse. This section of the review of the literature explores what could be found in this area.

Hashweh (1987), op. cit. reported that one of three experienced teachers who specialised in biology explained photosynthesis using the molecular/energy approach. The explanation was characterised by emphasis on chemical and energy-related aspects of biological processes at cellular level. The ideas that came out of the explanation showed that the conceptions of the chemical bond and energy in biology may differ slightly from those accepted in chemistry. According to that teacher, energy is needed to make complex molecules and that chemical energy is stored in chemical bonds. Photosynthesis was seen to function to trap energy in chemical bonds by attaching molecules to one another. Respiration was explained as a process of breaking down chemical bonds to liberate energy for cell activities.

The relationship between chemical bonding, energy and biological processes like respiration and photosynthesis seems fuzzy. Hapkiewicz (1991) reported that students stubbornly persist in believing that breaking chemical bonds releases energy. She accuses textbooks for encouraging this apparently erroneous conception by speaking in terms of energy-rich bonds in ATP molecules and energy stored in food molecules. Biology and chemistry teachers were therefore advised to work co-operatively in developing an accurate conception of chemical bonding in both these disciplines. She also proposed that an integration of biology and chemistry examples when teaching this topic would be helpful in alleviating the "supposedly" conflicting views presented in the two disciplines.

In a study to develop and use diagnostic tests to evaluate students' misconceptions Treagust (1988) reported that some of the students appeared to make consistent errors regarding intermolecular forces. Common misconceptions were the misunderstanding that "intermolecular forces are within a molecule" and that "covalent bonds are broken when a substance changes state". Peterson and Treagust (1989) reported that grade 12 students equated intermolecular forces with covalent bonds without any awareness of the variations in the strengths of covalent bonds compared to intermolecular forces. These ideas were found in students, but to what extent are they due to teachers' own erroneous conceptions of chemical bonding?

Bradley, Gerrans and Matthee (1985) provided evidence from their study of the views of secondary science teachers and student teachers about chemical bonding that pupils' misconceptions about chemical bonding are due, in part, to teachers' own misconceptions. They further noted that newly qualifying graduate teachers share the same misconceptions as the students and are likely to further pass them on to the pupils they teach. From this study it was found that both experienced teachers and student teachers exhibited similar views to misconceptions prevalent amongst students. The researchers attributed these misconceptions to the inadequacies of teacher training programmes in developing scientifically correct views about chemical bonding. For example, the misconceptions they found were that the forces holding atoms together in a molecule of carbon dioxide result from the overlapping of orbitals or sharing of electrons and confusion between causes of and effects of bond formation. Another prevailing misconception in the group studied was the use of the octet rule as an explanation of the formation of CCl_4 molecules from atoms.

Another study by Harris (1992) showed that even after treatment using a specially prepared package for addressing known misconceptions the following ideas were entrenched:

- chemical bonds in sodium chloride crystals are primarily due to attraction between oppositely charged ions,
- brittle solids have weak chemical bonds,
- forces holding C and O atoms in CO result from electron sharing (rather than electrostatic forces);
- chemical bonds form between two atoms because the atoms may share one or more pairs of electrons;
- that the actual distance between atoms in a molecule of H_2 is equal to the bond H-H bond length

Chemical bonding appears to be a relatively difficult topic, particularly because there are some inconsistencies in its treatment in biology and chemistry. Examples are the high-energy bonds in ATP molecules, respiration as an energy releasing process, photosynthesis as a process of converting and trapping light energy in complex molecules. As suggested by Bradley et al. (1985) amongst others, teacher education is the suitable starting point in addressing issues of subject knowledge and misconceptions of teachers. But this aspect is sensitive. Student teachers enter teacher training programmes in possession of high self-esteem founded on their academic achievement, and for someone to expose their erroneous ideas in their area of specialisation could have detrimental effects on their confidence (Gunstone, et al. 1993)

2.3.3 Students' ideas on Acids and Bases

Research on preservice teachers' concepts of acids and bases is limited. Some studies have been conducted with secondary school pupils. Ross and Munby (1991) noted that the topic of acids and bases occupies a central place in high school curricula, but surprisingly little is known about students' conceptions in this area. They conducted a study in which they involved high ability physics students in their final year of school and investigated in depth the concepts held by these students. They reported that from multiple choice data every-day phenomena of acids and bases and the concept of pH appeared to be well understood by many of the students. But in interviews some students appeared unaware that pH also applied to bases as well. They also reported that students experienced difficulties with base ions and ionic equations and writing and balancing chemical equations.

Another study by Cros, Chastrette and Fayol (1991) assessed knowledge and understanding chemistry of concepts among first year university chemistry students and how these progressed through the year. Their findings revealed that students' conceptions were positively modified by university teaching. Descriptive definitions of acids and bases changed to more scientific ones for the Bronsted-Lowry and Arrhenius theories. They also found that students continued having more difficulty relating to bases (defining and naming) than to acids. The perception of the base as a donor of OH^- ions also persisted. They concluded that despite their positive progress students seemed unable to see the relationship between the scientific notions they appeared to have mastered in their first year chemistry courses and their practical applications. They however, attributed this observation to the lack of practical work done this area.

An area related to acids and bases investigated by Schmidt (1991) was secondary school students' ideas and problems with the concept of neutralisation. Students' responses showed that there was a general assumption that acid-base neutralisation always resulted in a neutral solution irrespective of the strength of the acids and bases taking part in the reaction. Other students thought neutralisation to be an irreversible process. He proposed that students can be helped to develop a better understanding of this concept, particularly in reactions involving strong acid and weak bases by making them understand the two reactions involved, namely protolysis of the weak aid and the reaction of hydrogen ions and hydroxide ions to form water.

Among the few available a more directly related study was conducted by Mosimege (1995). Mosimege investigated physical science preservice teachers' misconceptions of acids and bases and how they relate to the students chemistry background. He also explored how the knowledge of acids and bases of college of education students compared with that of university students. Results of the study led him to the conclusion that the preservice teachers definitely had misconceptions in the topic of acids and bases. There were, however, no differences found between the two groups of students. Misconceptions were found in both groups. Problems found to be experienced by students related to identifying non-properties of bases, predicting the pH and order of acidity among substances, familiarity with examples of weak acids, and microscopic representations of aqueous solutions, limited familiarity of acid base th[illegible]s such as the limitations of Arrhenius theory were

2.4 Directions from Literature Review

Student teachers and practising teachers hold a variety of ideas about the nature of science, teaching and learning. It appears that teachers are responsible for many of the conceptions of science, teaching and learning and erroneous ideas regarding science concepts that students, and in turn, future teachers have. Generally these ideas are formulated both informally and formally during schooling and influence prospective teachers' thinking about their future profession in teaching and their initial field experiences. It has also been suggested that these invariably pass on to students, evidenced by shortages of students following science based careers especially in education. It also appears that unless these ideas are addressed directly by identifying, exposing and discussing them they will not be changed by normal insruction. Many of the researchers cited above are calling for teacher training programmes to help teacher trainees and practising teachers change their naive conceptions and to acquire appropriate conceptions of science, teaching and learning. In this way it is hoped that these will be passed on to the students and possibly more students will do science subjects.

Teacher education programmes need to take account of teachers' conceptions about the nature of science, teaching and learning. The desired outcome is for science teachers to acquire a conception of "teaching as conceptual change" because then they will plan for and use teaching activities which are based on students' conceptions. Teacher education activities which will help teachers acquire a conception of teaching as conceptual change need to be developed. Teachers also have to acknowledge that many of their conceptions are inappropriate and be willing to change them for more acceptable ones.

If learning science is viewed as a continual process of conceptual change, science teachers need to be able to facilitate that process, they need to know what their students know and plan their instruction to accommodate that. The call is for future science teachers to develop an understanding of how children learn science and how scientific concepts are constructed and therefore changing and not a fixed body of knowledge.

The deficit of adequate subject matter knowledge among preservice teachers maintains the vicious circle of underprepared students leading to underprepared teachers. Teacher trainers need to be aware of student teachers' limitation in subject matter. Student teachers need to be aware of their own shortcomings in content. If this is to be achieved concerted efforts are necessary to assist prospective teachers acquire appropriate conceptions at the same time they develop skills of how to transform knowledge to promote its understanding by pupil. Then there is a need for subject matter preparation of preservice teachers to be structured to complement the content they would be teaching in the future. This calls for a close study of the school syllabi during teacher training.

The present study attempts to identify and describe selected student teachers conceptions of science, teaching and learning how they influenced their experiences of the programme, as well as aspects of their content knowledge and how all the above affected their teaching practice. Throughout this review, science researchers and educators seem to be calling for a unifying view on teacher preparation: that of preparing teachers who have both subject matter knowledge and pedagogical skill and who can integrate these for effective teaching and learning.

2.5 Sources for methodology

Three main studies provided ideas for the design of the whole methodology of this study. These were Gunstone et al. (1993, op. cit.), Aguirre et al. (1990) and Hewson and Hewson (1988). As already mentioned above, the study reported by Gunstone, et al. (1993) provided the framework for exploring preservice teachers' experiences of the programme through diaries, interviews and observations of HDE classes and triangulation of the data. The three studies also provided questions for the interview schedule used for the initial and final interviews, with minor adaptations (See appendix 1 for specific contributions). Other studies used to derive ideas for data collection were Lederman and Gess-Newsome (1991) and Ellwein, Graue and Comfort (1990), used for the unstructured interview on teaching practice experiences.

Diagnostic tests used were obtained from Harris (1992) and Mosimege, (1994). The two were modified by either excluding questions or combining questions. Some ideas from Harris (1992) were also used for analysis.

CHAPTER 3:

METHODOLOGY

CONTENTS OF CHAPTER 3 PAGE

3.0 Introduction

This chapter describes the procedures used to obtain data on the experiences of selected Higher Diploma in Education students as they progressed through the course. It explores some aspects of their subject matter knowledge on chemical bonding and acids and bases and that of their colleagues'. I also explores their conceptions of the nature of science and its teaching and learning. Several methods were employed to obtain data for the study. These methods included three interviews with each of the selected case study students, observation of selected lectures and selected teaching practice lessons and diaries for those who could keep them. It was hoped that by using several different methods triangulation of data would be achieved. Diagnostic tests were also used for testing subject matter knowledge of the whole class.

Before beginning the actual study, I had discussions with the physical science methodologists during which we agreed that I could sit in the lectures. I also interviewed the chemistry methodologist to find out a bit more about the HDE programme as a whole. On the first day of the physical/general science methodology lesson I was introduced to the whole class of HDE students. The students were also informed about my intended study and their anticipated co-operation in the process. This broke the ice in preparing for my future attendance of the lectures. I then attended a few lectures for a start, getting a general feeling of what to expect and also becoming familiar with the students. This enabled me to identify suitable subjects for the study.

3.1 Selection of Subjects

By the end of the first block I had identified the subjects for the study, three at first, all males. But this soon changed when one of them failed to return in the second block of the university calender (i.e. May). I had to find more subjects. I then selected two female students to balance the two male students!

Thus four of seventeen HDE physical/general science methodology students were eventually selected for participation in the proposed study. In this respect the study was four case studies within the context of the class. The first selection of the three male students was based on the premise that they were "similar" to the students I would be working with as a teacher trainer on my return to Swaziland. These students could be considered comparable to Swazi students in terms of school background (exposure to school science facilities) and to some degree, cultural background. I was looking for students from non-TED schools, students who came from the (so-called) "disadvantaged" background in the South African system. Unfortunately two of the initial three students deregistered, one at the end of the first block and the other during the course of the second block, as mentioned above. Attempts to ascertain reasons for withdrawing were partially successful in the case of the second student, but no attempts were made to ascertain reasons for withdrawal by the first student as this happened very early in the course. A detailed description of each of the three remaining students is given in chapters 5, 6 and 7. Willingness to participate in the study and accessibility during teaching practice were other criteria considered when selecting subjects. Fortunately all the students who were approached expressed willingness to participate in the study without any problem.

This study focuses on the three case study students who completed the programme:

- Andrew, a male with some teaching experience in mathematics and science and who hold a BSc degree with a chemistry III major. Andrew was teaching part time as well during his training.
- Ferrial and Mary, young women who have no teaching experience, and who hold a BSc degree in biological sciences and chemistry 1.

The fourth subject is not included in the write up. The reason for this is that only the initial interview was conducted. When he eventually came to an interview he was in a highly upset, emotional state. Analysis of his interview transcripts did not provide useful data for the purposes of the study. He did not answer the questions satisfactorily in order to provide answers to the research questions. He was an interesting case in that he raised several sensitive issues not directly related to the study. He subsequently withdrew halfway through his HDE studies, so data from his interview was insufficient for a complete case.

3.2 Data Sources

The main data collection procedures were interviews, classroom observations and diagnostic tests. The interview schedule was adapted from those used by Hewson and Hewson (1989), Aguirre et al. (1990), Gunstone et al. (1993). Another interview schedule (consisting of only ideas) was designed using ideas from Lederman and Gess-Newsome (1991). Diagnostic test were taken from Harris (1992) and Mosimege (1994) with very minor adjustments.

3.2.1 Interviews

Three interviews were conducted for each case study. The first interview of about 90 minutes was conducted at the beginning of the study. The last interview was held at the end of it all, when they had concluded their classes. The first interview was used to ascertain the participant's background, their initial conceptions of science, science teaching, teaching tasks and learning. The third interview was similar to the first one except that it focused more on participants' conceptions of science, teaching and learning, and their perceptions of the methodology and additional studies course. The interviews were semi-structured and on a one to one basis. An interview schedule (see Appendix 1) was developed by adapting ones previously used by Hewson and Hewson (1988), Aguirre et al. (1990) and Gunstone et. al. (1993) and recreating some questions from ideas presented in these studies. The interview was piloted on two postgraduate students, for timing, questioning order and phrasing. As a result of this, the schedule was shortened. For two of the participants, Andrew and Ferrial, a second interview was held during the teaching practice period. The aim of this interview was to explore their feelings of the teaching practice process, difficulties or problems encountered, successes and failures. Ideas for these questions were obtained from a few studies including Lederman and Gess-Newsome (1991) and Ellwein, Graue and Comfort (1990). For Andrew the second interview also served to obtain data on his experiences of the physical science methodology course and the programme as a whole because he was unable to keep or hand over a journal. For the third participant, Mary, the teaching practice interview was combined with the last interview because it was not possible to conduct the interview during teaching practice due to time constraints. Parts of the teaching practice data had to be obtained later because Mary was unable to answer the questions as she first needed to reflect on her teaching practice experiences. These interviews were tape recorded and transcribed verbatim. Initial interviews involved the four participants, but only three participants took part in the later interviews. The fourth student (the second to withdraw) was excluded from this report because his interview transcript showed that he did not answer the questions satisfactorily, making it very difficult to find patterns and generate statements in a similar way to the other three cases.

3.2.2 Journals

The idea of using journal keeping by participants as a source of data was also taken from Gunstone et al. (1993). Participants were also asked to keep diaries of their experiences (feelings, perceptions, impressions, likes, dislikes, etc.) of the lectures and or classes they attended for the programme and teaching practice. As expected, this proved to be an onerous task. However, one of the subjects really made an impressive effort to keep one even during teaching practice. This journal proved very useful in accessing her experiences. Another case study participant kept one before going to teaching practice, but was unable to continue. These two diaries were collected at the end of their formal training. The third participant claimed to have kept one but it was never received despite efforts to get it back.

3.2.3 Class observations

The third data source was classroom observation. The three students were studied while interacting with their colleagues and the lecturer during classes and were also observed during their teaching practice. Teaching practice lesson observed for the three remaining students were on acids and bases, chemical bonding and on convection and radiation.

The observations of the classes were intended to be unobtrusive. As a researcher I was a non-participant observer in the sense that I made no contributions during observation of any of the lessons. My role was known to all the student teachers. During each observed session I would sit either behind the students during lectures or at the back on one side of the class during teaching practice, after setting up recording equipment. This strategy has been suggested as the best way to achieve non-participatory observation (Cohen and Manion 1985). Furthermore, I referred students who asked questions to the teacher, though sometimes I was tempted to answer them. I also made sure that I was present before the lesson started. Occasionally, during teaching practice the venue would be used by another class just before the lesson to be observed. This meant that I had to set up the audio-recording equipment while the students were settling down. I observed a number of teaching practice lessons and before long students felt comfortable with me and the curious students talked to me about my purpose there at the end of the lesson.

Physical science methodology lectures

Several classes were observed including three on chemical bonding, one on acids and bases, symbols and representation, the nature of science. Detailed field notes were only made during two chemical bonding classes (see Appendix 4 fieldnotes for class discussion 1) because these classes actually focused on both content and pedagogy. An ordinary audio-tape recorder was used to make tape recordings of these classes were made for purposes of enriching the field notes. Audibility was not of the best quality as can be noticed in the transcripts and field notes in Appendix 4. A record of the activities and verbalisations was also kept.

Teaching Practice

My initial introduction to the school principals was very informal. I simply went with M1 to the respective schools. M1 informed the principals about the purpose of my visit and requested permission on my behalf to visit the school as I wished. She did not see it necessary to make it formal and as she had thought the principals were casual about it too. It was thus not necessary for me to report each time I was at the school. For each visit I made to the school I went straight into the laboratory or classroom where the lessons were held.

The same procedure as that used in the physical science methodology lectures was used to obtain data during the teaching practice lesson observed. In these lessons verbalisations of students and teacher trainees were tape recorded and scripted where possible, classroom activities that took place were also noted. An attempt was made to record as much as possible of what happened during those lessons.

The classroom observations conducted for this study were very unfocused. I was more general in the observation without focusing on particular things. I tried to record as much as possible of what went on during the lessons. Field notes, some enriched by tape recordings, were made. However, in analysing the field notes some degree of focus was required and the categories guiding the description were identified.

3.2.4 Diagnostic Tests

Diagnostic tests to ascertain the status of the students' subject matter knowledge on chemical bonding and acids and bases were administered to the whole class. The two topics, acids and bases and chemical bonding, were selected because they are discussed as part of the science methodology course and there was a good chance of these topics being taught during teaching practice. The tests are given in Appendix 2A and B.

The acids and bases test (Mosimege 1994) consisted of twelve multiple-choice questions and seven structured questions. It was administered to the whole class during the last two weeks of the year. The reason for asking the students to write only one test was that the test itself was being developed and it was not possible to obtain the a test in time. The topic was discussed earlier in the year - May when I was not ready. The test was long, so it was given as a "take home test". Only six out of fourteen test scripts were returned for analysis.

For chemical bonding a test adapted from Harris (1992) was administered as a pretest a week before the topic was discussed and as a post-test during the last lecture of the year. The test had ten multiple choice questions. To probe deeper the students' understanding of chemical bonding concepts, students were asked to give reasons for selecting their answers. The pretest was again given as a take home test because of time constraints and ten were returned.

Students' chemical background was also sought, from M3, for purposes of establishing links between chemical background and knowledge of chemistry concepts.

3.3 Reliability and Validity

This is a qualitative study. It is well known that data obtained from qualitative studies are subjective in nature and therefore vulnerable to validity and reliability criticisms. Methodological triangulation (Cohen and Manion 1985) was used in an attempt to ensure some reasonable lev of reliability and validity. As indicated above the present study made use of triangulation between the methods used for data collection: observations of lectures and teaching practice lessons where field notes and tape recordings were made, semi-structured participant interviews and to a lesser extent diaries. The idea of triangulation in this study originally came from Gunstone et al. (1993).

3.4 Data analysis:

Data analysis involved a stu... of the sources of data for content. This helped derive information about participants experiences through the course, their conceptions of science, science teaching and learning and teaching tasks, and any patterns of change in these, patterns in classrooms practice and their perceptions of their successes and failures. This was done for each participant. Data analysis procedures were also derived from the studies which shaped data collection procedures.

Analysis of the diagnostic tests focused on aspects of science content in which students appeared to be experiencing problems, and how these were dealt with during class discussion in the case of chemical bonding. The diagnostic test scores were used for qualitative purposes, for indicating the status of the subject matter knowledge of the class in the topics tested. Analysis of the diagnostics involved identification of students' ideas on concepts related to chemical bonding and acids and bases. Responses in the pretest and post-test were compared to determine any changes that might have occurred as a result of discussing the topic (chemical bonding) in HDE classes and/or teaching it during teaching practice. Chapter 4 describes aspects of chemical concepts explored in the tests.

3.5 Generalisability

This study involved case studies. Case studies can be unique instances in many aspects. Student teachers enrolling in the HDE programme can vary from year to year both as a group and as individuals. Because of this characteristic of the study the findings cannot be extended even to the next member of the same class. Though generalisations cannot be drawn from this study, it would certainly inform any researcher who considers embarking on a similar study since

> we would suffer long delays indeed if our every new encounter required us to start afresh rather than rely on previous experience in discerning an essentially predictable world. (Wolcott 1994:33).

For this reason a detailed description of the findings is given in chapters 4, 5, 6 and 7 to allow "enthusiastic" readers to make their own interpretation and draw their own conclusions from this study (Wolcott 1994; Brickhouse and Bodner 1992).

C TER 4

SUBJECT MATTER KNOWLEDGE.

CONTENTS OF CHAPTER 4 PAGE

4.0 Introduction

Until recently post graduate teacher training programmes have ignored the subject matter knowledge of teacher trainees leading to their partial success in teaching procedural knowledge and inadequate support for declarative knowledge (Hashweh 1987; Hauslein, Good and Cummis 1992). Only recently, in the mid 1980s, have serious debates taken place regarding the importance of subject matter knowledge versus education courses in preservice programmes (Ferguson and Womack 1993). In this study attempts were made to explore the importance of discussing content in reducing the teaching of misconceptions in the classroom. As mentioned in Chapter 3, the areas of focus in this study were chemical bonding and acids and bases. These two topics were chosen because they were discussed in methodology classes and from previous observations by M1, these topics are taught during teaching practice. This would make it possible for me to observe their teaching.

This chapter is divided into two main sections. The first part contains the analysis of the field notes taken during methodology classes devoted to chemical bonding and an analysis of student tests on the topic. The aim was to ascertain the status of the HDE students' content knowledge in chemical bonding. The second part focuses on the students responses to the acids and bases test.

4.1 Chemical bonding

Student teachers' views about chemical bonding and related concepts were determined by analysing their responses together with explanations, in both a pretest and post test. The post test was administered when all the classes discussing chemical bonding had been completed. The test was used to establish the status of students knowledge of chemical bonding concepts before instruction and to establish whether any conceptual change took place during the teaching of the course.

4.1.1 Diagnostic test analysis:

The test was used to determine HDE students' views on the following aspects of chemical bonding, discussed in the order given below.

- origin and nature of the chemical bond (test questions 1, 4, 5);
- *distinction between intermolecular and intramolecular forces (test questions 3, 7, 8);
- atomic and molecular dimensions (test question 6);
- *link between macroscopic properties and microscopic structure (test question 2);
- *structural change during phase change (test question 9) and
- understanding of the term molecule (test question 10).

The numbers in parenthesis correspond to the questions in the test (see [Appendix 1A]) dealing with the aspect investigated. (*These classification aspects are taken from Harris (1992).

As mentioned in Chapter 3, the pretest was given in a questionnaire form as a take-home test prior to the discussion of the chemical bonding in the physical science methodology classes. The test was given a week before the discussion of chemical bonding started. Only ten of the sixteen student teachers in the class returned the questionnaires in time. Ferrial (one of the cases in this research) only returned her responses after the discussion had started. Analysis of students' conceptions on these aspect of chemical bonding are therefore based on only the ten questionnaires returned on time. The post test was written during the very last lecture of the course. Fourteen students were present. Data from the additional four students has not been included in the discussion because they were not useful in showing the effect of the chemical bonding classes in the methodology course and additional studies.

4.1.2 Observation of methodology classes

The field notes taken during the class discussions on chemical bonding were analysed with a view to determine aspects of chemical bonding addressed in these classes and issues that seemed problematic for the student teachers. The discussion below will integrate relevant aspects of the field notes with issues arising from the pretest and post results. It is hoped that such a fairly detailed discussion will inform the conclusions drawn regarding the effect of discussing chemical bonding in the HDE courses. The term 'class discussions' is preferred to lectures because as with the other sessions these were more of a discussion between the lecturer and the student teachers as opposed to normal lectures where the lecturer does most of the talking.

General features of the observed class discussions.

Four class discussions on chemical bonding were observed. Three were offered in the physical science methodology and one in the physical science additional studies. Two of the three physical science methodology class were conducted before teaching practice and focused on content issues. They helped students revive their content in the topic and addressed errors in their conceptions of chemical bonding and related concepts. These two class discussions also highlighted contradictions between material being presented in class and that current in school textbooks and notes. The lecturer highlighted problems that had been experienced in this connection in the past. The lecturer also stated that they wanted

> [...] to get students' ideas on how to cope in teaching practice. The main concern is that you are well equipped for the topic before you go out to teach. [CD1:263]

Class discussions

The topic on chemical bonding was offered by a lecturer (M6) from one of the colleges of education in Johannesburg in conjunction with M1. M6 introduced the first session of the discussion by relating bonding to strength of materials used in construction of structures requiring immense strength: such as concrete, steel bars and stone, but not plastic. With these example she was able to relate the strength of construction material to their microscopic structure: the bonding between the atoms.

The first discussion session focused on

- origin of forces of attraction and bond formation.
- network and simple molecules
- chemical reactions and chemical bonding
- hydrogen bonding and intermolecular forces

The second class discussion which came a week later explored further some of the issues raised in the first session and also explained and consolidated student teachers' understanding of chemical bonding and related aspects.

In the second session the following aspects were discussed:

- cause and effect of chemical bonding, including its definition
- hydrogen bonding
- structural representation
- covalent, ionic and metallic bonds
- dimensions of atoms and molecules.

It will be noticed that the first two were dealt with in the first session. In the second session they were taken a step further for more clarification.

At the start of the first class discussion on chemical bonding, an assignment was given to the student teachers. This was aimed at getting them to think about how to introduce chemical bonding to secondary school students. The second class discussion was thus introduced by first looking at the assignment questions and student teachers' ideas arising from these questions.

During the methodology classes, chemical bonding was discussed in an open ended way and student teachers were encouraged to review their own understanding of the concepts and to question their views on the concepts as well as to address their questions. All the aspects of chemical bonding in the diagnostic test were discussed in these classes. The reason, though not ascertained, could be that M4's review of the pretest responses prior to the class discussion gave her some insight to specific problem areas that could be addressed. Attempts have been made to show this by integrating the students' responses in the test and the manner in which these concepts were addressed. Class discussion of each theme will follow the description of the responses for each theme. The pretest served to inform the methodologists of the students' conceptions prior to discussing chemical bonding. There were more aspects of chemical bonding discussed in those methodology classes than reported here-those which were not directly linked to the question in the diagnostic test have been excluded.

4.1.3 Students' chemical background

The term "chemical background" is used here to refer to the highest level of chemistry done prior to enrolling in the HDE programme. This is summarised together with test scores for multiple choice questions in Table 4.1 below.

Table 4.1 Summary of HDE students of chemical background and test scores

Students*	Chemical background	Test Scores	
		Pretest	Post test
1Ferrial	Chemistry I	6	8
2 Mary	Chemistry I	4	5
3 Andrew	Chemistry III	4	6
Student 4	Chemistry III	6	9
Student 5	Chemistry III	3	7
Student 6	Chemistry III	6	7
Student 7	Chemistry I	3	9
Student 8	Chemistry III	5	9
Student 9	Chemistry II	4	9
Student 10	Chemistry III	5	8
		Class Average 4.6	7.7

* The numbers 4 to 10 are arbitrary labels for protecting student's identity

4.1.4 Test Analysis and Results

Results of the analysis of the multiple choice responses to all questions in both pretest and post test are summarised and reported in Table 4.2 below. The numbers in the table are the actual numbers of students who selected that option in each question.

Table 4.2 Summary of responses to multiple choice question for both the pretest and post test.

Options	A		B		C		D		Other	
Questions	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	9	2	0	0	1*	8*	0	0		
2	1*	2*	1	0	4	7	4	1		
3	0	1	1	2	7*	6*	1	2	1(BC)	
4	4	2	1*	7*	3	1	2	0		
5	3	1	1	0	1*	9*	4	0		1
6	1	1	2	0	1	0	6*	9*		
7	1	0	9	9*	0	0	0	1		
8	0	0	8	10*	2	0	0	0		
9	3*	6*	3	2	4	2	0	0		
10	1	0	0	0	1	1	8*	9*		

* denotes the correct option.

A method used by Ntho (1991) and Harris (1992) among others was applied to indicate those questions for which students changed erroneous ideas they may have held before the topic was discussed. In this method the possible effect of the class discussions on chemical bonding is shown by the shift in the number of students who change their views between the two tests. The data obtained from comparing responses of individual students in each question in the pretest and the post test are given in Table 4.3 below.

Table 4.3: Shifts in choice of option between pretest and post test for each HDE student involved in the study.

	QUESTIONS									
Shift	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
R-R	1	[illegible]	6	1	1	5	8	8	2	7
W-R	7	2	0	6	8	4	1	2	4	2
R-W	0	1	1	0	0	1	1	0	1	1
W-W	2	4	2	1	0	0	0	0	1	0
W-U	0	3	0	2	0	0	0	0	2	0
Total	10	10	9	10	9	10	10	10	10	10

Legend: R-R = right, W-R = wrong to right; R-W = right to wrong,
W-W =wrong to same wrong; W-U = wrong to different wrong;

With a sample size of 10, statistical analysis would be inappropriate. Therefore I cannot state with certainty whether shifts are significant or not. So a qualitative discussion is used in which actual students' views are explored in the aspects presented in each question in the test. Shifts are also included in the discussion and are represented graphically at the start of the discussion of questions where there appears to be big shifts or no shifts displayed.

4.1.5 Origin and nature of the chemical bond:

Question 1:

Figure 4.1 below illustrates the performance of the student teachers in both the pretest and post test.

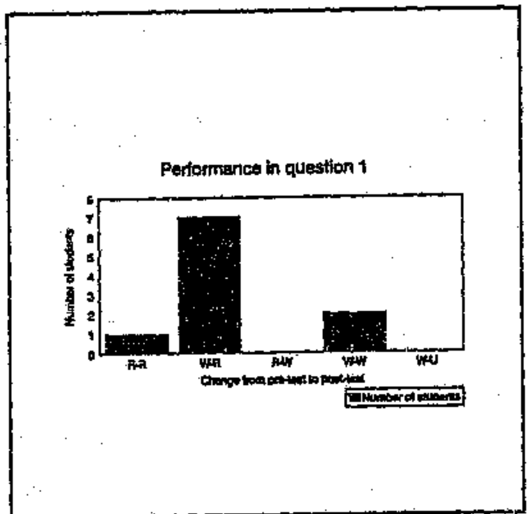

Figure 4.1 Performance shifts for question 1

Question 1 tested student teachers understanding of the primary cause of the chemical bond in the sodium chloride crystal. From Table 4.2 it will be seen that in the pretest only one student, Ferrial, appeared to hold a correct conception of the electrostatic nature of a chemical bond and she maintained this conception in the post test. While the rest (9) seemed to think that chemical bonds resulted from attraction of oppositely charged ions. The idea underlying the major distracter (A) was that of electron transfer from one atom to another to form oppositely charged ions which attract during bonding. The same conception was also displayed by Ferrial though she selected the correct option. Since Ferrial returned her responses later, it is possible that the class discussion influenced her choice of option C for question 1 as shown.

F: C*: Ionic bonds. NaCl consist of Na^+ and Cl^- ions held together by electrostatic attraction.

According to this reason the attraction is between the ions instead of electrons and protons which is the generally accepted conception.

(F represents Ferrial C* denotes correct answers. Explanations are also given verbatim or with minimum modification for purposes of authenticity of the ideas presented by the student teachers.) Similar ideas were displayed in the responses of five other students 5, 6, 7, 8 and 10. Student 10 went on show further inappropriate conceptions by stating that

> Electrostatic forces are very weak and could not be responsible for chemical bonds in NaCl.

The reason given by student 6, another chemistry major, for choosing A as the key displayed an understanding of the involvement of the octet rule in bonding thus:

> 6; A: Na is in group 1 and easily loses an electron to become a positive ion. Chlorine is in group VII and likes to gain an electron to become a negative ion. Both lose and gain electrons to obtain a more stable electronic structure, viz a full valence shell.

Similar observations were reported by Bradley et al. (1985), from a study where 73% of the student teachers involved perceived the octet rule as an explanation for the formation of CCl_4 molecule from carbon and chlorine atoms.

Data from analysis of the post test suggest a change in these conceptions by seven students (Fig. 4.1). Student number 6 did not seem to have changed his views on bonding in a sodium chloride crystal. The same idea presented in the pretest was given in the post test as shown by the response below.

> 6: The chemical bonds in sodium chloride crystals are primarily due to A: attractive forces between oppositely charged ions. This causes the atoms to come close enough together so that their respective atomic orbitals may overlap to form molecular orbitals.

There seems to be disparity within the response. While the first part has the connotation that oppositely charged ions are present and therefore no atoms, the latter talks of atomic orbitals overlapping due to ionic attractions.

Student 8 appeared to have changed views but disputed the concept discussed as the key in defining a chemical bond during the class discussions thus

> 8: C: electrostatic forces are not chemical bonds.

An interesting observation to note is that a student who seems to have changed his/her conceptions has actually not changed. For example student 8 chose the correct response but the reason given was in direct conflict to what was discussed in class. Ferrial's response is another example. What also emerged from the responses in this question was that prior to discussing chemical bonding, there was a strong perception that charged ions are responsible for holding the sodium and chlorine in the crystal lattice.

Question 4:

Figure 4.2 above shows the shift in students performance from pretest to post for question 4.

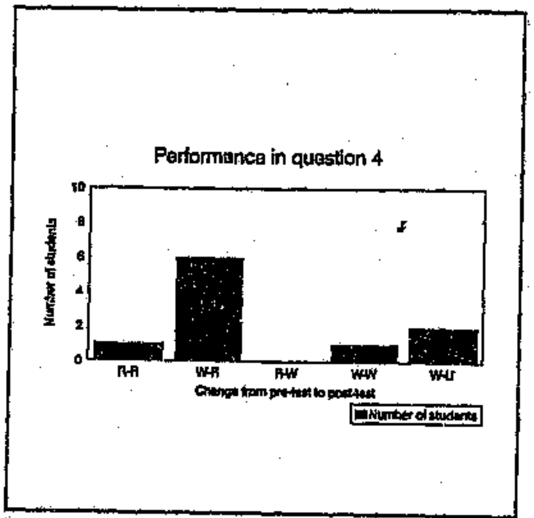

Figure 4.2 Performance shift in question 4

This question sought students understanding of the nature of the force holding carbon and oxygen in a carbon monoxide (CO) molecule. Again only one student, number 8, selected the correct option without adequately qualifying it with an appropriate reason. The explanation given by the student did not display much understanding of these forces. For example:

8: B*: Electrostatic attraction is a force. The question asked for the FORCE that holds the C and O together. Indeed there is an electrostatic force, options A, C and D do not refer to FORCES.

The other students gave the variety of explanations given below ranging from stable octet to orbital overlap:

3: C: the forces that hold the two atoms together is not electrostatic. A distribution of electron cloud density is responsible for the reaction

4: D: they are covalent bonds so share electrons not electron pairs and form a stable octet

6: A: Carbon doesn't share electrons and electrostatic attraction is out. A stable octet comes from sharing of electrons.

5: A: The bond in CO is a triple covalent bond caused by the overlap of p-orbital.

7: D: Electrostatic attraction occurs between ions and this is a covalent bond.

9: A: Electrostatic attraction (B) does not necessarily result in a <u>bond</u> to form a molecule. Although C and D are true in the bond of the molecule : they do not result in the <u>force</u> holding the atoms together; ie force as a result of orbital overlapping.

10: A: CO has a triple bond therefore pi bonding is involved —> orbital overlapping.

Notice how students 3, 6, 7 and 9 dismiss electrostatic forces as being responsible for bonding in carbon monoxide. It will also be appreciated from these explanations that prior to class discussion orbital overlap (option A) also dominated the student teachers' understanding of bonding in CO. Again a similar observation was made by Bradley, Gerrans and Matthee (1985). Also emerging is the perception that electrostatic forces have no role in covalent bonding, as in the case of CO. The importance of electrostatic forces in bonding was also not displayed for ionic bonding in sodium chloride in the pretest.

Student 7 clearly perceived bonding as involving ions as in the sodium chloride crystal to be different from covalent bonding, thus showing an understanding that there are different types of bonding as propagated by the syllabus and textbooks.

Post test analysis data again seem to show a shift in the conceptions of these student teachers (6 student teachers), and reasons given displayed some understanding. Option A was still a viable option for two of the students (3 and 6). Some examples of the views students showed in the post test are given below.

6: A: Orbital overlapping indicates that there are electrons close to the nuclei.

8: B*: Electrostatic attraction is a force - none of the other options have a connection with "forces".

10: C: A, B and D are all as a result of C.

Student 8 still uses the same tactic he used in the pretest to derive a reason for choosing the correct answer.

Question 5:

For Question 5 student teachers were required to show their understanding of the causes of chemical bond formation. Performance shifts for question 5 are given in figure 4.3 below. Notice how all the students chose the correct option in the post test.

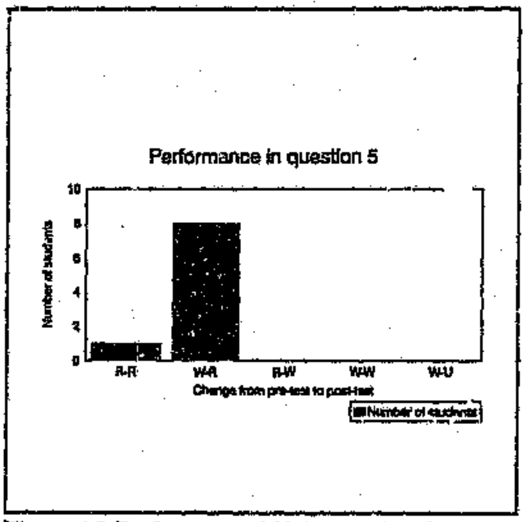

Figure 4.3 Performance shift in question 5

Again only one student (6) selected the correct option in the pretest, that chemical bonds form when electrons are simultaneously between the two nuclei of the bonding atoms. The student's reason for the choice of the option did not, however, demonstrate his understanding of the reasons for a bond forming.

6: C*: **Each of the other occurs only in specific cases.**

Major distracters for question 5 were A (sharing one or more electron pairs) and D (kinetic energy of the two atoms decreases). Below are explanations for the choices students made.

3: A: **chemical bonding occurs as a result of electron density shifts.**

4: D: **this is the ...*(word not legible)*.... are we can be sure of ie energy whole less than energy of individual parts. Other answers depend on the type of chemical bond.**

8: D: **Atoms will only bond if the energy state of the system after bonding is less than that of the separate atoms before bonding.**

9: A: **It is not the kinetic energy, but the overall energy that decreases (therefore not D) C does not result in a chemical bond; an octet of electrons is not necessarily obtained by a chemical bond (not B). By sharing**

electron pairs a chemical bond forms.

Students 4 and 8 display the same correct reasoning about energy changes in a bonding system, but they are not answering the question asked because the option they chose referred to the kinetic energy rather than the overall energy of the system.

Analysis of responses for question 5 in the post test indicated a large shift towards the correct response, shown in Table 4.3. Reasons by students 3 and 9 are the effect of the electrostatic attraction of electrons of two bonding atoms to the two nuclei, i.e. bonding.

5: A: A bond involves 2 electrons which are shared between atoms.
8: C*: C = BASIC definition of chemical bond.
10: C*: A, B and D are all as a result of C.

From the response given by student 5 there are indications of some understanding regarding the nature of a chemical bond, though she did not answer the question. Students 8 and 10 chose correct options but the reason were not convincing.

Major variations from accepted chemical bonding concepts exhibited in the pre- test were related to the cause and effect of the chemical bond (Harris 1992). Students believed chemical bonding results from the formation of a stable octet (3), orbital overlap (3); electron sharing (3), all of which are the result of the force of attraction between the protons and electrons of neighbouring atoms. Also dominating was the view that ions are formed before bonding takes place. The conception that electrostatic attractions are responsible for bonding appeared unfamiliar to all the ten students.

The origin and nature of chemical bonds was not well understood by the HDE students prior to class discussion. Even Ferrial who appeared to be knowledgeable by selecting the correct option, this choice was not followed by an explanation which exhibited clear understanding of the concepts sought. Surprisingly, in some cases some of those who chose inappropriate options displayed some understanding in the explanations they presented. Discussing aspects relating to cause and effect of chemical bonding during the methodology lectures appears to have helped the preservice teachers in this class to change their inappropriate conceptions towards more acceptable ones. Below is a description of sections from two lessons in which chemical bonding was discussed with respect to the nature and origin of chemical bonds. Both class discussions addressed this aspect of chemical bonding in various ways. Ways in which this was tackled during class discussion are illustrated below: directly as

- origin and nature of chemical bonds and
- covalent, ionic and metallic bonds, and indirectly as
- cause and effect of bonding; and
- network and simple molecules.

The origin and nature of chemical bonds.

The origin and nature of chemical bonds was introduced by tapping students' knowledge of forces, including those discussed in physics. This was followed by a demonstration of electrostatic forces to show that chemical bonds are electrostatic in nature and originate as forces of attraction between positive and negative charges. The discussion was also linked to teaching this aspect at school level. The excerpt below shows the approach student teachers could use in class.

> They *[school pupils]* will have done something on the structure of the atom so that they know that there are protons in the nucleus which are positively charged surrounded by an electron cloud that's sufficient. Either you can think of your electrons as particles or as a negatively charged cloud. I think that you need to perhaps tell them to think of these electrons in both ways. So you notice we have not introduced the molecular orbital model, and we have not introduced the quantum mechanics model and I think it is inappropriate to do that at school level. [CD1:270]

For school purposes she also suggested an analogy of a lit candle where the actual flame represented the nucleus of the atom and the light emanating from that flame to represent the sphere of electrons or charge cloud. Interpretation of the light from the two candles brought close together is analogous to the overlap of electron cloud when two atoms come together in bonding. With this analogy in mind and using the valence bond model of chemical bonding she went to discuss bond formation in the hydrogen molecule ion (H_2^+) (see figure 4.4 below). From the discussion she derived the definition of a bond given in excerpt [CD1:271a] below, it should be noted that this definition happens to be directly addressing question 5 in the diagnostic test.

> A bond is a pair of electrons. A strong force is caused when a pair of electrons are simultaneously near two

nuclei.[CD1:271a]

Not only was the candle analogy useful in showing the concept of charge cloud overlap during bonding but it also made it possible for the student teachers to appreciate the wave nature of electrons. Mary did not seem to appreciate this as demonstrated in excerpt [CD2:280] in the subsection on covalent, ionic and metallic bonds below.

Questions students raised following the given definition attempted to bring about visualisation of the position of these electrons during bonding and pairing and how to deal with the situation at school.

R: [...] A pair of electrons, are they always the same distance all the time?
M6: You are thinking of the particle model, for a start. Aren't you?
R: Ya.
M6: Remember that is explicitly what I said, think of the light analogy because the particle model of an electron is ..... So honestly I don't know where this electron is. I just know that there is high electron density in this region {between two bonded nuclei in a diagram drawn on the board, as in Fig. 4.4}
R: [...] At school I've been trying to incorporate all these other things of hybridisation and everything to do with the particle model and I find it very difficult. [CD1:271b]

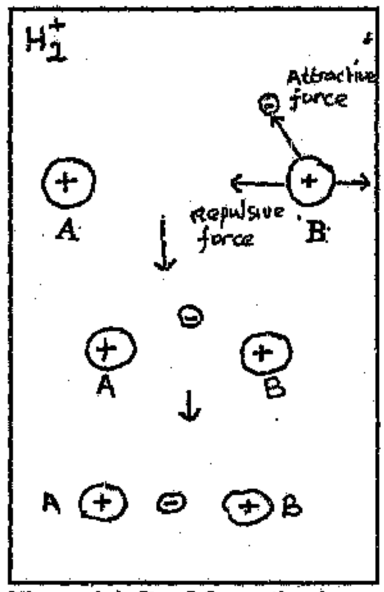

Figure 4.4: Bond formation in H_2^+

Covalent, ionic and metallic bonds:

Another problematic area discussed was the idea that covalent and ionic bonds are different. Metallic bonds were included in the discussion. To illustrate the similarities between covalent, ionic and metallic bonding water, sodium chloride and metallic iron in all three phases were used as examples. The discussion focused on coping with these three types of chemical bonds generally perceived in the school situation. M6 first criticised the way these are treated in the syllabus and the general practice in school when discussing bonding. The following excerpt, [CD2:280] shows how she treated the concepts and the problems some of the student teachers voiced as the discussion progressed. The excerpt also provides information for directly answering question 1.

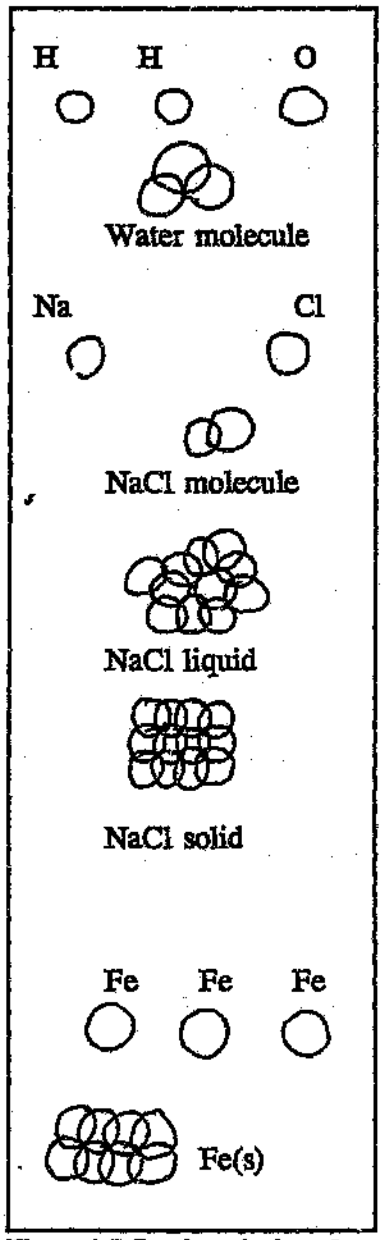

Figure 4.5 Covalent, ionic and metallic bonding

M6: Anything we have said so far does not distinguish between bonds, we just talk about bonds. Right. ..... And in fact as far as you know that is true for every bond. So why do we start at school with distinguishing rather than start with what is similar? Then .... to start with the specific differences before we even start with our basic parts. (....) So let's start with what is traditionally called the covalent bond. If we had hydrogen and an oxygen atom say for instance would be forming the water molecule. The force of attraction between them *would cause* overlap of orbitals ..... that there is what is called covalent bond. What happens in sodium chloride? Let us just take for a start what would happen in the gaseous phase if you could have a situation of isolated sodium atoms and isolated chlorine atoms. What would form in the gaseous phase? Gaseous sodium chloride. {pause} Would we have a crystal?

K: No, a molecule.

M6: You would have a molecule. So how many atoms in the molecule in the gaseous molecule?

S: Two.

M6: So you would have a similar situation to that one {water as in Fig 4.5} You would have a covalently bonded sodium in that molecule. What would you have in the liquid phase? .... your diatomic molecule .... clustered to ....

K: You would have more molecules.

M6: You have more of these molecules joining up. So you have these clustered, not a specific number because .... And in the solid?

Mary: But how can there be bonds between every atom? Will all the atoms form bonds?

M6: (sic) But how can there be bonds between every atom? Will all the atoms form bonds?

Mary: Because like in that .... in the network structure...

M6: Oh! You are talking about the solid? (Mary:Ya) in the salt?

Mary: I don't understand how it will work.

C: What do you mean every atom?

K: Will all the atoms form bonds?

Mary: You can't have that.

M6: Ok. Will you look at this picture. Alright. As your sodium and chlorine come together, first you will just have two of them, and then as they move from the gaseous to the liquid phase more of them will bond to form a cluster and as you move into the solid phase they move into a structure which has a lattice. In other words spacings is the same between every other atom between every nucleus in that structure. So then the position of every atom is then fixed and only vibrations are allowed. I don't understand what your problem is.

Mary: My problem is that [....] if you say that both sodium and chloride (sic) have valency of one and they bond with each other [...] then how on earth can they bond with others? (Oh) But that's what the general idea is. Then how on earth can they bond with all these other atoms? [...] There's nothing left to bond with.

M6: There's nothing left to bond with. What we've got here is an electron charge around every nucleus, say following excerpt, [CD2:280] shows how she treated the concepts and the problems some of the student teachers voiced as the discussion progressed. The excerpt also provides information for directly answering question 1.

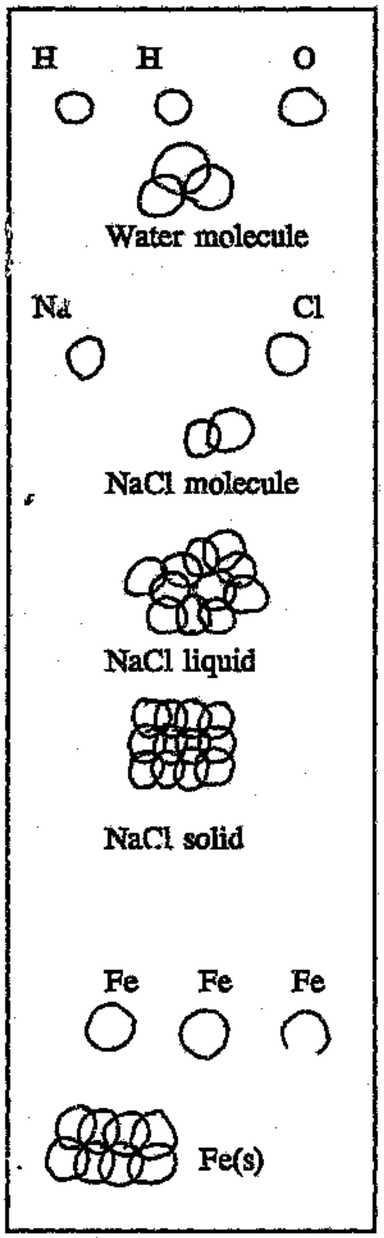

Figure 4.5 Covalent, ionic and metallic bonding

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Mary: My problem is that [....] if you say that both sodium and chloride (sic) have valency of one and they bond with each other [...] then how on earth can they bond with others? (Oh) But that's what the general idea is. Then how on earth can they bond with all these other atoms? [...] There's nothing left to bond with.

M6: There's nothing left to bond with. What we've got here is an electron charge around every nucleus, say sodium - there's a charge cloud around that and some charge cloud around that {chlorine atom} So there is a force of attraction between those .... Say you have a force of attraction .... (Ya) and if I have one here and one there and one there in three dimensions. So there's no reason why those atoms there should not approach simultaneously. There will also be a force of attraction all the way round.

Mary: That can't be a bond. ... A bond results in the sharing of electrons. [CD2:280]

Mary's problem was reconciling the particle view and the wave view of the electron to understand the nature of the bonds in network structures as discussed using sodium chloride as an example. She was advised to view bonding in both ways, as involving the electrons as particles and as a charge cloud to comprehend how sodium and chloride could be bonded to more than one atom simultaneously in the lattice.

She is exhibiting a strong conception of the electron as a particle and that of a bond as a pair of electrons. Similar problems were observed during her teaching practice, described in Chapter 7. Fortunately during teaching practice Mary did not have to discuss the sodium chloride lattice.

Cause and effect of bonding:

This was another aspect of chemical bonding that students did not seem to have a good understanding. Related to this was also the understanding of the meaning of the chemical bond and the order of events during bond formation. M6 addressed misconceptions identified and reflected in their responses in the assignment, to the question "what is a bond" or "what causes a bond?" by stating that

> Many people in response to 'what causes a bond' said because they share electrons, as if sharing was the reason for the bond to form. Now as I've said, the overlap of orbitals is a result of the bonding because it is the force of attraction that pulls them together and that forces overlap of orbitals and as a result electron sharing. [CD2:273a]

Students wanted to know which of the three comes first. Her response to this question addressed, to some extent, questions 1 and 4. Her explanation was

> [...] the force of attraction between them which then causes the bond or the bond which means there is a strong force of attraction. [...] In some ways there is a circular situation, but [...] you need to think carefully what is the origin of these. [CD2:273a]

This aspect, origin of a bond, was further explored in terms of these forces to establish a reasonable order of events. An example to show the interaction between M6 and the students is excerpt [CD2:273c] given below.

I: What will ....
M6: Right what brings them together?
S: ....
M6: Is it the potential energy that brings them together?
Rob: The electrostatic forces brings them together, between the nucleus and the electrons.
M6: So in other words the electron configuration, the whole configuration, not only the electron configuration of your separate atoms. It is the origin of the electrostatic forces. Is it sufficient just to have atoms .....
Brian: Also the lack of kinetic energy because at certain temperatures they move apart. So .... they need to be close enough together and the only time they'll be close enough is when they ...
M6: Are you saying they will bond if the two atoms have very little ...... (Brian: ....)
Kim: We can say they will bond if the energy is the same as ....
[.....]
M6: Ok remember last week we spoke about the fact that overall there is a net attractive force and the repulsion comes into operation when your nuclei come so close, too close in fact. So when they are furthest apart there is actually a net attractive force. But we've got to have enough kinetic energy for these two atoms to approach and come close to each other. [CD2:273c]

It was observed that despite the lecturer's attempts to show the important role of electrostatic attraction for bond formation and that orbital overlap and electron sharing are only effects of bonding and not the cause, later on in the class discussion this aspect was revisited as student teachers continued to show misunderstanding of what a chemical bond is. The excerpt below follows a comparative discussion on the ball and stick model and the overlapping circles diagram used in representing single molecules and students' reasoning on the matter.

Charles: Can I just ask something. If 'here is a bond between atoms, would there always be this overlap? I mean ... two circles like that say would there always be that type of overlap?
Jim: Overlap occurs before the bond forms.
M6: Overlap occurs before the bond forms (in tone indicating disagreement with the statement)
Jim: ......
M6: What do you think? What is a bond?
S: An overlap of orbitals.
M6: No. A bond is not an overlap of orbitals! What is a bond?
Ss: Sharing of electrons.
M6: No it's not a sharing of electrons. {students laugh at their errors}.
Brian: It's a force.
S: It's a force.
M6: It's a force of attraction. Thank you. A bond is a force of attraction which results in{pause}
Brian: Sharing of electrons.
M6: A sharing of electrons and overlap of orbitals. That's what I said about cause and effect. So it's because of that force that orbitals overlap. [CD2:277]

Notice from this excerpt how dominant the orbital overlap and electron sharing as causes of bonding are in students conceptions. This excerpt also shows information which students could use to answer question 4 on bonding in carbon monoxide.

Network and simple molecules:

Students also had the opportunity to compare simple molecular and network structures in a group activity. The activity involved the breaking or attempting to break a variety of materials such as wax, copper, quartz, sulphur, iodine and calcite. It was followed by a classification of these materials in terms of possessing strong or weak forces, being composed of simple molecules or network molecules. During the discussion of the activity, some assistance was given for using the same exercise with std 9 pupils. As will be noticed in the excerpt below, the assistance included definitions which the student teachers did not seem to know.

Now what we need to do then is to say what do we mean by simple molecules, what do we mean by network molecules. So at this point in teaching std 9s I would then go on to explain what I mean by that. Now a simple : :d in fact in this hand out there is a definition of what is a simple molecule and what is a network structure. [....] I think the best way to explain this in std 8 is to actually draw the diagram, but I'll give you the definition first. It consists of unlimited very large numbers of atoms joined in 3 dimensions by strong forces which we call chemical bonds. [.... She draws on the board as in fig. 4.6 as she talks to illustrate the molecular structures under discussion] A simple molecule consists of either an explicit number of atoms joined by chemical bonds or an unlimited chain in one dimension of bonded atoms. What does a simple molecule look like? It might be diatomic, it might be like sulphur which we know to have 8 atoms joined in a ring structure. It might be a chain such as you get with polythene. [CD1:266]

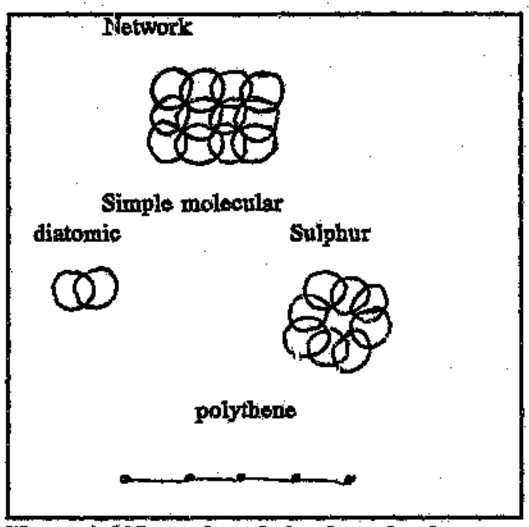


Figure 4.6 Network and simple molecules

Emerging from this excerpt is that chemical bonds are strong forces of attraction in both simple molecules and molecules of network structures. Differences between the two were discussed in terms of atomic and structural composition, breaking of chemical bonds versus separation of molecules. This part of the discussion addressed questions 1, 4 and in some way question 2 on the microscopic structure and properties of brittle solids.

4.1.6 Distinction between intermolecular and intramolecular forces

From the analysis of the pretest responses students appeared to have a good comprehension of the following aspects of chemical bonding:

- the relationship between bonding in a substance and its colour
- the distinction between intermolecular and intramolecular forces with respect to the melting point
- strength and distance between neighbouring non-bonded and bonded nuclei
- the composition of a molecule.

This is shown by the numbers of students who chose the correct answers to questions dealing with these aspects, questions (3,7, 8). Students who displayed errors in their conceptions in these areas seemed to have misread the question. This conclusion was drawn from the observation that even though their selected option was wrong, their explanation displayed appropriate understanding of the concepts referred to in the question. The following discussion provides support for this conclusion.

Question 3:

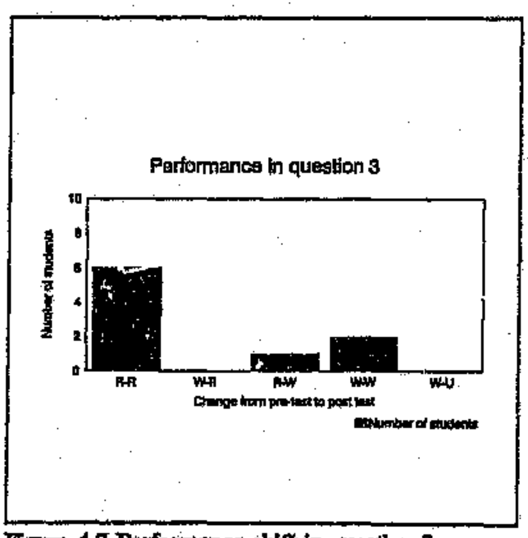


Figure 4.7 Performance shift in question 3

Question 3 aimed at ascertaining student teachers' views on the influence of intermolecular forces on the colour of molecular solids. Notice from figure 4.7 above which represents the performance in question 3, that there are no shifts from wrong to right answers while two students maintained their incorrect conceptions.

Many students as shown in Table 4.2 correctly identified that colour was not determined by intermolecular forces but rather intramolecular forces. The choice by those students who selected options B (weak forces between the molecules of molecular solids account for fact that such solids can dissolve without a chemical reaction) and D (such a solid melts at a comparatively low temperature) could be attributed to misreading the question because their explanations did not match the chosen option. For example:

5: B: Even molecules with strong intermolecular forces can be dissolved without chemical reaction

8: B and C*: Colour is a property of a substance - there are weak forces between oxygen molecules and oxygen gas is neither grey nor black.

9: D: If the forces between molecules are weak, little energy is required to melt the solid.

There were no shifts from wrong to right answers as reflected in Table 4.3. However, in the post test one student, 5, who selected a wrong answer did show an understanding of the effect of intermolecular forces on properties of molecular solids, as shown in the example below:

5: B: A chemical reaction will occur when it is dissolved because the molecule is likely to "break" up or bonds will be broken.

Question 7:

Question 7 explored student teachers' understanding of the relationship between melting and the strength of forces between atoms in a pure substance. Most of the students displayed no difficulty at all apart from one student whose explanation demonstrated a clear understanding within the context of the question, hence no performance graph is given.

Question 8:

Question 8 explored the relationship between intermolecular forces and intramolecular forces on the distance between neighbouring nuclei in an iodine crystal. In the pretest two students chose option C (iodine forms diatomic molecules).

3. C: because the I_2 molecule has "covalent" bonds, the atoms in the molecule would be closer together than in the crystal

It will be appreciated in this example that though the chosen option is incorrect the explanation shows partial understanding. The idea portrayed here is that the length between atoms in an iodine molecule (supposedly I_2 molecule in the gas phase) would be shorter than in the crystal. This seems to portray a conception that in the crystal the atoms, whether bonded or not are more apart than in the diatomic gaseous molecule.

In the post test all students chose the correct option, with one doubtful reason "Iodine is a big molecule".

Class discussion

During class discussion intermolecular forces as an aspect of chemical bonding was discussed in relation to a teaching package on chemical bonding prepared by the same lecturer offering the topic. She asserted that intermolecular forces are part of the syllabus and therefore should not be viewed separately from chemical bonding. A short exercise taken from the package was used to illustrate the effect of intra-intermolecular forces on the distance between bonded and non-bonded nuclei in the iodine crystal (see figure 4.8). The exercise led to the conclusion that short distances between iodine nuclei represented strong forces of attraction, that is chemical bonds. Longer lengths represented weak forces of attraction or intermolecular forces between molecules of diatomic iodine in the crystal. The relationship between potential energy, distance between adjacent atoms and bonding was discussed leading to a link between these three, thus: bonding occurs at minimum potential energy and the force of attraction is the strongest. This discussion addressed question 8 of the diagnostic test and all students in the post test chose the correct option but shifts involved only two students.

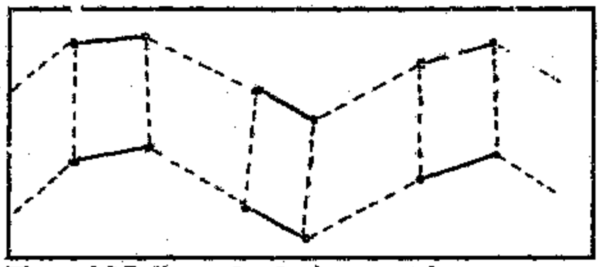


Figure 4.8 Iodine molecules in a crystal

Hydrogen bonding and intermolecular forces was another area where student teachers were uncertain and therefore anticipated difficulty teaching. In the excerpt below Winnie raised this issue and her concerns in teaching this concept.

Winnie: When you're teaching hydrogen bonding...

M6: I've always taught in inverted commas
Winnie: needs to be redefined. It is difficult because textbooks refer to it as hydrogen bond.
M6: But the textbooks make it clear that it is an intermolecular force.
Winnie: But it calls it a bond and that causes confusion
M6: It can and you need to focus your pupils attention that it is actually not a bond. [CD1:269].

It appears that Winnie was not comfortable with the use of "bond" for an intermolecular force.

4.1.7 Atomic and molecular dimensions.

Question 6:

This question tested student teachers' understanding of atomic and molecular dimensions. It was based on a diagrammatic representation of a homonuclear diatomic molecule showing the distance between bonded nuclei, that is bond length, denoted by x (see Appendix 2A:6) and they had to name distance x. Figure 4.9 below illustrates how students performed in the question. Figure 4.9 above shows the shift in students performance from pretest to post for question 4.

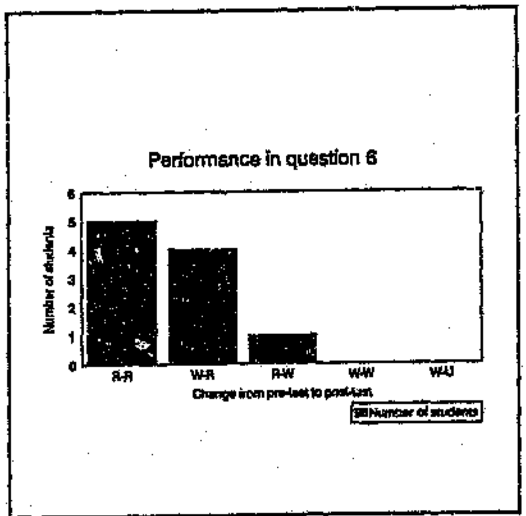


Figure 4.9 Performance shifts in question 6

In the pretest four students were diverted to other options: 1 by option A; 2 by B and 1 by C. Only one of these gave an explanation.

10: B: Assuming atoms making up a molecule are identical, X is covalent radius by definition.

In the post test only one student, 6, erroneously thought that x represented the atomic radius.

During class discussion treatment of this aspect differentiated atomic radius, covalent radius, van der Waals radius and bond length. Students did not appear to have problems during the discussion, though the analysis of question 6 in the pretest shows a few errors which appeared to have been rectified as shown in fig 4.9.

Structural Representations:

This was another area of discussion in the second session that was related to atomic and molecular dimensions. The aim here was to focus student teachers' attention on some of the general assumptions made by teachers about their pupils' understanding and authors about their readership regarding diagrams used to represent substances and their microscopic structures. Students were given an activity involving a 2 dimensional picture of a single molecule and a 3 dimensional model of a molecule. Examples are shown in the figure 4.10. Emerging from students' presentations of what they could deduce from the diagrams and molecular models was the importance of clarity and labelling of representations to avoid misinterpretations. Emphasis was also placed on the size, bond angles, bond lengths in giving good representations. For example:

M6: Let us look at this one at this stage. Look at this picture at the bottom. What does that picture {A in fig 4.10} What does this picture tell us that this {B in fig 4.10} one does not?
S: Bond length.
M6: Bond length. Can I get an estimate. [...] So if you were looking at that picture, how would you work out bond length?
K: Measure from the centre of one to the centre of the other.
M6: Ok. From the centre of one circle {B} to the centre of the other. And in this one {A}
Ss: Measure the length of the sticks.
M6: The length of the stick. ...... So what's wrong with this picture {A}?
S: The stick is misleading the bond length.
M6: Misleading. Ok because some people would say well the stick is the bond. [CD2:277]

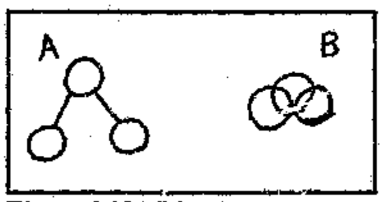


Figure 4.10 Molecule representation

Other limiting factors of the representation were highlighted such as spacings, pictures not depicting reality, i.e. representing non existing features, circles representing nucleus and core electrons which does not apply to the H^+ ion. Students were also made aware that what was important was that

> You've got to know what it represent, and teachers don't normally encourage that. [....] It's just that you have an agreement on that symbolism. As long as everybody agrees on that symbolism, and we've got to explain this before we use it. [CD2:278].

4.1.8 Link between macroscopic properties and microscopic structure

Question 2:

Question 2 looked at the properties of brittle solids. This question appeared quite problematic for most students. The major distracters in the pretest were C and D, while C was the major distracter in the post test. Again only one student, Ferrial, chose the correct option in the pretest, but changed to a wrong one in the post test. Her initial response had a doubtful explanation thus

> A: process of elimination!

Figure 4.11 below illustrates further the shifts among the other students.

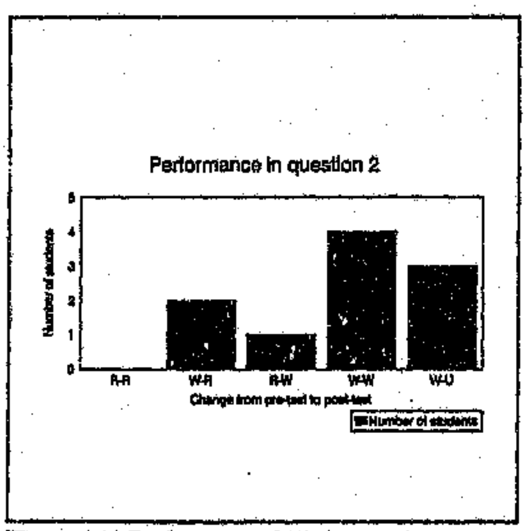


Figure 4.11 Performance shifts in question 2

Selection of a correct response without proper explanation could be due to the influence of the first session on chemical bonding. Further ideas displayed by the other student teachers were:

3. D: the intermolecular bonds are strong, leading to distinct breaking of the bonds
4. B: property of bei g brittle is a result of way a metal is structured (delocalised electrons in positive ions) which results in electrical conductivity.
5. D: brittle solids tend to be network solids or lattices which imply the existence of strong intermolecular forces
8. C: As they have week chemical bonds they will break easily if a force is applied.
9. D: A brittle solid is not necessarily composed of simple molecules (not A); and not necessarily a conductor of electricity (not B). "Breaking" up a solid does not break chemical bonds (ie chemical composition of molecules) ie not
10. C: A is not necessarily <u>always</u> true; neither is B. The solid would <u>NOT</u> be brittle if D were true.

So prior to discussing chemical bonding, student teachers' ideas regarding the macro/micro properties of brittle solids did not seem to be well in place. Only student 6, displayed some understanding of weak intermolecular forces being responsible for brittleness, though not linking this property to simple molecular structure. On the other hand two students (4 and 10) did not link brittleness to simple molecular structure while displaying an understanding that chemical bonds are not easily broken by mechanical means and that strong intermolecular forces are in no way responsible for brittleness. Another two students associated brittleness with network structures while a further two were not clear about the relationship between chemical bonding and intermolecular forces. This point may seem to be in conflict with what is reported above. Attempts to ascertain consistency were unsuccessful because of the differences in the contexts of the questions.

Only two (4 and 8) from the original ten students changed their choice to the key in the post test. Student 4 displayed a more acceptable conception while student 8 simply refuted one of the options as shown below.

4. A*: chemical bonds- composed of simple molecules since can be broken up quite easily (without breaking bonds)
8. A*: Not B as metals (electrical conductors) are malleable.

The major distracter in the post test was option C. Students 1, 2, 6, 5, 7, 9 and 10 correctly understood the meaning of brittleness as synonymous to breaking up easily but attributed this property to weak chemical bonds. Their responses however displayed an understanding that chemical bonds are weak and therefore easy to break. For example:

1. C: easily broken down
2. C: weak chemical bonds can be easily broken
5. C: The weak chemical bonds would mean that it can break apart easily.
9. C: The bonds can be easily broken if the substance can be broken up easily.

Three of the students (5, 7, 9) showed the same shift from thinking that brittle solids are likely to have strong intermolecular forces (D) to having weak chemical bonds (C). While students 2 and 10 did not change their erroneous views about microscopic structure of brittle solids. The aspect tested in question 2 was discussed in class as described in the section on network and simple molecules above.

4.1.9 Structural change during phase change

Question 9 evaluated student teachers' comprehension of the effect of melting on the structure of a network solid. Figure 4.12 below shows the shift in students' performance in question 9.

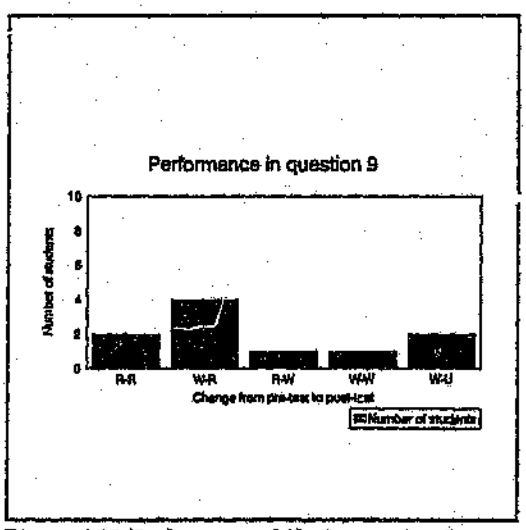


Figure 4.12 Perform... shifts in question 9

It will be seen from Table 4.2 above that only 3 students (3, 4, 10) chose the correct option in the pretest and their explanations showed proper understanding. Major distracters for the others were B and C. A variety of views emerged from their explanations as shown below:

5: C: On melting, the forces between the ions in a network solid are weakened and the energy of these ions is increased therefore the ions move from the fixed positions.

7: B: Metals such as Au have metallic bonding and don't exist in lattices.

8: B: Melting is a physical and not a chemical process as only a phase change occurs ie only intermolecular bonds and NOT intramolecular bonds are broken.

9: B: Chemical bonds are broken in order to break the network, but this may not cause a chemical reaction. Only if the network is an ionic network, then the ions move from their fixed position.

10: A: B is false, converse of A. D: dissociation involves H_2O. C: ions, molecules etc not only "ions".

What may be worth noting here is that while the choice of option by students 5 and 9 does not appear to answer the question, their explanations display a high degree of correctness. But student 9 appears to be less knowledgeable about the relationship between chemical reactions and chemical bonding. Student 8 appeared to view melting as a physical process and not being aware that in network solids all the forces of attraction are intramolecular. She also had the general conception that melting involves only intermolecular forces. This conception also suggests that the student is unfamiliar with the microscopic structure of network solids.

Analysis of the responses to the post test shows that four students changed their views. Again students choosing the key displayed understanding in their explanations, though limited, for example:

2. B: intermolecular "bonds" are broken during melting --> this is a physical process (as opposed to breaking intramolecular bonds which is a chemical process)

9. C: Positive and negative ions dissociate in water (not D), A and B can be argued - depending on your view point.

10. A*: B see A. D debatable.

Ferrial did not change her erroneous views at all. While others (2, 9) changed to other erroneous conceptions.

Chemical reactions and chemical bonds:

The approach M6 used to discuss microscopic changes accompanying phase change was through examining the relationship between chemical reactions and chemical bonding. Examples of science processes like dissolving and melting of network and simple molecules were used during the discussion of this relationship. For example:

M6: What would you say a chemical reaction is?
Kim: ... chemical reaction breaks and make bonds.
M6: Remember it is a chemical bond. So lets call it a bond, you break a bond, right K said that a chemical reaction is a process in which you break or presumably make chemical bonds. [.....] If I take sodium chloride salt and I dissolve it in water, is that a chemical reaction?
Jim: You break bonds in sodium chloride molecule.
M6: Yes you are saying that sodium chloride bonds will be broken up, so you say you break bonds. Ok you're right. [...] If you dissolve a network solid a chemical reaction takes place. If you dissolve a molecular substance no chemical reaction takes place. [CD1:268a]

M6 acknowledged that the breaking of chemical bonds during dissolution or melting of network solids is a controversial area. The reason should be known among science teachers and other science educators that these two processes have been for a long time regarded as physical processes which did not bring about chemical reactions. The lecturer's statements did not go unchallenged as shown below. Again during the discussion of chemical bonding and melting students were given guidelines, based on the melting point and bond energies, for determining whether simple molecular solids or network solids were being melted.

M6: [..] what about when you melt it *(molecular solid)* [...] What will happen when you melt sulphur? Is it a chemical reaction? Do I break a bond?
Kim: breaking bonds between the molecules.
M6: In sulphur, no we don't have bonds between molecules. A bond is a strong force that hold atoms together to make a molecule. So you know you are not breaking chemical bonds when you melt your sulphur and when you heat the iodine you are not breaking chemical bonds nor when you melt the wax. [...] You were able to melt that substance because you did not need a whole lot of energy because you did not need to break chemical bonds. [...] When you melt gold do you break chemical bonds? Well you need lots of energy, so you do. You break up a network structure. [..] Right as a rule of thumb, over 800+°C, high melting point, generally indicates a network structure, ... up to 800°C for melting point, ... a little bit of overlap there but generally represents some form of molecular structures. [CD1:268b]

Emerging from this excerpt is the strong emphasis on breaking of chemical bonds on melting networks solids but no chemical bonds are broken on melting simple molecular solids. Some students challenged the lecturer's statements which did not make much sense to them and to further clarify other aspects of bonding. The excerpt below will show some of the interesting questions raised during the discussion.

Charles: Sorry. If there is no bond between molecules then what hol. the molecules together?
M6: Remember we defined the bond as a strong force
Rob: So a hydrogen bond is not a bond?
M6: No. So now a strong force is greater than 100kJ/mol. Ok. And we find ... intermolecular forces are the hydrogen bonds. It's not a bond but it's an intermolecular force, it's approximately 40kJ/mol. .... < 40kJ/mol is intermolecular force, 100kJ/mol < is a bond. [CD1:268c]

More students appeared not to understand why the melting metals is regarded a chemical reaction. The difficulty they experienced led them to question what seemed to be individually constructed definitions, as it appeared to be the case in this class discussion. The lecturer had to show support for her statements by quoting international bodies that agreed on what she had just presented to the class. She also confirmed their concern about the importance of consensus on definitions among communities of scientists. The following excerpt [CD1:269] s... 's the actual events in the class discussion.

Ki...: Are saying that melting gold is a chemical reaction?
M6: Yes. [students laugh, uncertain about the ideas] By my definition. But notice I'm being quite frank with you, not everybody would agree with me. There are more imminent scientists than myself who would agree.
Ivy: This is your definition, where did you get it from? If you can change a definition, we can also call a bond anything.
M6: No the definition on the bonds is well accepted. [...] [CD1:269]

4.1.10 Molecules

Question 10 assessed students' definition of a molecule. Only two students answered the question wrongly in the pretest. This concept appears to have been in place for the majority of the students.

In her discussion of simple molecules and network molecules M6 also explored student teachers' definitions and conceptions of molecules, thus:

M6: Ok. Now in my definition here what would you say I have called a molecule? .... (Ss: ....) What is a molecule? Is this a molecule {pointing at network structure on board, fig 4.6 above}
S: ... part of a network
M6: Ok let's have a look at (S: ...) Yes it's a network molecule. [...] Right we are going to get a definition of a form of molecule. We are going to call that a molecule and we are going to call that a molecule {Fig 4.6}.
S: ... anything with more than one atom.
M6: Anything with more than one atom. If there is something distinctive that would say that this is a molecule rather than the whole thing {circling the 8 atoms sulphur in fig 4.6}
S: Bond.
Rob: Atoms must be bonded together.
M6: Ok. So it's a group of clusters lets say of more than one atom

Rob: joined by a chemical bond

M6: joined by a chemical bond. Remember we just call that strong force a chemical bond. Ok so a molecule then is a cluster of atoms joined by strong forces - chemical bonds. [CD1:268d]

Thus a molecule was redefined to accommodate simple and network molecules in solid phase. A general conclusion drawn was that all molecules are characterised by a chemical bond as a force of attraction. Notice also that excerpt [CD1:268d] provides information for answering question 4 in the diagnostic test.

Both the lectures were rich in content and students were given abundant help to assist them in refreshing their memories regarding chemical bonding. They also had the opportunity to have their conceptions tested and verified. Many changed the conceptions they had prior to the lectures, as shown by the results of the diagnostic test. Also important was that they received specific tips on how to approach and how to deal with some problematic areas in the topic at the secondary level.

Results from the analysis of the post test suggest that a conceptual change took place in some cases to more acceptable conceptions as was intended by the discussion. In particular intended changes in conceptions were effected in aspects of chemical bonding relating to the nature and origin of a chemical bond, atomic and molecular dimensions, microscopic and structural changes that take place when phase changes occur. The sample was very small to draw any generalisable conclusions, but some supporting evidence has been provided that preservice teachers in this sample did have conceptions about chemical bonding that varied from the accepted one and that some of these changed as a result of these being specifically addressed in the physical science methodology.

A discussion of the subject matter knowledge of the particpants in the case studies is given in each of the chapters 5, 6 and 7.

4.2 Acids and Bases

4.2.1 Student Teachers' responses

Acids and bases was the other area of student teachers' subject matter knowledge explored in this study. Again the number of students who returned their questionnaires was very small - only six. Analysis of these questionnaires revealed some interesting information about the student teachers' concepts of acids and bases. Discussion of the results is given for each student teacher because the sample was too small for clustering their ideas on the aspects tested. Focus is dir~~ted at those areas that seemed difficult. Areas where no difficulties were identified are only highlighted for the six student teachers.

Table 4.4 below shows a summary of the performance of the students in the multiple choice section of the test.

Table 4.4: Summary of student performance in multiple choice questions

	Question											
Options	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
A	0	6*	0	1	0	0	0	5*	0	6*	6*	2
B	0	0	1	0	3*	1	5*	1	0	0	0	0
C	0	0	0	0	3	4*	1	0	0	0	0	0
D	6*	0	0	0	0	0	0	0	0	0	0	0
E	0	0	4*	5*	0	1	0	0	6*	0	0	4*

It is clear from Table 4.4 that none of the students appeared to have any problems with concepts such as amphoteric or amphiprotic as tested by questions 1 and 9; acid dissociation tested by question 2 and pH tested in question 10 and 11 (see Appendix 2B for the test).

In section B of the test all students, except Ferrial displayed some understanding of how indicators function. Three of these five student teachers, student 7, student 9 and Andrew, however, presented only one view of the indicator, as a weak acid. Despite displaying knowledge of the mechanism of the indicator they had difficulty matching the indicator to the type of acid-base titration as given in the test. They all identified the appropriate indicator for the strong acid strong base titration except for student 4, who was also the only one able to identify correctly the indicator suitable for a strong acid weak base titration. Andrew was the only one to match correctly an indicator to the titration involving a weak acid and strong base. During the lessons on acids and bases discussion of indicators this information was not explicitly stated to students. Students were only informed briefly about how indicators work.

The use of equilibrium arrows in chemical equations by the student teachers did not demonstrate that they understood the direction of equilibrium for the reaction involving ethanoic acid and water. All the students except student 4 used arrows of equal length. This representation suggests a balance rather than equilibrium lying to the left since ethanoic is a weak acid. For the reaction of ammonia and water (NH_3 + H_2O), students 7, 9, 11 and Andrew also used equal arrows, while Ferrial showed that equilibrium lay to the left and implying that ammonia is a weak base. Student 4 correctly used a single arrow representing a complete reaction to the right as ammonia is a strong base.

The remaining questions in both sections A and B will be discussed separately for each student who displayed limitations or errors in his/her conceptions. The questions that posed difficulties will be indicated for example as A1 for question 1 in section A, B1 for question 1 in section B.

Student Teacher 4: A5, A12, B1, B2, B3, B4.

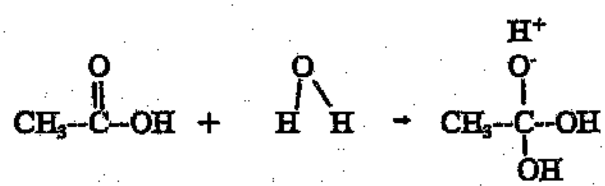
Student teacher number 4 passed chemistry III, at Wits in 1992. S/he appeared to have erroneous idea about electrical conductivity and aqueous solutions of acids (question A5) and the order of acid strength (question A12). His/her limitation in knowledge of acid strength was further confirmed by giving nitric acid (HNO_3) as an example of a weak acid in question B4. This question required students to give an example of a weak acid and then show how it dissociates in aqueous solution using a chemical equation. The equation given suggested a complete dissociation thus:

$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$$

and therefore that nitric was a strong acid. From this observation it appears that student 4 was unable to represent the reaction of a weak acid and water or has some shortcomings regarding chemical equilibria. Other responses that indicate some limitations of student 4's knowledge of acids and bases are those furnished for B1, B2 and B3. For B1 s/he could not recognise that ethanoic acid was an acid according to Arrhenius as shown by the response:

No. Wouldn't *(ethanoic acid)* donate protons-full of OH attachments which are basic.

The dissociation equation for the chemical reaction which occurs when ethanoic acid reacts with water, required in B2, was given as



Notice how the product in this reaction reinforces the response given above for B1. The response to B3(i) is quite vague in that s/he does not state whether Cl^- is stronger as an acid or a base. If it can be assumed that s/he meant stronger base as the statement suggests, the assumption would contradict the response in B3(ii) which implies that NaCl is acidic in aqueous solutions. The lack of clarity in B3(i) and the response in B3(ii) indicate that student 4's knowledge of conjugate acids and conjugate bases is also limited as well as her/his knowledge of weak acids and the reactions of acetic acid and water. The microscopic representation given by student 4, figure 4.13, does not reflect a good understanding of such representations. This representation does not show a liquid state, nor hydronium ions as the equations shows. The given key does not corresponding to the species represented in the diagram.

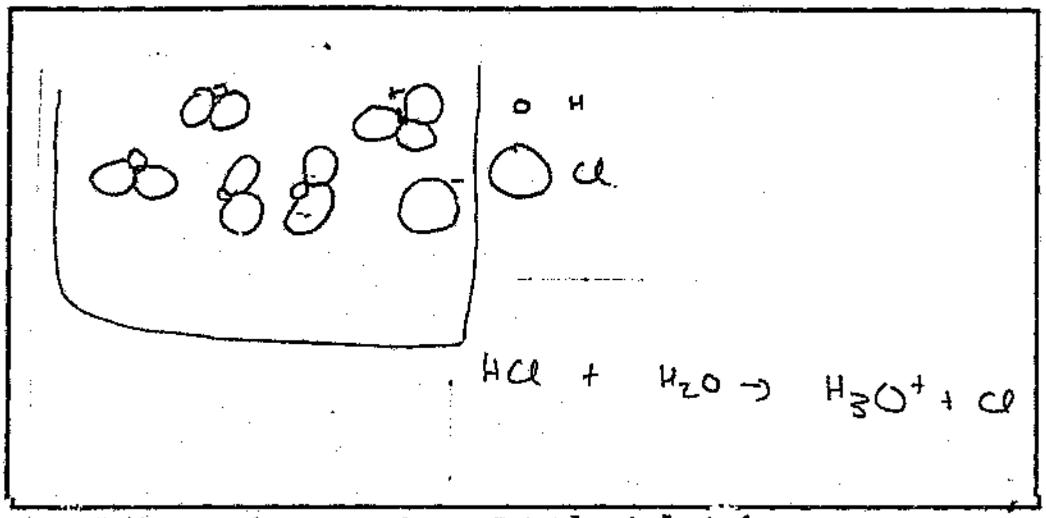


Figure 4.13 Microscopic representation of HCl (aq) by student 4

Student Teacher 7: A3, A6, A12, B1.

Student teacher number 7 passed chemistry I at Wits in 1991. She appeared to have some problems with A3, which assessed knowledge of the properties of acids, bases and their salts. She gave no response to this question. Question A12 assessed knowledge of acid strength. She chose an option which suggested that she thought that nitric acid was the weakest acid in the list and the ammonium ion was the strongest acid (increasing order of strength: nitric acid, acetic acid, water, ammonia, ammonium ion). It will be noticed that this order is almost in decreasing order of acid strength, except for the last two.

Questions A6 and B1 were based on the Arrhenius theory of acids. Student 1's responses suggested that she did not know anything about this theory or its limitations. While the response to A6 suggested that she thought the objection to the theory was that there would very few acids available (option E), she was unable to give a response on whether ethanoic acid is an acid according to the same theory.

Figure 4.14 is a microscopic representation produced by student 7. While this representation is not too far off it does not show the molecular composition of the

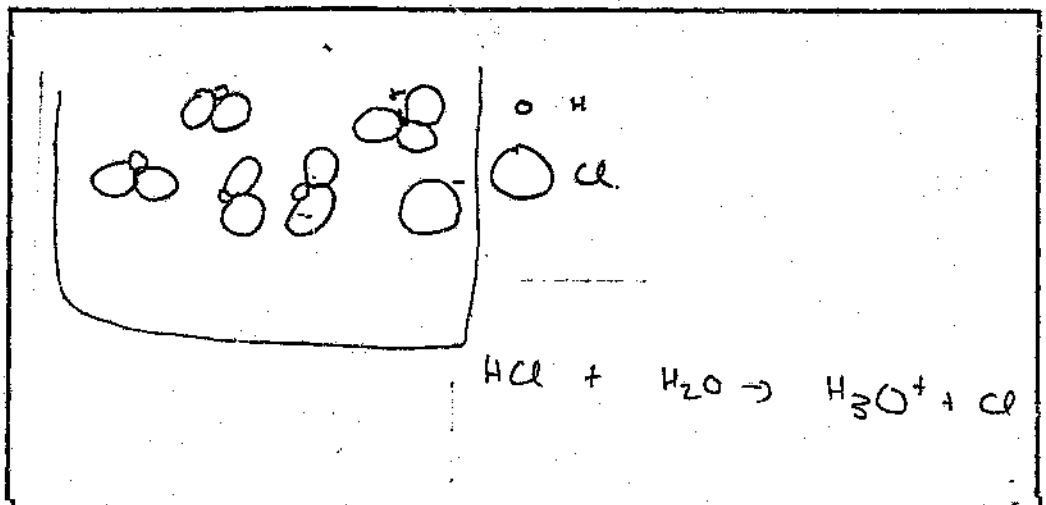


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Figure 4.14 is a microscopic representation produced by student 7. While this representation is not too far off it does not show the molecular composition of the constituents of the solution.

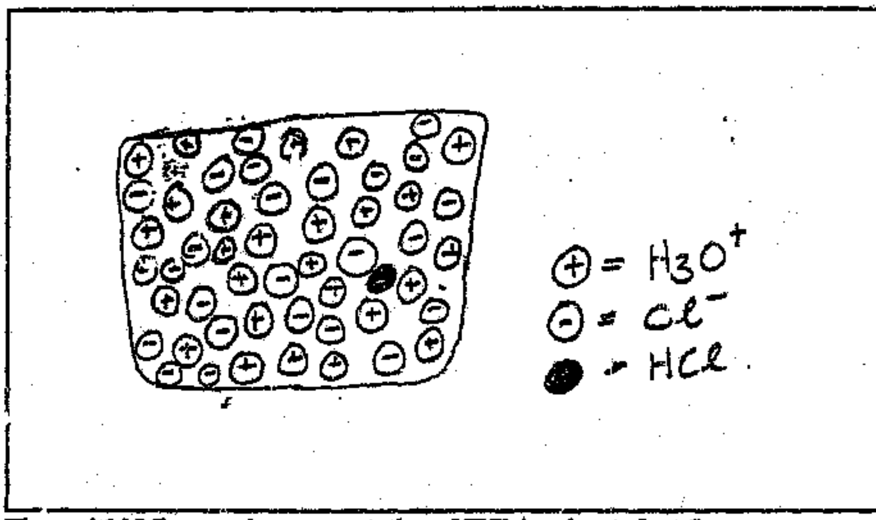

Figure 4.14 Microscopic representation of HCl (aq) by student 7

Student Teacher 9: A3, B1, B3.

Student teacher number 9 passed chemistry II (auxiliary) at Wits in 1993. She also had difficu[illegible] with questions A3 and B1, and also with question B3. The response she gave for A3 (option B) contradicts the generally accepted acid-base reactions according to the Bronsted-Lowry theory (i.e. acid base reactions involving transfer of proton from acid to base). Her response to B1 does not provide sufficient evidence to show how knowledgeable she may have been. She did not state nor give reasons whether ethanoic acid would be an acid or not according to Arrhenius' theory. Only the equation for the dissociation of the acid in aqueous solutions was given. The response to question B3 shows that she could not differentiate between the acid-base strengths of the chloride ion and the acetate ion. She could neither comment on the pH of the solutions of the sodium salts of these two anions.

The microscopic representation of the same solution given student 9 is given in figure 4.15 below. This representation demonstrates an understanding of the microscopic structure of a dilute aqueous solution of hydrochloric acid. Since no water molecules are drawn or shown in the key they could be assumed.

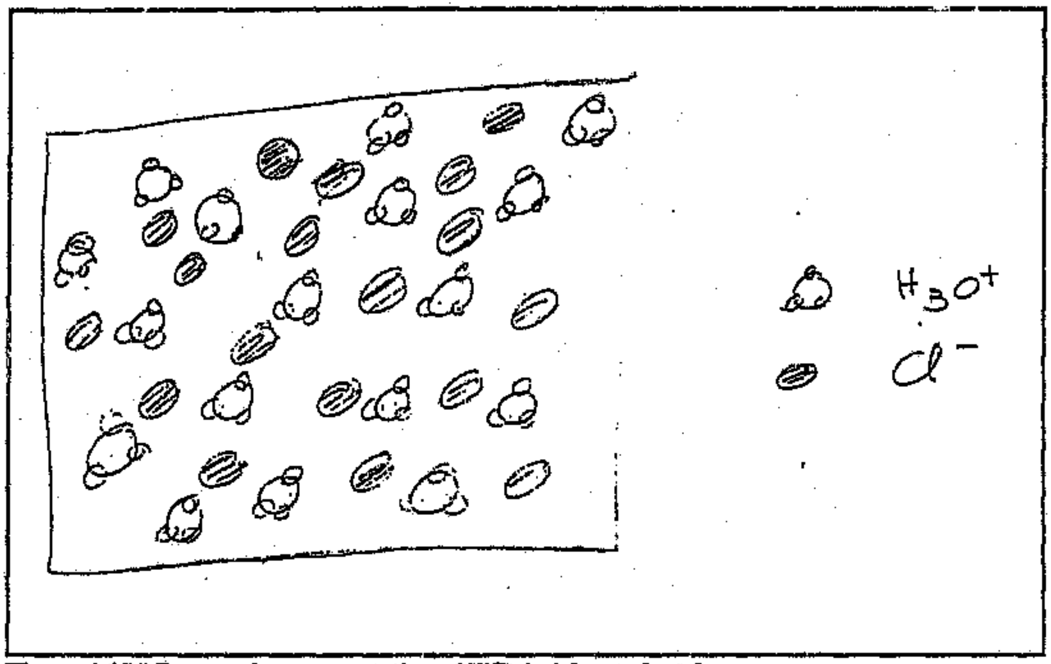

Figure 4.15 Microscopic representation of HCl (aq) by student 9

Student Teacher 11: A5, A6, B4, B6. (No data on chemical bonding diagnostics) Student teacher 11 passed chemistry III. His erroneous conceptions were related to thinking that good electrical conductivity is a property of aqueous solutions of all acids indicated by his response to question A5. It was surprising though to note that while he was unable to identify correctly the objections to the theory that acids dissociate to give hydrogen ions, he was able to use the same theory to explain acidity of aqueous ethanoic acid (question A6). This observation could suggest that he thought that hydrogen ions can exist freely in aqueous solution. In fact this conception is further endorsed by the following responses for explaining acid strength versus concentration, given for question B6:

> a) strong acid gives off H^+ easily (complete dissociation). Concentrated acid is large number of H^+ in solution.
> b) No, one can have lots of H^+ in solution but they may not come from purely dissociated ions.

Strange, though is that his microscopic diagram (figure 4.16) does not show any free hydrogen ions. The only serious limitations of this representation is the large spacing for it to represent a liquid.

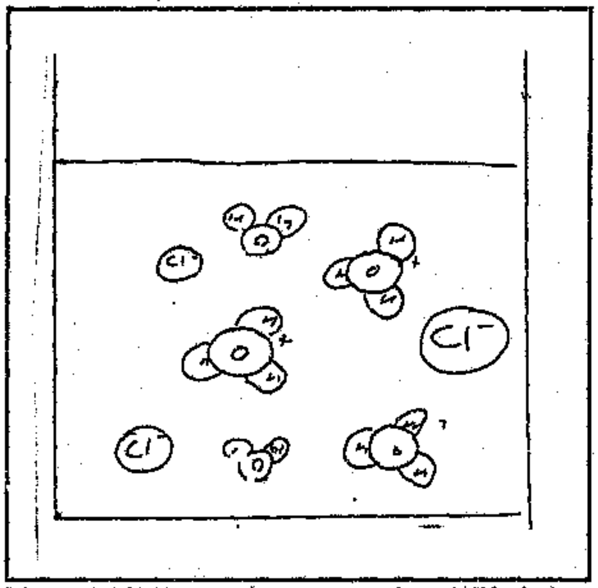

Figure 4.16 Microscopic representation of HCl (aq) by student 11

4.3 Lesson observation

4.3.1 General features:

Only a brief description of the methodology lessons on acids and bases is given to contextualise the discussion of the students' ideas given above. Two lessons dealing with concepts in acids and bases were given during the HDE physical science methodology course. Both lessons were practically oriented, though some theory was also discussed. The structure of these lessons did not centre around any prior conceptions on acids and bases held by the students. However, attempts have been made in this discussion to highlight sections of the lessons that addressed difficulties students experienced in the test. The first lesson was a 'hands on 'workshop where students used low-cost acid-base indicators prepared by M1 from chopped beetroot and red cabbage. They used these with known household substances like battery acid, vinegar, water, bicarbonate of soda and caustic soda to set up "controls" (producing something like a pH chart for these home made indicators). The same control was set up for commercial indicators: universal, methyl red, methyl orange and phenolphthalein. These two controls were then used to classify unknown substances (sucrose, sodium carbonate, citric acid, table salt and aluminium carbonate) according to whether they were strong acid, weak acid, weak base, strong base. Students worked in groups with each group using one home-made indicator and one commercial indicator. Where a group deviated from the results of the other groups students in that group were expected to explain their result. With this exercise the students were able to compare these home-made indicators with commercial indicators and see the different colours produced with acids and bases of varying strengths. The second lesson focused mainly of the reaction of acids and bases.

During the discussion of students' results from the practical activities, various aspects of the test were addressed. M1 was involved in the evaluation of the test prior to its administration. So it is possible that M1 may have deliberately treated these concepts. Between the two lessons the following aspects raised in the test were discussed in the lessons:

- the presence of hydrogen as a common feature of acids like hydrochloric acid, sulphuric acid, nitric acid, vinegar. citric acid, tartaric acid
- acid dissociation
- extraction of hydrogen by bases
- microscopic representation of aqueous solutions and molecules of acids and bases
- how indicators work
- reactions of acids with metal carbonates/ neutralisation and chemical questions for these reactions
- interpretations of microscopic diagrams of the product of these reactions.

CHAPTER 5

CASE STUDY 1: ANDREW

CONTENTS OF CHAPTER 5 PAGE

5.0 Introduction to the three Case Studies

Each of the following three chapters, Chapters 5, 6 and 7, describes data analysis and findings for the case studies.

Data analysis for these case studies firstly involved a study of all the sources of data, i. e. interview transcripts, field notes of teaching practice observation and diagnostic tests responses, for content.

Data relating to the background of the subjects was obtained from participants responses to questions specifically designed for that purpose in the initial interview [see Appendix 1A for interview schedule]. From this information a profile for each subject was constructed which provides the subjects' educational background, reasons for pursuing a teaching career, perceptions of the teaching profession and ideas of characteristics of good teachers. The profile also describes the subjects' conceptions of science [Appendix 1B], science teaching and learning [Appendix 1B, C, D], their experiences and the researcher's perceptions of their teaching practice.

Analysis of interview transcripts to identify conceptions of science involved generating and tabulating statements that had some reference to the nature and content of science. The techniques used for tabulating statements generated from qualitative data was similar to those described in Hewson and Kerby (1993).

Although all sources of data (field notes and interview transcripts, journal entries) are not attached as appendices references to them have been given as codes for future reference.

5.1 Introduction to case study 1

Case study 1 focuses on "Andrew", a young married male who had had some experience in teaching science and maths at the secondary school level. Andrew was also teaching these subjects on a part time basis during the study, while a full time registered student for the HDE programme.

5.2 Brief background

Andrew was the only male participant involved in the study. I therefore sought his permission to identify his gender in presenting the views described in this chapter. Andrew is originally from Namibia where he did his primary education in Afrikaans. He transferred to Cape Town where he attended a non-racial, church run private school which attracted students from all over South Africa, for his secondary education. The medium of instruction in this school was English. On matriculation he joined the University of Cape Town (UCT) for his first two years of tertiary education. In his third year he withdrew from UCT for politically related reasons. The following year he enrolled at Wits and withdrew again, this time for financial reasons as he was now responsible for his own tuition fees. Two years later in 1993, he returned to Wits and successfully completed his Bachelor of Science degree, majoring in chemistry. During his three years of absence from university he taught science and mathematics to standards 6, 7 and 9 on a full time basis at a school in Ennerdale. The rewards were not good, possibly because he had neither a first degree nor a teaching qualification. The poor salary encouraged him to resume his studies and obtain a teaching qualification. Andrew is married with two children.

5.3 Reasons for joining the teaching profession

Unlike other people who become teachers due to circumstances, Andrew seems convinced that teaching is his vocation as he describes in excerpt [I1:1a] below.

> I've never decided to become a teacher. I've always been a teacher. [...] I was always helping others (Mh) you know in maths and science, in particular um from STD 7 onwards. .... It *[decision]* was formalised when I was in my matric year because in my matric year I was um a prefect at a hostel and err during the study periods [...] I used to help them, I was paid for that (ok) from std 6 right up to matric. ..... the decision to become a professional I think was made during those three years I was teaching. [I1:1a]

It is therefore not surprising that Andrew appears satisfied with this career despite its relatively low status compared to other professions. His claims regarding his satisfaction about the profession are:

> I think, first of all, I love the subjects that I am teaching, maths and physics. (Mh) And secondly [....] I know that I teach well [....] I enjoy working with students. [I1:1b]

He appears committed to the profession with no intentions of changing to another career. His beliefs about his future in the profession are that he will always be a teacher, though not necessarily at school level.

> [...] at least I would always be a teacher. (Mh) It would just depend on which on-in which structure I would be teaching ok. [...] I would either be a teacher in a school or that's what I'm planning for at least the next 10 years. (Mh). But I am looking at err other options like educating people in industry for example. [...]. I might be teaching in a private sector. [I1:2a]

5.4 Perceptions of the teaching profession

Personally, Andrew perceives teaching as an honourable profession but feels that in reality it is not attributed the honour it deserves as a profession by certain circles in society such as parents and government people. His reasons are based on the observations that teachers do not have any control over remunerations, teachers have no control over time, they are not really accountable to others, their job is not specialised and worst of all they do not behave like professionals. He believes that

> Professionals in my experience would go out of their way to satisfy the time. In this case which would be to the students. In my experience most teachers are just doing their job. Its not student orientated or client orientated it's-it's a job that has to be done so its done. ...... it's almost like unskilled labour they just do it because they are expected.

His reasons for joining the teaching profession, his intentions regarding the teaching career and his perceptions of the profession seem to complement one another. To him teaching is an honourable profession and that he has a commitment to it.

5.5 Characteristics of good teachers

Apparently he had not met good teachers as a school student who could have influenced his decision to pursue a teaching career. Instead he thinks that the teachers he had were more friendly and good people than good teachers. However, he has some convictions about characteristics of good teachers as shown in excerpt [I1:2b] below. Notice that all these characteristics are affective attributes.

> [...] I don't think that in my high school career I had a good teacher. [...] good people teaching ... [...] but they were not good teachers. Um, Primary school career I distinctly remember my Afrikaans teacher at that stage and I think enthusiasm was one of his most outstanding characteristics. Enthusiasm and discipline ... [...] School teachers weren't very good. They were more friendly than good-good teachers, good people. [...] enthusiasm, [...] knowledge of what is going on very good knowledge of what is going on and love for what you are doing. Those are the elements of good teachers" [I1:2b]

5.6 Conceptions of science

Analysis of Andrew's interview transcripts revealed the ideas summarised in Table 5.1 below. New ideas emerging later in the study are given in *italics* in the final interview column.

Table 5.1: Summary of Andrew's views about science:

Initial interview [I1]	Final interview [I3].
Science: • is a process involving observation, experimentation, investigation, establishment of facts, interpretation, analysis, explanation,	**Science :** • *consists of a body of knowledge;* • *it's a process of accumulating knowledge not necessarily complete or satisfactory* • it's activity orientated with a knowledge base (intent to gain knowledge); • tries to explain how the world works (clarifies) **Scientific process:** • Scientific knowledge is produced by observation, intended or unintended, experimentation; • has both hypothetical part and speculative;
Scientific knowledge: No data available, not explored as such.	**Scientific knowledge:** • no distinction between scientific knowledge and other knowledge; • *it involves hypothesis not prevalent in other subjects as in science;*

It should be noticed from Table 5.1 that Andrew holds the process - product conception of science. His initial response to what science meant to him betrayed only the process view, and he sounded somewhat doubtful as shown in excerpt [I1:4] below.

> I think science has got to do with experimentation, investigation, you establish the facts. So its a process (Mh) involving those steps. I think. [I1:4]

There was some confusion regarding the relationship between science and facts. It was not clear whether facts constituted scientific knowledge or not, but Andrew was certain that facts could be established through the scientific process but were not science in themselves as excerpt [I1:5] below shows.

A: [...]. Once a fact has been established it is no more science because its not a process that's what I'm saying essentially. ... to talk about a desk {hitting the desk} for example as fact is not science, it's a fact

I: So yo-you consider facts not be science?

A: No. To modify that and talk about scientific fact .... relating it to science rather .... it to science, its been discovered by scientific process or so, (Mh) it is scientific fact. But a fact in itself is a fact.

I: But once it has has reached that, I don't want to put words into your mouth but once it has been established as a fact it ceases to be science?

A: Not necessarily it can be ... what I'm saying is it's no longer part of the scientific process which I consider ... sci nce to be as a process. What then you can maybe say is it's a fact. It has been established by scientific means (Mh) but it is not science in itself ... once it is established then it is fact but as long as you're involved in the process you might establish the fact again, *[it]* still is science. If you establish the fact going through scientific process but that is still science, I mean it's still facts. It's still facts. [I1:5]

It seems from this extract that Andrew views the process of discovering or establishing facts as science but the established facts are not science because they are outside the process. In his view facts can only be related to science. The views displayed in excerpt [I1:5] were presented at the beginning of the study. It will be noticed, too that at this time Andrew views of science were dominated by the process view. Unfortunately his ideas about facts in relation to science were not explored in the third interview. It appears Andrew expanded his views during the course of the year. So that later in the last interview, his responses reflected a much broader view of science as shown in excerpt [I3:27] below.

> [...] science [pause] consists of a body of knowledge ok (mh). However, er it is not just merely a body of knowledge [...]. It involves more than just the body of knowledge it involves you know um activity also (mh) an intent to gain more knowledge, to clarify um you know er to try and explain how the [...] world works. So it's er-it's activity orientated at the same time er it has a knowledge base. Ok. (Mh) Um so that's what science is to me means, it's a [...] process of accumulating knowledge and er not that knowledge is ever um satisfactory or complete (Mh). But the scientist is engaged in activity um the process of accumulating that knowledge (mh) and explaining how things work you see. [[I3:27]

Portrayed in this presentation is that science is a process by which knowledge is generated and that knowledge changes. This implies that science consists of both the processes and the product of those processes - the knowledge itself.

5.7 Conceptions of science teaching

His conceptions of science teaching and teaching in general were derived from interview data directly addressing that concept on the instances and non-instances of science teaching [see Appendix 1B] and teaching tasks [Appendix 1C and 1D]. His ideas of teaching comprised the involvement of any one of the activities summarised in Table 5.2.

Table 5.2: Andrew's views about science teaching

Initial Interview [I1]	Final Interview [I3]
• helping students discover knowledge and skill for themselves, teacher should be more of a guide than pass on information	• teaching is about facilitating the learning process.
• providing opportunity for discovery, creating a relaxed, comfortable atmosphere that is conducive to learning;	• leading students to discover what the teacher intends them to discover.
• presenting information or knowledge.	• the transfer of knowledge or information.
• clarifying things for students.	• clarifying students misconceptions.
• taking part in a teaching activity.	• *consolidating students' ideas, or*
• using teacher aids.	• *getting students to think about a particular situation or problem.*
• improving students' knowledge and experiences.	
• developing critical thinking.	
• requiring students to recall information.	

Andrew's conceptions of science and science teaching were well established and have been influenced by the way he has been taught. After all he has been teaching for some time in the same way he has been taught by his previous teachers and has developed some degree of confidence in teaching.

> [...] I thought [...] I was a good teacher because um I taught the way my teachers taught and the pupils were very happy with the way I taught because that's how they have been taught. (Ok) It's just that maybe I taught better than what the teachers taught-the way that the teachers taught them. [I2:18]

During the interview Andrew was asked to give his theory of how teaching occurs and how learning occurs. As is the case for many of us, he experienced difficulty explaining how teaching occurs but his theory of learning came out clearly in both the interviews. In the second interview it was better formulated (see excerpt [I3:29b] in section 5.7.4 on page 92 below) than in the first interview shown below in excerpt [I1:6] and, which does not contain anything on teaching.

I: I would like you to sort of give some kind of summary, that is a brief description of your theory of how teaching and learning occurs.

A: I'm sorry I've just been confused a bit the last three weeks. [...] By Skinner and Piaget and all those guys because, I mean we have just looked at how learning takes place.

I: Ok. Initially what-w-what ideas did you have?

A: Initially that is initially I did not have a particular theory of how learning takes place. [...] I had some sort of idea and my idea was um (pause) people are continually constructing knowledge and knowledge is built on previous knowledge. (Mh). That's why it is so difficult for people's ideas for example about something to change even though they are confronted with lots of overwhelming

> conflicting ideas that whatever they believe, that might be right. There is a base of information [...] on which knowledge is based, on which more and more knowledge is built and sometimes even though it might be wrong. The base of knowledge rejects that which contradicts with it even though there is only one ... [...] essentially what happens is knowledge is accumulated um but before it is sort of absorbed you know taken in, to his first sense (mh) So basically that's how learning takes place to me (ya). But personally I feel I think as far as my subject is concerned that err anybody that I teach will be able to pass my subject, that's my initial that's my fundamental belief. (Ya). Given the right amount of time or given enough time any student that does my subject will pass at least in standard grade. (Ok). You see what I'm saying everybody has the capacity to learn (Mh) to the degree that is necessary for him pass. [I1:6]

There seems to be a slight shift in conceptions of teaching science between the two interviews as shown in Table 5.2, some correspondence is shown between the first items in the two lists. The phrasing has been modified for purposes of clarity.

The following ideas will be described in an attempt to illustrate Andrew's views of teaching:

- teaching is facilitating the learning process;
- teaching is knowledge presentation and transfer;
- teaching is improving students knowledge and experiences;
- science teaching is leading students to discover what the teacher intends them to discover.

In illustrating these ideas initial and final conceptions (classified according the interview data from which they were obtained) are considered simultaneously. This is an attempt show changes in conceptions of science teaching and learning during the period of the study.

5.7.1 Teaching is facilitating the learning process:

Andrew believes it is important for the teacher to be more of a guide than to simply engage in teaching as passing on information to the students. He felt the teacher had an obligation to prepare the students for their future encounters as the excerpt below shows.

> ... I think the teacher's responsibility is not only to teach. (Mh) um student's knowledge but to teach them how to learn, you see how to acquire knowledge [...] it is important for the teacher to be able ... do that. [I1:4]

During the course of the programme Andrew seemed to develop a strong conviction that teaching involves the facilitation of the learning process. This conception was only demonstrated in the final interview as the following excerpts show. It is possible that the HDE programme was responsible for this change.

[Appendix 1C:1] in response to item on teacher handing out crystals:

> Teaching is taking place definitely ok (ya). Because the teacher is there facilitating um you know the learning process which is what teaching is all about. [I3:29]

[Appendix 1C:3] in response to item on students in library working on problems :

> [.....] one student could be facilitating the learning process for the other student (mh) that could be teaching. [I3:30a]

[Appendix 1C:5] in response to item on a teacher questioning a student's statement:

> Teaching in my definition is definitely taking place. The teacher is definitely facilitating as a teacher in that he is attempting to-to clarify maybe some sort of misconception according to the teacher (mh) or he is trying to consolidate the [...] students ideas or perceptions to try to get the student to think more about this particular question. [I3:30b]

Embedded in excerpt [I3:30b] is the view that teaching is clarifying science concepts to students.

5.7.2 Teaching is knowledge presentation and transfer

This conception may appear to be contradictory to that discussed in section 5.6.1 above. This could suggest that, for Andrew these two conceptions exist collaterally and can be complementary to one another.

Some of Andrew's responses seemed to indicate that the presence of a teacher is not necessarily a prerequisite for teaching. It is apparent that he believes that whenever knowledge or information is presented either by means of a teaching aid (e.g. TV, textbooks, recipe book) or by a teacher or any other person, teaching will take place. However, he acknowledges that the kind of teaching that may take place is not always necessarily effective. Here are some examples to illustrate this view:

[Appendix 1C:4] in response to item on a university lecturer lecturing to grade 1's on molecular orbital theory:

> [....] teaching is definitely taking place because knowledge is being presented. I'm assuming that in my definition of teaching, the presentation of knowledge, (ya). I'm not being specific about that [...]. [I1:8a]

[Appendix 1C:3] in response to item on students in the library working on problems:

I can say they are using it as a teaching aid but they are not necessarily having a teacher involved and using one way of teaching aid teaching is t-is to teach. (Ok) Teaching is in that sense taking place err even though you can't say that the teaching is taking place when the textbook was closed and shut, but when it's open and is presenting something in some sort of ways which is what teaching is attempting to do [...]. [I1:8b]

[Appendix 1C:3] same as above:

Ok. However, the textbook which is the teaching material um provides the opportunity for teaching or learning to take place [....] textbook is substituting as the teacher. Um therefore I could say as far as the textbook is concerned that teaching is taking place. [I3:30b]

[Appendix 1C:2] in response on item about a student watching TV:

[.......] And although it's [...] not an active interactive discovery type of situation, knowledge has been passed, information has been passed over and you know the realisation that plastic-the realisation of the process of how plastics produced from coal is a learning experience for the student (ya). So there teaching would be taking place. ......, [I3:30d]

In this respect Andrew recognises that teaching is about serving as a source of knowledge and skill to students and that this is actually the function of the teacher. To teach he believes the teacher must be well skilled and posses a vast knowledge base exceeding the syllabus.

Um Ok. It is very-ok first of all the teacher-I mean that is actually the function right (of serving the students as a source) ya as a source of knowledge (ok) and skill. Um secondly [pause] I [...] don't mean that in the confines of just science teaching. I mean in general (yes) ok. So that is what teaching is all about sort of you can say. So if you're going to be teaching then obviously you have to be you know that you should be well skilled you should have a vast knowledge base, one which exceeds the syllabus you know (yes) because apart from helping students you know with their current problems it makes science more interesting, it make the teacher more confident, it makes the students more confident because [.....] they can depend on the teacher you know because the teacher is [...] well informed. [....] And also if it comes to asking questions in the class perhaps it goes outside the syllabus, the teacher can be embarrassed because you know he is not that source of knowledge and skill that he is supposed to be. [I3:34]

5.7.3 Teaching is improving students' knowledge and experiences:

There are possibly various ways of improving students' knowledge and their experiences. Part of the teaching task as seen by Andrew is the expectation that students reproduce what they have been taught. Assumed in this view is that

[...] different activities constitute teaching. Well as long as the activities are exercise or an attempt um to fulfil the aim of improving-improving tea-improving children's knowledge and experience, and enriching experience then teaching is taking place. [I1:9)

5.7.4 Teaching is leading students to discover what the teacher intends them to discover

Good instructional strategies for effective teaching of science seems to require teacher to provide opportunities that will

> .... [...] help the students themselves to discover knowledge and skills on their own. .... [I1:3]

It is important for the teacher to provide opportunities for students to experience discovery on their own. Science teaching is facilitating scientific discovery. This view can be shown in the exemplary excerpts given below.

[Appendix 1A:1]: in response to item on a teacher handing out crystals:

> In this particular case [...] the teacher is supposed to lead them to discover something (mh) alright. And I would assume that there would be something about the crystals that the teacher is attempting them to discover, [...] and the teaching part is leading them to discover what it is that she wants them to know [I3:29a]

[Appendix 1A:8] in response to item about a student baking:

> ...] So Science teaching is definitely taking place because facilitation is being made you know for scientific discovery you know (mh) but it doesn't mean that the person is supposed to be necessarily ... engaged or interested in the scientific processes that are taking place. [I3:32]

As mentioned above, it was more difficult for Andrew to describe how teaching occurs than it was to describe how learning occurs. The data from the initial interview seem to suggest that he was unable to give a theory relating to how teaching occurs. However, by the end of his pre-service training he had developed some kind of theory of teaching, or rather he was able to derive one from his conception of learning. This statement does not necessarily imply that the HDE helped him develop a kind of theory for how teaching occurs. He was more convinced with how learning should occur as demonstrated in excerpt [I3:29b] below.

> [...] My theory of teaching or how teaching-how teaching should occur is very linked-very closely linked to how learning should take place (mh). And in my personal experience and the way I feel is people learn better when they discover things for themselves. ... learning takes place through discovery in other words .... and self realisation, realising that. Ok sometimes its discovery um you discover something when you are told something you know what I'm saying. So you discover what you are told. So in essence it's only once you realise and understand what it is that [....] you are being told or ... that learning actually takes place ok. Learning is an active process as far as I'm concerned. The student is engaged it's almost like discovery has taken place for themselves. Teaching therefore would then be facilitating you know that discovery process. Because the teacher is teaching um when he is leading the students to make their own discovery [...] Um that is how teaching occurs and that's how learning occurs to me. [I3:29b]

5.8 Conceptions of science learning

A summary of Andrew's views about learning are given in Table 5.3 below. These statements have been taken from the data sources with minimum modification.

Table 5.3: Summary of Andrew's views about learning

Interview 1	Interview 2
• learning is the continuous construction and accumulation of knowledge • learning depends on students not the teacher or what is being taught; • learners must be actively involved in discovering things for themselves or solving problems; • learner must be aware that s/he is accumulating knowledge; • can be a subconscious activity • depends on how material is presented: simple or difficult to follow; • depends on teacher's success in his/her attempts;	• learning is about acquiring knowledge • learning is finding out about things through discovery and self realisation; • learning is an active process and depends on the active involvement of students • learners must be engaged actively mentally in discovery • learning depends if there is a new body of knowledge being transferred from one to the other and therefore on whether learners are discovering something new;

As can be observed from extract [I3:29b] above, Andrew found it difficult to discuss teaching without drawing upon his ideas about learning. He was convinced that teaching and learning are neither mutually exclusive nor inclusive and that one is not necessarily a natural consequence of the other. Teaching attempts to bring about learning (Hirst, 1971). While Andrew acknowledges this, he is also convinced that teaching could occur without learning and is supported by Hewson and Hewson (1988) in this belief. In his description of learning, he emphasised the constructivist view of learning which places the learner at the centre of the learning process. He thus appeared to hold a strong belief that the learning process depends on various aspects of the learned material and the learner. To illustrate these ideas the following extracts are given. That is the learning process depends on

- the student not so much on the teacher:

[Appendix 1C:2] in response to item on student watching TV

> [...] The TV could be a teacher aid .... but that doesn't necessarily mean that the student is learning. And in that case learning depends on the learner not on the teacher so much. [I1:8]

- how the material to be taught is presented not on what is being taught:

[Appendix 1C:4] in response to item on the lecture on molecular orbital theory

> [..] learning in this particular instance {molecular orbital theory lecture to grade 1's} (mh) depends on the students um not necessarily on the what is being taught. So even though it might be a difficult subject it does not mean that at the end of the day the student has learned nothing.(Mh) It's difficult to say the student is learning something (Mh) it depends on how it is presented whether simple enough for them to follow it etc etc etc. [I1:8-9]

- whether the student is listening attentively:

[Appendix 1C:4] in response to the same item as above

> [...] they do learn that depends on the individual whether the individual is engaged in listening attentively, or in discovering something. [I3:31b]

- whether the students are actively engaged mentally in thinking about the task at hand or actively involved in discovering something new:

[Appendix 1C:3] in response item on a teacher questioning a student's statement

> As far as learning takes place depends on whether [...] in the process um each student is actively \engaged in discovering something [I3:31a]

Excerpt [I3:29] on page 92 above also shows that Andrew's views were more applicable and less theoretical. This was not the case at beginning of the study. Apparently he was already in possession of these theories prior to entering the HDE programme as excerpt [I1:7] below shows.

I: The theory that you have just mentioned about that there is a knowledge base on which additional knowledge comes in and depending on how it features that it-it is rejected. Did you have that idea before you joined the HDE?

A: Yes I did. I've actually done-this particular idea comes from the err err the course that I was doing on intellect improving your intellect -that's basical and I did it sometime in my first year university, (Ya) sort of memory things (ya) where you improve your memory type of things. [I1:7]

It is not clear whether the views expressed in excerpt [I1:7] above are based on the recent theories of learning just discusses in lectures or those are ideas he had prior to his HDE lectures.

From these extracts and other data not reported here it appears Andrew views learning as a process involving:

- knowledge acquisition be it construction or accumulation bay adding on to store of concepts;
- understanding what is being presented by the teacher or what is discovered by

the learner;

Andrew also viewed learning as an active process in which students are actively engaged in discovery of new ideas, the transfer of a new body of knowledge or the acquisition of new knowledge. These views complement some of his views on teaching.

[Appendix 1C:5] in response to item on a teacher questioning a student's statement

> .... I think learning will take place if um the student is actively engaged in thinking about answering the question. [.....] Learning is about acquiring what is supposed to be knowledge, ok. (Ya) And if he's engaged in thinking about the question and answering and giving some sort of justification in his answer then he will be engaged in learning. [I3:31]

[Appendix 1C:3] in response to item on students working on problems

> [...] As far as learning takes place depends on whether there is new body of knowledge that is being transferred by any one of the two students and whether in the process um each student is actively engaged in discovering something there. [I3:30]

5.9 Andrew's experiences

Like Ferrial and Mary, the other two participants in the study, Andrew had been asked to keep a journal of his feelings, thoughts, encounters etc. during the course. He claimed to have kept a journal which unfortunately I was not able to see. Andrew's experiences during the programme were therefore obtained by interview and a variation of stimulated response. According to Clark and Peterson (1986) stimulated response involves replaying audio- or video tapes of episodes of teaching to enable the listener or viewer to recollect and report on thought processes during these episodes. In this study by "a variation" of stimulated response I refer to a process of stimulating recall by using the teaching plan followed for core science and the physical science methodology courses.

As mentioned earlier Andrew has some teaching experience. At the start of the HDE programme he had the following expectations from the physical science methodology course. To be taught:

- how to approach problem areas in the std 8, 9, 10 physical science and how to explain these concepts to students.
- how to prepare coherent lessons and how to deliver them effectively.
- to learn how to deal with my students and their misconceptions and problems.

the learner;

Andrew also viewed learning as an active process in which students are actively engaged in discovery of new ideas, the transfer of a new body of knowledge or the acquisition of new knowledge. These views complement some of his views on teaching. [Appendix 1C:5] in response to item on a teacher questioning a student's statement

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- how to prepare coherent lessons and how to deliver them effectively.
- to learn how to deal with my students and their misconceptions and problems.

From this excerpt it will be seen that Andrew hoped to acquire some skills to address specific issues which he had identified as posing problems inhibiting him from teaching effectively. He hoped to acquire procedural knowledge and not so much, declarative knowledge.

Attempts have been made to divide the description of Andrew's experiences into two parts: experiences relating to HDE courses (both campus based and teaching practice) and personal experiences. But as will be seen, it was difficult to separate these experiences.

5.9.1 HDE related experiences

Andrew's experiences of the HDE programme were not necessarily pleasant ones. The year had ups and downs to a point where he considered withdrawing from the programme. The description that follows highlights some episodes in Andrew's experiences.

Andrew taught for a few years before deciding to professionalise his teaching career. He verbally acknowledged immense benefit from the HDE programme, highlighting that

> I think personally I have benefited, because a lot of the things I have been exposed to in this course and [...] I can only talk for myself actually, (yes) um is that this discovery learning, I mean these teaching methods and teaching theories [...] are things you never come across um when you are doing the BSc degree for example. (Mh.) And even when you enter the classroom situation those things will never be brought to your attention unless you attend a course like this. So I feel personally I've benefited. [I2:17].

He went on to say this about the course

> I think it's very practical. Um I think it is very teacher specific meaning that you know it equips the person to be a teacher. [I2:17a]

He felt he developed this appreciation of the HDE courses because he had been exposed to inferior education as a school student. He claimed that during the courses in the programme he came across a number of things for the first time. For him it was a very enlightening regarding available strategies which he was not aware of. He said that

> We never did discovery-worksheets you know. We didn't really have worksheets we just did things out of the textbook you know. We had to do questions and stuff like that out of the textbook, etc etc. I mean where I come from I was lucky that they had a lab. But even with the presence of a lab a fully equipped lab the teacher wasn't competent enough to-to demonstrate. [...] I've never personally touched any of the apparatus until I came to matric in the physical science situation. It

has always been demonstrations done by the teacher. Um we've never had to fill in sort of um-um you know worksheets, you know where you go through experiments and you observe certain things and you fill in stuff. We've never done that kind of stuff. (Ok) Um and because I've never seen a worksheet before I've never felt competent enough to draw up a proper one. [...] So I mean personally I think I've benefited an incredible amount. [I2:17b]

It does not seem that even at matric he had a chance of engaging in practical work and worksheets. Also in his teaching prior to preservice training, Andrew followed a teacher centred approach which was reflective of his experiences as a scholar and which he thought then and now, was very good. Discovering different methods of teaching could have implied that he would start using a different approach to teaching from the way he has been taught. The practical nature of the courses also gave him some ideas on how to organise and run practicals in his own classroom.

He claims to have come across teaching and learning theories he had not been aware of as an unqualified teacher. His benefit from the HDE was further enhanced because he had been exposed to part time teaching while doing his HDE. His involvement with teaching at the same time as his HDE studies could have opened opportunities to try out these theories and methods. So though he should have been in an advantageous position of 'on the spot' in-service, his students were not reaping the benefits of his training. Neither was he able to implement the newly acquired knowledge and skill, as he describes below.

The students unfortunately can't get the benefit of my of my knowledge here because of the time factor (Mh ok.) So er, but personally I think they-they enjoy my lessons you know just personally (Ya). And also I meet their expectations. If I had to teach in a different way. I think it would be very traumatic for them if I had to teach discovery learning and those kinds of things, especially in the first few weeks or so [I2:18].

This anticipated trauma raised more anxiety in Andrew because he had initially presented a predominantly didactic aspect of his teaching with which the students were familiar and could relate to and which they preferred. The change was not welcomed by the students. In some ways the rejection of Andrew's change of teaching style from teacher centred teaching towards more student centred teaching landed him in a frustrating situation. In the school where Andrew taught there was no understanding that Andrew was a student teacher. He was regarded as a fully fledged teacher who had to meet all the school requirements and was therefore judged like all the other teachers by the students. Andrew's curiosity about students' perceptions regarding his teaching led him to a disappointing discovery of unpleasant comments in evaluation forms completed by the students.

> [...] initially I was very comfortable with the way I taught and the students thought I was good (mh) in the way that I taught initially. (Ok). And when I came to university they told me otherwise, because my style of teaching was more than um you know that sort of teacher orientated teaching. (Ya.) And I changed my style the students didn't like it (At the beginning of the year, this year) Ya when I changed my style of teaching in accordance with what they wanted [...] Ok. So what I found was, and it - the next evaluation forms, I checked through them and I looked at the comments. And they actually said that in the first few months I was good. I was a good teacher. (Mh). And when I changed my style to pupil orientated learning where they must learn a little bit more-where there's more expected of them and I teach a little less, they actually didn't like it and er what I found was that [...] they sort of marked me down from my evaluation. I just checked, I wasn't supposed to check, but I just checked. (Ya). So personally I feel demotivated. I've been feeling demotivated for a little while now for about three months or so. That's one of the things that contributed to my negative attitude towards teaching was ..... (that you were trying to implement what you have learnt from your methodology?) That's it. That's it. (Only to find that it is not received with enthusiasm as you would have expected) That's it. And personally also I feel a little less confident than I was at the beginning of the year, as a teacher [I2:24]

Andrew had hopes of improving his established confidence of being a good teacher by enriching his teaching methods by implementing suggestions from the HDE programme. This experience was sufficient to discourage him and cause him to revert to his teacher centred mode of teaching, as was so predominant in the teaching practice lessons observed and described in section 5.9 below.

As mentioned earlier Andrew was teaching part time in a school which had no facilities for teaching science. He was only able to apply the new skills and knowledge acquired from the HDE programme to a limited extent. It should therefore be appreciated that the limited application was not always by Andrew's choice but was dictated by the situation. He felt that he was driven to relying on didactic teaching because

> ... the discovery method is very impractical (In this situation?) In this situation. (Ehe) Um because we don't have the time. And apart from that particular teaching method or strategy there is only the one that is teacher centred. I would like to believe that I found a compromise between the two (Mh). Then my guided discovery is a verbal one. You know where you don't have this what's the name-drawn up and where you provide them with cues. (Mh.) You know. Um asking problem questions um you sort of guide them along you know and um I would like to believe that at the end of the day they discover these things for themselves (Without actually manipulating stuff) Ya without practically manipulating things. [I2:17]

Andrew was thus faced with the dilemma of satisfying the requirements of the methodologists as a student teacher and those of the students as their teacher. Andrew tried to merge these two pedagogical sides by applying what he called "verbal guided discovery", as mentioned in the extract above. Also as a teacher in a centre which was geared at matriculating students Andrew was faced with conflict between the tasks of trying to teach for some understanding and drilling the students for exams. The latter seemed to dominate as shown in the description of the observed teaching practice lessons (see section 5.11).

Andrew's students rejected his change from teacher oriented teaching style to student centred teaching. The rejection of the change to teaching styles by students (and co-operating teachers) is a common thing among student teachers (Clark and Starr 1991). This, among other drawbacks in the school, limited Andrew's attempts to implement suggestions from the HDE programme. He managed to change his approach to lesson preparation because this did not directly involve the students. But he found this to be a time consuming exercise. Initially he spent much less time and used very few resources when preparing. But after he started with the HDE programme he realised that his lessons were below standard. When he applied what he had learned he started using more textbooks and spending more time. He later claimed that he prepared better from several textbooks because

> [...] certain textbooks emphasise certain things and they leave out certain things, whereas others emphasise others. (Ya) But I think the importance of it all is when you get a global view as you select, you can select what is actually important, you know what I'm saying, because another of the resource material that I use is specifically aimed um at the sections that are examinable ... the end of the year, you know what I'm saying, (Mh) so they are exam orientated. [I2:15]

He felt more confident with his lesson preparation though he was convinced that the use of different textbooks did not broaden his content knowledge. This was because whatever was presented in the books was not new to him. But this confidence was counteracted by rejection by students and he could not implement his lessons as he prepared them.

Andrew was also concerned about his assessment and evaluation by his lecturers. He claimed he was assessed only once. What he overlooked, however, was that he was not present on two occasions when the assessing lecturer visited the school for observation. To show his concern he went to the extent of asking me on three occasions to

> ... make some sort of evaluation because you [*researcher*] have been there consistently and you have sort of seen exactly what I've [*Andrew*] been doing all the time unlike somebody that's coming in and just checking me once etc etc. [I2:18-19]

Being absent was fairly common for Andrew. He was also absent from several HDE classes and it was only natural for him to be concerned with the influence one teaching practice assessment would have on his overall performance. Also being aware that he was limited in applying the suggested approaches because of the school and students' expectation, he was afraid of being marked down during assessment.

5.9.2 Personal Experiences

Most of Andrew's unpleasant experiences during his professional training were not directly linked to the HDE programme. The above discussion shows that during his year of study, Andrew was engaged in three separate activities which were taxing academically, professionally and socially. These activities were his HDE studies, teaching science and mathematics to matric students (for which many educators have some idea of the commitment required) and being a conscientious family man. These activities can be particularly strenuous when combined and in this instance constituted a demanding lifestyle for Andrew. The effect of these demands climaxed in the second block of the Wits calender, especially in June. Andrew informed me of his depressing situation during an informal interview sometime in July. What he disclosed explained his absenteeism observed in the last two weeks of June, when he was not attending any of the HDE courses at all. Apparently during the June period he had eight examination papers to set for the classes he taught. He felt he had geared himself to a stressful lifestyle. The other responsibilities he had included of course his studies, house chores and taking a child to school every morning. As a result of the latter he found himself always running behind schedule, for example rushing for taxis to Wits, sometimes missing essential meals like breakfast. All this culminated in a stress related cold and he claimed to have collapsed at some point. He felt completely burnt out and could not cope. During these times he seriously thought about withdrawing from the programme. It seemed his commitment to teaching and school requirements and domestic chores were of greater priority than his studies. In a later interview he had this to say regarding his home life:

> [...] when you are single you have the luxury of arranging your time and planning. You plan it. When you are married like I am and you have two kids below the age of three, they don't care about your plans, you know. If you decide you want to sleep from um twelve o'clock to six o'clock, or you want to get up early in the morning, sometimes four o'clock, they get up earl-they get up any time they want to. Um and they keep you awake and by the time you want to get up and do what

> you have planned to do you're also exhausted and you know, you are just not able to do it. And it's not a one of thing, it's something that happens frequently you know. [I2:13a]

It seemed he had to carry out his share of the home chores and that the only time he could concentrate of his own studies was during the day when he was also exhausted. Fortunately the stress period described above was fairly brief. Andrew thus stayed on because he felt the third and fourth block had less work for him with no exams to set, though the other responsibilities were still there.

So considering his stressful lifestyle at this point during the study, naturally I asked for his opinion about the idea of studying and working at the same time. His response was

> I think it's a good idea, if you are doing this particular course it's an excellent idea, because it gives you practical um training on the spot, sort of. It is almost like inservice training. So-and personally if that was all I had to do it wouldn't have been a problem. (Aha) So as far as I'm concerned there should not be a problem. It should actually be to your-to your advantage. [I2:13b]

5.10 Andrew's knowledge of chemical concepts

Andrew is a 1993 Chemistry III graduate from Wits. His knowledge of chemical concepts, together with that of the rest of the group, was diagnosed by means of two tests [see Appendix 2]. Since he had considered withdrawing from the course he had not bothered to do the test on chemical bonding. It was not until during the teaching practice after he had decided to stay on that I followed him and asked him for the test. So he took much longer to do the test than the rest of the group. This is reflected by the detailed reasons he gave (see Table 5.4 below, pre-test column). In interpreting his responses it should be remembered that Andrew was absent when chemical bonding was discussed in the physical science methodology classes (see chapter 4), that he did not do additional studies and only attended the very last chemical bonding session in November. This last session focused in part on students' experiences of teaching chemical bonding during teaching practice and analysis of sections on chemical bonding from textbooks chosen by students. Student teachers were expected to identify misconceptions or errors propagated by school textbooks. This exercise prepared students for a similar exercise when they get to the schools. So it is difficult to draw any conclusions about the effect of the classes on observed conceptual changes, if any, regarding chemical bonding.

Table 5.4 Andrew's concepts of chemical bonding

Responses in Pre-test (Explanation verbatim) Class average: 4.6		Responses in Post-test Class average: 7.7	
1.	A: the crystal lattice consist out of packed Na^+ and Cl^- ions	1.	A: reaction is characterised by electron transfer
2.	D: the intermolecular bonds are strong, leading to distinct breaking of the bonds	2.	D: breaks clearly => strong forces between the molecules
3.	*C: the colour of a molecule does not depend on the strength of the bonds between the molecules	3.	*C: the absorbance of light of all wavelength, it is due to the chemical bond, will indicate strong bonds.
4.	C: the forces that hold the two atoms together is not electrostatic. A distribution of electron cloud density is responsible for the reaction	4.	A:no explanation
5.	A: chemical bonding occurs as a result of electron density shifts.	5.	*C:no explanation
6.	*D: because it describes the length of the bond (or the distance) between the two molecules or atoms.	6.	*D:no explanation
7.	*B: melting requires that the bonds between the atoms should be broken. The greater these forces between the atoms the higher would be the melting point because more energy is required.	7.	*B:no explanation
8.	C: because the I_2 molecule has "covalent" bonds, the atoms in the molecule would be closer together than in the crystal	8.	*B:no explanation
9.	*A: there exist chemical bonds between the molecules in a network solid	9.	B:no explanation
10.	C: not always wise to talk about bonds because a molecule of NaCl, how do you classify this?	10.	*D:no explanation

* denotes correct response

His responses to questions 1,4 and 5 [Appendix 2A] suggest that he did not undergo any change of ideas regarding the nature and origin of the chemical bond. The fact that he was unable to answer questions 1 and 4 or justify his correct answer to question 5 supports this assertion. Another disturbing observation is that he changed from a correct response, both option and reason, to an incorrect response for question 9 on structural changes. It appears Andrew needed the discussions he missed considering the shifts that were observed for questions 1, 4 and 5 and slightly for question 9, see Table 4.3 on page 49. Both his scores were below the class average of 4.6 in pretest and 7.7 in post test. Further data would be required to validate the possible conclusion that he scored better in the post test because of the last discussion on chemical bonding and the assignment.

Results of the exploration of Andrew's conceptions of acids and bases are given in Table 5.5A and Table 5.5B below.

Table 5.5A Andrew's responses to acid and bases test (Section A)

Question and correct response	1D	2A	3 E	4 E	5B	6C	7B	8A	9B	10A	11A	12B
Andrew's responses	D	A	E	A	B	C	C	A	B	A	A	B

Notice from Table 5.5A above that the only wrong answers chosen by Andrew in the multiple choice section were questions 4 and 7. Choice of option A for question 4 meant that Andrew thought that ammonia was a proton donor. This was possibly a careless mistake because it was contrary to what he taught during his teaching practice, discussed below. His other error of selecting option C for question 7 also conflicted with the ideas he presented in teaching practice lessons. Table 5.5B below shows a summary of his responses to section B of the test.

Table 5.5B Andrew's responses to acid and bases test (Section B)

Question	Responses
1	$CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$ Yes. Because ethanoic acid "releases" (sic) H^+ in solution.
2	$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
3	i) Cl^- is a weak base; CH_3COO^- is a strong base ii) NaCl solution will be slightly basic; CH_3COONa solution will be basic
4	$H_2CO_3 + H_2O \rightleftharpoons H_3O^+ + HCO_3^-$
5	An indicator is a weak acid that changes colour with the loss of H^+ ions. Hence as the $[OH^-]$ in solution increases H^+ ions are lost from the acid, this lead to a change in colour. The decrease in OH^- ions in solution has the opposite effect. b) i) A ii) B iii) B
6	a) Conc acid is undiluted, strong acid is an acid that has a high tendency to dissociate. NB! (sic) b) No. Undiluted acid does not affect the tendency to dissociate, hence not necessary a strong acid.

Table 5.5B on Section B of the questionnaire does not reflect many erroneous responses. However Andrew seems to have had problems with microscopically representing an aqueous solution of hydrochloric acid [Appendix 2B:7]. His representation to question 7 is given in figure 5.1 below.

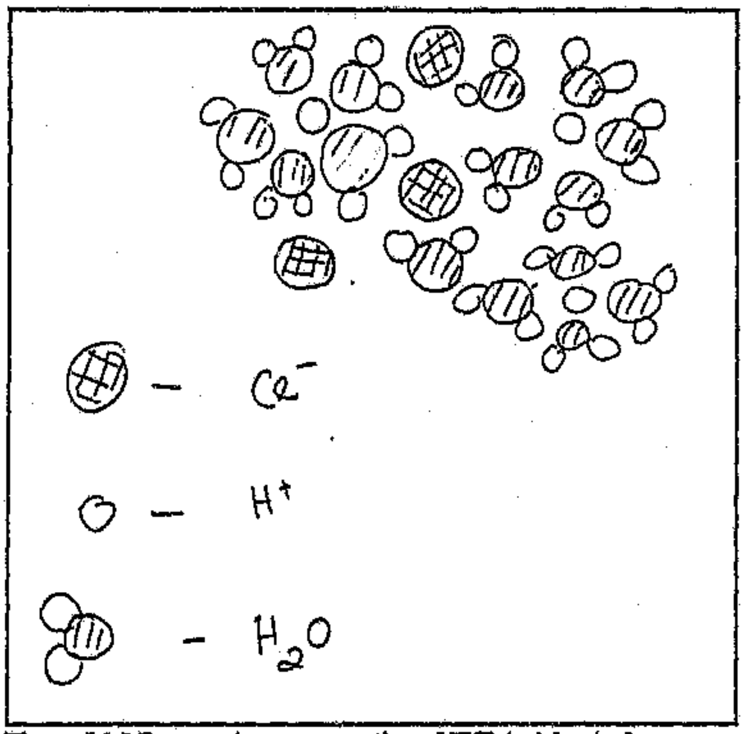

Figure 5.1 Microscopic representation of HCl (aq) by Andrew

It shows a correct orientation of the water molecules and the chloride and hydrogen ions. What is disturbing though is that there are no hydronium ions represented and that free hydrogen ions are depicted to exist in solution. It will also be observed that his response to question 6 illustrating the limitations of the Arrhenius theory of acids is correct. He was also observed during teaching practice explaining that the theory failed because hydrogen ions are highly charged and too small to occur freely in solution. Now what is interesting is that his microscopic representation of the same concept does not agree with the conceptions he appears to hold. This could mean that Andrew does not have a proper microscopic understanding of concepts like aqueous solutions of acids in this case. Similar finding have been reported by Ramot (1992).

5.11 Teaching Practice observation

A brief description follows of the school and the student body of the school where Andrew taught part time and conducted his teaching practice. This contextualises the description and informs interpretations made from Andrew's practices.

5.11.1 The school

The school is located on the 4th and 5th floors of a building in the centre of Johannesburg. Almost all the classrooms overlook a busy street. This means that most of the time learning is disturbed by noise from traffic outside.

Andrew's description of the school was that it is

> .... a matric centre. There's std 9 to std 10. [...] ... It has been called with a lot of other schools like .... Street colleges. [..] And it's essentially a private school um supposedly on a multiracial basis. Er... er... on a profit making basis. [I1:4]

Since it is a matric centre, teaching in the school tends to be directed toward the matric exam. It appeared the students were specifically drilled toward getting their matric. The examination driven way of teaching in the school was also acknowledged by Andrew during an interview where he stated that

> .... the nature of the school is such that we are exam orientated [I2:16]

In some ways the students are treated almost like college students as the school is run more like a tertiary institution. There is no normal school discipline. Students come into class any time, and sit down. There is no bell to mark the beginning and end of lessons. The school is double streamed, with only std 9 and 10 classes.

5.11.2 The Student Body

The school is potentially multiracial but

> ..... the people who do really take advantage of it is Africans. (Mh) So um in fact the population in the particular school that I'm in um they are all African. [I1:4]

The students are supposedly mature and

> ..... come from a variety of backgrounds. Um most of them have done matric already. Um those who will not have done std 9 will have done insignificant amount of work in std 9 work. Er and there are those of course who would not have even done std 9. And so that's a mixed bag of students and they have to do matric. [I1:4]

In addition

> .... though they may be disadvantaged students, the assumption is that students don't know anything.

Because um you don't know what background they come from, you don't know whether the std 9 they have done is you know up to standard sort of. So although some of them I mean though they may be disadvantaged that's the assumption that we make and we work out from there. (So you assume they are "blank slates"?) Well essentially yes. [I2:15]

The latter two quotations give some idea of the kind of support systems that teachers are expected to provide to the students in the school. The teachers are also working under a tight time scheme in preparing the students for their exams.

5.11.3 The Classroom

The school has no science laboratory or equipment for teaching science. All science lessons are held in an ordinary classroom, which has been specifically allocated to science classes. However, other lessons were also held in the same classroom. The absence of a science laboratory and science equipment meant that practical work at the school was severely limited.

The classroom was furnished by 14 long desks each capable of accommodating two or three chairs. Also available was a smaller teachers' desk at the right hand corner of the classroom from the teacher's perspective. The classroom was fairly crowded with very little space between the front wall and the front row of desks. This allowed little more than for the teacher to pace while talking to the class. The lack of space at the front discouraged Andrew from using an overhead projector, among other things, partly because

You see the problem with the overhead projector is first of all, I mean the objective is to face the class. The way the class is structured if I were to use the overhead projector I would have stand in half way between the benches because the space between the board and the pupils is so small [I2:20]

There were no teaching aids except for the chalk-board and one white board. There were sockets available and they were in working condition.

5.11.4 Classroom Observations

Brief background

In all, ten standard 10 physical science lessons were observed, nine lessons on acids and bases and one final lesson on chemical equilibrium. Three lessons, most representative of his teaching style, were selected for analysis. Thus analysis of detailed field notes from these lessons facilitated the identification of categories to focus the description below.

Each lesson began later than the appointed time. Two factors were partly responsible for that. Lessons observed usually came soon after Andrew's other std 10 class. So he took advantage of the fact that he was taking the next class in the same room to conclude his lessons properly. Unfortunately this also affected other lessons. The other factor was that students usually took time to settle down before the lessons began. The absence of a warning bell to start and end lessons was also a contributory factor to the late start of lessons. Andrew was quite accommodating regarding the late start. He often waited patiently for five to ten minutes before starting the lesson or making a formal request for the students to be quiet. Once the students were settled and the lesson had begun Andrew had no classroom control or management problems.

Lesson discourse

In describing the teaching style utilised by Andrew during his teaching practice, focus is given to the following

- general features;
- the questioning style;
- handling of students' responses;
- handling of students' questions.

General features

All the lessons were expository in nature with the exception of lessons which were specifically designed for students to work individually on activities such as when students worked on exercises. The lessons were predominantly lecture type and teacher orientated, especially because Andrew did most of the talking. The teacher centredness of these lessons and the degree of student involvement will be illustrated by some excerpts used to exemplify other characteristics of Andrew's lessons.

Andrew seemed to have great difficulty reconciling what he had all along thought was a good method of teaching with the new methods acquired from the HDE programme as reflected in excerpt [I2:24] on page 98.

description below.

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Lesson discourse

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General features

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Andrew seemed to have great difficulty reconciling what he had all along thought was a good method of teaching with the new methods acquired from the HDE programme as reflected in excerpt [I2:24] on page 98.

All the observed lessons were theoretical even though there were sections which lent themselves to simple demonstrations such as electrical conductivity of aqueous solutions of hydrochloric acid and ethanoic acid, pH and neutralisation. Students therefore relied on what Andrew told them and what they could recognise, usually with help from Andrew, from the lesson as it progressed. It was apparent that Andrew was revising for exams, ensuring that they became familiar with the strategies of answering exam questions which is what the school was geare.: to. It is clear that standard 10 was not the most suitable observation class for this study.

Each lesson began with some revision and consolidation of concepts dealt with in the previous lesson and gradually led to the concepts to be discussed in that lesson. The following excerpt taken from the third lesson on acids and bases as an example of how Andrew introduced one of his lesson and how he developed it into the day's theme of protolysis and acid strength. S1 and S2 ' ': excerpt below denote different students, not necessarily the same students in di' , or subsequent excerpts.

A:	As far as you are concerned or as far as you can remember how are acids defined according to Lowry and Bronsted?
S1:	Acids are proton donors.
A:	Acids are proton donors.
S2:	Bases are proton acceptor.
A:	Base is a proton acceptor. [Writes on the board as in Fig. 5.2] Valerie how are acid base reactions characterised? [pause] By what are they characterised? [pause] Acid-base reactions how are they characterised? Or what happens in an acid base reaction?

<u>Lowry-Bronsted</u>
Acid -proton donor
Base -proton acceptor

So acid base reactions are characterised by proton transfer.

Figure 5.2 Class notes

V:	The acid donates the ions to the ...
A:	What ions?
V:	The hydrogen ions.
A:	The hydrogen ions. In other words, what is a hydrogen ion? A hydrogen ion is a... (Ss: proton) a proton. Ok. So the acid donates a proton to the base ok. So what do we call that process? The movement of a proton from an acid to a base? ..... What do we call it?
Ss:	(chorus) conjugation conjugation conjugation .
A:	Catherine what are you talking about? [They laugh] We said an acid base reaction is characterised by an acid donating a proton to the base ok. What do we call this process? Let me ask you what happens to the proton in that process? The proton is (Ss: transferred) is transferred. "So acid base reactions are characterised by proton transfer." [Writes on the board, Fig. 5.2] Mazuza?
M:	Yes sir.
A:	We have a certain name for the process involving proton transfer. What do we call the reaction in which proton transfer takes place? ....
M:	Acid base pair.
A:	Is that what we call the reaction? [L3:1]

And this is how he introduced the fourth lesson:

> ... Ok. We will start today by just revising the concepts dealt with the last time. ....When we started the discussion last week we wanted to find a way in which to compare acids with bases ok. To compare especially the strength of one acid with the other one. ..... [L4:1]

Excerpt [L3:1] is long and it has been deliberately left that way because it is illustrative of other characteristics of the lessons such as the style of questioning, cognitive level of the revision questions, the students' responses and the approach Andrew followed in responding to the students' answers discussed below.

It will be noticed in [L3:1] that during revision Andrew wrote the responses to his leading questions on the board for students to copy if they so wished. He used the same strategy for writing notes on the board while the lessons progressed. He also allowed them time to take down the notes.

Interpretation:

Being a matric centre the school working structures and students' mind frames are geared towards exam preparation. Both these features dictated how Andrew taught. Also the lack of resources for teaching science might have contributed to Andrew's reliance on the lecture-discussion mode of classroom instruction.This was unusual because these subtopics were excellent opportunities for discovery learning according to his expressed beliefs especially because the students were assumed not to know much about them. Possible reasons for this could have been students rejecting his attempts to involve them. By relying on the teacher talk teaching strategy Andrew acted as the main source of knowledge. He told the students almost all that they needed to know because even the cues he employed were teacher initiated.

By revising previous lessons Andrew maintained a good link and continuity between his lessons. Andrew also ensured by writing on the board that students kept a record of correct information for later use in preparing for their examinations.

Questioning style

In describing Andrew's questioning style attention is given to the cognitive level of the question, frequency of questioning and the direction of focus of questions. Andrew's questions tended to be addressed to a few individual students. Only 9 out of 24-27 students were personally asked to respond to questions. Andrew seemed to know these few students fairly well. He seldom posed a question to the whole class or waited for students to volunteer to answer questions. As will be noticed in the excerpts which follow, he usually called the student to answer just before or immediately after posing the question. Andrew seemed aware that he was engaging only a few students in class discussions. He explained his actions by saying that

> Look, there are-I do pick on certain students um to answer certain questions [....] And I think one of the reasons is because um I didn't make an active attempt to know all students. (So you don't really know all the students?) I don't know them by name [...] Sometimes it does come to mind right but you see the-maybe I should have made the effort now that I'll be there full time. But initially when I wasn't here full time, I just came in, delivered a lesson and then left... [I2:25]

It was surprising that even though he had been working with the students every day of the week and sometimes twice a day he still did not know the names of all his students. Andrew's style of questioning varied. It can be observed from excerpt [L3:1] above that the cognitive level of the revision questions and, as will be seen in excerpts [L3:9] and [L4:6] below, the level of questions used during the lessons was generally low. They were largely knowledge questions requiring recall or recognition of a specific and correct answer. There were, however a few questions requiring explanations showing students' understanding and their ability to apply the knowledge they may have gained. Excerpt [L3:9] below illustrates some of the problems students encountered when confronted with questions demanding more than recall or recognition. For example after a discussion of acid strength and K_a values students were given a task of arranging five acids in increasing order of acid strength on the basis of their K_a values. The task required students to display their understanding of the relationship between K_a values and acid strength and they were unable to do that. When he gave tasks like this, he moved around monitoring students' progress in the task. When he identified a student or a group of students having difficulty he helped those students there and then. But if the problem recurred in another group he tended to interrupt the whole class to address it. It will also be observed that in the process of helping students in the task he resorted to using low level questions.

A: [.....] Arrange the acids in order of increasing strength. [Students seem to be having difficulty. Checks if students know what they have to do]. Valerie. Your K_a gives you some sort of value of whether it is a strong acid or it is a weak acid. Isn't it? Ok. If your K_a value is big what can you tell me about the acid strength?

Ss: Big, large

A: It has a high acid strength. Ok. In other words, if I have two values here, For some acids HA my acid strength is 3-my K_a value is 3 right. But for some other acids, HB my K_a value is 10. Which of those two will be the stronger acid?

V: HB

A: HB will be the strong acid. Why? Because my K_a value is (Ss: high) is high. It is bigger than the K_a value of HA. [L3:9]

Another issue that emerges from excerpt [L3:1] is the issue of wait time. Andrew's wait time varied from 2 seconds to seven seconds. In most cases he did not have to wait long because students responded quickly. Sometime he posed questions while writing some notes on the board to get students to think about the question while taking down notes.

Interpretation:

Andrew posed questions that he was sure students would answer successfully. This line of questioning could have been an attempt to provide and maintain a classroom environment that was conducive to learning, though not necessarily contributing to learning (Lederman, 1992). Also contributing to the supportive learning environment is Andrew's ability to phrase his questions in different ways to enhance comprehension of the questions by the students. The success of answering questions in class can motivate students to take part in class discussions whereas high order questioning may discourage this particularly when the success rate of answering is low. Another possible factor that may have led Andrew to indulge in low level questioning was his assumption about the student body as stated in [I2:15] on page 106 above.

Handling of students' responses:

As stated above, most of the questions students responded to were teacher initiated. Andrew employed three ways to deal with students' answers to his questions. These were

- reiteration;
- redirection after rephrasing the questions and then leading students to the correct answer; and
- challenging students' responses and then guiding them towards the answer.

It can be seen from extract [L3:1] above that if the student's response to the question was correct, Andrew reiterated it as in his reply to S1 and S2. If the response was partially correct he posed a further question to lead the student to the desired response, for example Valerie's and Ss' responses in excerpt [L3:1] above. If the answer was incorrect he challenged the students by repeating the student's answer in a questioning manner as in Mazuza's case, before retracing his discussion and leading them to the answer. A more illustrative example of the latter point is shown below in excerpt [L4:6] on a discussion of the concentrations of the hydronium and hydroxyl ions in a neutral solution.

A: [...] Then similarly the concentration of the hydroxyl ion Mazuza, should be (...) Now the hydronium ion concentration is 1,0 x 10^{-7} mol dm^{-3}, what can you tell me about the hydroxyl ion concentration ?

M: Probably twice that.

A: Probably twice that? Ok. Previously we said our hydroxyl ion concentration is equal to our hydronium ion concentration in other words this is equal to that [pointing to the equation on the board $[H_3O^+] = [OH^-] = x$ representing that] Ok. (ya) Right. So our hydronium ion concentration is equal to 1 x 10^{-7} mol dm^{-3}. What can you tell me about the hydroxyl ion concentration ?

M: It will be the same.

A: It's gonna be the same. In other words it will be 1 x 10^{-7} mol dm^{-3}. Ok. [L4:6]

The question that Mazuza had to respond to was also a recognition question. It was only after Andrew "led him by the hand to the answer" that Mazuza was able to see it and then he probably did not understand.

As mentioned before Andrew usually directed questions to particular students. The chosen student was not always successful in answering a question, as shown for example in [L3:1] and [L4:6] above. Sometimes, Andrew redirected the question to another student or opened the question to the whole class usually after some rephrasing and the inclusion of further cues. For example:

A: [...] Now if something is not neutral-the solution is not neutral what could it be, from your past experience what could it possibly be, Busi there at the back? Busi if your solution is not neutral [some ss say something inaudible] what could it possibly be? (neutral) from your past experience, it's not neutral [waits for student to respond] what could it possibly be? Philip do you want to help? It's not neutral (It's not neutral?) er ya.

S: I think it's because maybe the, what is it ...

A: Ok. What I'm asking is that if something is not neutral in accordance with what we have done so far and remember we only talked of acids and bases the-if it's not neutral Abel what do we call that one?

Abel: acid

A: The-it could be either acidic or

Ss: Basic.

A: Ok. (Ss: Oh! [realising how easy it was]). [L4:7]

Interpretation:

A common feature of Andrew's response to students' correct answers was to restate the answer without making any changes. This must have been Andrew's way of emphasising and reinforcing an appropriate response from a student.

Challenging an incorrect response was Andrew's way of telling a student that the answer was wrong without humiliation. The technique of leading the students almost step by step to the correct answer was possibly a way of encouraging students to try again. Very often the students then arrived at the desired answer successfully. This strategy could have been Andrew's way of compromising for relying more on theory for his lessons.

Though he rarely used it, the technique of redirecting questions had the effect of enhancing students' participation in class. The rephrasing or repetition of questions with minor changes was a common occurrence and was possibly aimed at making the questions more accessible to the students.

Handling of students' questions

The duration of Andrew's talking in the lesson depended on the aims of the lesson. For those lessons where he had exercises for students, he talked less. Those lessons are not described here. The initial lessons on acids and bases were devoted to theory, including a brief history of acids and bases. In those theoretical lessons Andrew did most of the talking. In spite of this, the classroom environment allowed students to pose questions during both individual exercises and discussions.

> Don't wait on me. If you have a problem raise your hand so that [illegible] attend to you. But in this particular case identify your acid base pair. [He moves around to individual students - explains and shows how they should go about doing it and how one becomes the base and acid. Students discuss among themselves as well. Some hands go up, he checks them. Student ask question on what happens in 'water and water?'] [L2:6]

Though the lessons were mostly teacher centred, it is clear from the above extracts that Andrew endeavoured to engage students in the learning process through teacher initiated questions. Students also became actively involved in the lessons by posing questions to Andrew whenever they wanted. They even felt free enough to challenge him on some aspects of the class discussions. The questions asked by the students usually required clarification of issues either directly related to the lesson or from students' previous knowledge or on issues that interfered with their understanding or from sheer curiosity.

Andrew may not have been able to provide the opportunity for students to discover things for themselves, but he certainly created a relaxed, comfortable and possibly enjoyable atmosphere conducive to learning as he describes in excerpt [I1:6] below, as a strategy for effective teaching.

> Good strategies would involve the discovering of things for oneself (Mh) I think another good strategy is try to make sure that err I think the kind of atmosphere that would be conducive to err learning. To me that is a relaxed enjoyable atmosphere. [I1:6]

Andrew's responses and explanations to students' questions varied. Sometimes he used analogical explanations. Analogy is defined by Gentner and Jeziorski as

> a mapping of knowledge from one domain (the base) into another (the target, which conveys that a system of relations that hold among the base objects also holds among the target objects. Thus an analogy is a way of noticing relational commonalities independently of the objects in which those relations are embedded. (quoted in Dagher, 1995:261)

An example of the use of an analogy was the illustration of how acid strength is determined:

Estella: Sorry sir, why is it that in these two solutions ..... [inaudible]

A: You see that is precisely what we want to avoid. Well that's the same question that they asked. You want to say something is a strong acid ok. Listen, if we are talking about Xolani and talking about Abel here. Ok. And now you want to compare Abel and Agnes and Xolani. You've got to compare them with something. You've got to compare them to the same thing. You can't compare Abel and Xolani by using Arnold Schwarzenegger and using me for example [students laugh] you know. And then on the basis of that Arnold and Xolani are strong compared to me [Ss continue laughing] Now if you compare Abel and Agnes to Arnold Schwarzenegger then he's gonna be weak. But it be just that Abel is just .... [Students' laughter causes inaudibility] .... Ok Abel, you see that's what I'm saying. We've got to have a reference point. In this case we want to look at acid and base strength by looking using one of these reagents not more than one, so we are just looking at water. Right. .... [L3:5]

Analogical explanations were not only restricted to responses to students' questions. Another instance where Andrew used an analogy was in attempting to illustrate equilibrium concentrations by means of chalk pieces:

> ..... In other words what you have is you have a piece of chalk. This piece of chalk dissociates right (Uses chalk pieces to explain equilibrium concentration, breaks the chalk piece into two pieces.) For each one piece of chalk you have another piece. [L4:6]

Here he explains proton donation analogically:

> So in other words the donor must be (...) taking part in the same reaction. So in other words it's a process whereby the acid gives the proton and the base accepts the proton simultaneously. Ok. It's almost like me giving this chalk to Xolani [He explains analogy giving chalk to Xolani]. Right. It happens simultaneously. It's not like in a case where the acid gives the proton and the proton floats around there somewhere first and then after a little while it arrives at the base, [L2:4]

Interpretation:

Analogical explanations were not a common occurrence. There were few instances which were easily adaptable for use as analogies. Analogies have the potential function of clarifying science concepts provided they communicate the message properly (Dagher, 1995). That is why it is important to show how they relate to the phenomenon being explained and how they do not. In the case of acid strength Andrew managed to show how the analogy related to the point of reference for the discussion, that is the water against which acid based strength is measured: donating a proton to or abstracting a proton from water. However there is also the potential for students to equate acid strength to human strength in the battle for the proton between the donor and the acceptor, which is contrary to the spontaneous nature of such reactions. Another suitable strategy to explain abstract concepts was his use of quantitative examples. Such examples employed arbitrary numerical values, usually number of molecules, to show the acid -base strength. He acknowledged the inappropriate use of molecules instead of moles, as he has done in excerpt [L3:6] below, as an attempt to make understanding of the underlying principles easy for the students. An example to show this was Andrew's response to Xolani's question on the use of the hydronium ion to judge acid strength:

A: .... Therefore to have a strong acid what do you expect about the hydronium ion concentration? It has to

Ss: High, high, high.

A: Ok. If you have a weak acid what do you expect about your hydronium concentration?

Ss: Low, low, low.

X: From that sir how do we judge that the hydronium ion is low or high?

A: That is exactly where we are going. How do we know quantitatively, in other words we can measure which one is a strong acid and which one is (weak acid) is the weak one. Ok. Now obviously if we were able to determine the amount of the hydronium ions right, then you should be able to say ... whether it is strong whether it is weak. So now in other words you may want to take a 100 molecules of HCl and add it to water and I find that 99 of them dissociate. In other words I have 99 molecules of um hydronium. And the same, I also take 100 molecules of ethanoic acid, I add it to water I find, of course it's a weak acid and less hydronium ion say 50 hydronium ions then I will know that this is my stronger acid because I have more hydronium ions there than I have there for the same amount. [L3:6]

Interpretation:

The use of concrete examples seemed a good strategy to explain how the degree of dissociation of acids relates to the hydronium ion concentration and thus acid strength. Andrew used specific examples of acids: hydrochloric acid and ethanoic acid (as stated in the syllabus) which already have specific K_a values, in conjunction with arbitrary numbers to represent the number of molecules undergoing dissociation. The example is not representative of the actual situation in the dissociation of hydrochloric and ethanoic acid in water.

As mentioned above, students' questions required Andrew to clarify aspects of acids and bases. But sometimes the students' questions deviated slightly from the lesson theme. The following extract attempts to illustrates this observation.

A: .... Then in other words the reaction will always go to completion ok. In that case what can you say about the acidity? (....) The acidity would be (...) In other words a strong acid. Is it logical. The more hydronium ions you find the stronger the equilibrium. So in other words you expect this equilibrium reaction for the hydronium ions to go to the right for a strong acid Ok

X: You judge with the hydronium.......

A: We judge the acidity by looking at the concentration of the hydronium ions

X: What if there was no hydronium ions ......?

Estella: What if there was no HCl and H_2O?

A: What if there was no hydrogen chloride (and water) and there was no water

X: Yes. Would we judge with the hydronium ions also?

A: Look, in an acid solution what happens is um the acidity is defined as transfer of (proton) Ok. What you are saying is if there was no proton here how would we have (if there was no water) if there was no water there ...

S: What if it was something like $H_2O + CO_3$, would we get HCO_3 + OH What would we say in that case?

A: Well that's something else which we are coming ..... we are not looking at bases ok. Just leave that one out. Right. Um We are looking at what happens to acids when you add them to water. Ok. What you will find is that you have hydronium ions formed and chlorine (sic) ion formed. Ok that is when you have your acid and your water. That is what we are looking at now. .... not venture into something else. And we say in ..... once you find hydronium ions and chloride ions um because your hydrogen chloride dissociates ok. And the degree of dissociation, in other words the more it dissociates the greater will be your hydronium ion concentration. The greater your hydronium ion concentration the greater will be your acid strength.

V: So which means its only acids which react with water? (A: Only acids ...) React with water.

A: No no that's not what we are saying. What we are saying ...

V: I want to know if acids act only on H_2O to make acidic solutions..

A: No. no Lowry and Bronsted said whenever a proton is transferred then you have an acid base reaction.(Ok) So it doesn't matter who is involved or what is involved. But for our particular situation we want to see that what happens when hydrogen chloride reacts with water? Ok. And that is the dissociation that I have explained. Ok. And the reason why we use water is because water is gonna be, we will cover that later, is gonna be um the reference point from which we are going to measure everything else. You are going to see what happens when you put another acid in water. Ok. Just so that we have another reference point. [L3:4-5]

This extract also shows students challenging what Andrew has been discussing thus far in lesson 3. The students want to know what happens in situations which do not involve water or will not involve the hydronium ion. Too many questions were presented almost simultaneously, and were not so much focused on the Bronsted-Lowry theory of acids and bases under discussion. The simultaneous presentation of varied questions made it difficult for Andrew to answer any of them directly. So he opted for diverting the question relating to bases for later discussion, ignored the others, discouraged students from asking questions which could result in deviation from the lesson and continued explaining proton transfer in acids and water. Andrew's avoidance step seem to have led to Valerie's question which revolved around the necessity of water for acidic properties. Valerie's question forced Andrew to address Estella's and Xolani's questions.

Sometimes Andrew was comfortable in telling students that he was not willing to venture into foreign territory. At some point in the lesson he had difficulty in responding to another question posed by a student:

X: Is amphiprotic different from amphoteric?

A: Let's divide this. Let's look at what ampho- comes from [pause] [...] it's a derivative of the word .... also for amphibian has dual characteristics, ok. An amphibian can live on both water and on the land. Now .... [.....] amphoteric [..] ... dual characteristics and -terric is what has got to do with territory, ok. But I'm not going to teach biology, I don't know biology. We either have to get out of that before it is too late [students laugh]. Let me stick with what I know. Amphi- mean dual characteristics and -protic just means proton. Ok

X: Why do they say protic because it can act either as an acid or a base? So ...... can act either as an acid or a base?

A: Protic But you understand where the word comes from. Ampho means dual characteristics, and protic just refers to the proton. The fact that it can both accept and donate a proton.Ok I'm not going to venture into those territory?. [L3:2-3]

The above excerpt also show Andrew's skill in providing some theoretical background before arriving at the answer to the student's question. Andrew's skill in using underlying principles was exhibited better in lessons directly related to the lesson theme. A more illustrative example of a situation where he discussed the answer from first principles involved the discussion of the concentration of the hydronium ion and hydroxyl ion concentration in lesson 4:

A: .... H_3O^+ concentration is gonna be higher than hydroxyl ion concentration right. And the reason being that when you add the acid to the water it generates hydronium ions, ... you expect hydronium ion concentration to increase. Ok. That's what we are going to say next.

adding of an acid increases the H_3O^+ ion concentration in such a way that $[H_3O^+]$ > $[OH^-]$. Such solutions are said to be

Figure 5.3 Class notes

S: It's confusing because they are equal.

A: Ya. No. They are equal in a neutral solution. [...] Can we go through this again. Neutral solutions, you have hydronium ions and you have hydroxyl ions ok. Now we went on the presumption that because acids generate hydronium ions then where hydronium ion is generated the solutions should be acidic. Ok. But we find no. Our definition says that when the hydronium ions and the hydroxyl ions, when their concentrations are equal then the solution is neutral ok. So the fact that there's hydronium ions is not good enough it's gone up a little more than ..... the hydronium ion. What we said was when we add initially we did it with water ...

neutral. There's the hydronium ion being equal to the hydroxyl ion, I mean the concentration ok. But when you add acid more hydronium ions are generated ok. Therefore the hydronium ion concentration now becomes more than the hydroxyl ion concentration. And therefore we have assumed that in an acidic solution our hydronium ion concentration is greater than our hydroxyl ion concentration. .. Write it down ... and if you do not understand it then we can come back to it [write on board and students copy as in figure 5.2]
Ok. So according to this definition in a neutral solution our concentration of hydronium ions is equal to our concentration of the hydroxyl ions. Any problems with that? (Ss: No). Acid solution the $[H_3O^+] > [OH^-]$. Now. Ok. But in an acidic solution our hydronium ion concentration is bigger than our hydroxyl ion concentration. That is the difference between a neutral um solution and an acidic solution. Ok. ......[L4:8]

It was rare that students presented Andrew with a question he couldn't really answer. A situation like this occurred when he was challenged by Mazuza regarding the spontaneous nature of proton transfer. The question came up in two lessons partly because Andrew did not address it the first time. Andrew was not confident about the answer to the question. He did not want to prolong the discussion, either, as this would have been of no significant benefit as far as the lesson was concerned. Below are two extracts from different lessons showing the context of the interaction.

Mazuza: What causes ...(Pardon) What causes the proton to be donated?
A: [Reiterates] What causes the proton to be donated? [He whistles and the class laughs] Essentially what happens is your hydrogen chloride dissolves in water, dissolution, ok. Dissociates ... because of the reaction ... If we need that it is something that we are going to look at. Just bear that in mind. I will remind you when we get to that section. [L3:2]

Mazuza: Sir, my answer is not yet clear. The question that I have I want to know what initiates um the release of a proton between the two water molecules?
A: Essentially I said .... [Mazuza continues but is quite inaudible because of traffic outside. He was asking something to the effect that] ... you have a proton being transferred on the other side to one water, the same proton can be transferred to the other. If there is a case whereby there is transfer of proton .... If it happens simultaneously, why should we conclude that there will be hydronium ions formed? During this time there is some dialogue ..]
Mazuza: ... matter of transferring it back transfer of its own proton. What initiates that? ... They might have equal forces ..., will they be able to do that? (Andrew invites Mazuza to see him later. Then continues his explanation of acid/base/neutral solutions: writes as in fig. 3.
A: Ok. Look at the same time ... what you are saying is true. Transfer of the proton is not only one way. Transfer of proton , becasuse of the equilibrium transfer of proton takes place the one way and the reverse way ok. So in one particular time ... does that answer your question
Mazuza: Let me say [A interrupts]
A: It's the same question as what initiates a chemical reaction. It's the same question (yes) [The dialogue continues around this issue] It happens simultaneously ..... even if it happens simultaneously nothing would be able to happen because I mean if it happens simultaneously-it's like that you know what I'm saying it's like that. I mean if you look at the water molecule you are just going to see the two water molecules you are not going to see that the transfer (Yes) of the proton
Mazuza: Ok. Now why should we conclude that um that there will be a hydronium formed? ......
A: Because like we said you are assuming that reactions takes place simultaneously but it does not .

Adding a base increase the OH^- concentration such that $[OH^-]$. $[H_3O^+]$. Such solutions are said to be basic

Figure 5.4 Class notes

What happens is that um because you're saying that proton transfer happens simultaneously in other words one water molecule donates a proton to the other water molecules and that's not how it happens. There is transfer taking place but what you have is not necessarily that the proton will be first transferred is taking place you hear what I'm saying. One transfers the proton to the other water molecule and that water molecule does not necessarily transfer that proton back to the original water molecules. That water molecule might get a proton from another water molecule etc etc. [....]

Mazuza: What I want to know is what initiates that [meaning proton transfer]

A: What initiates it I think it is the electrostatic forces .... What I'm saying it's intermolecular forces and electrostatic forces ok. The water molecules are providing ..... the kinetic energy [Mazuza interrupts again inaudible] Ya they might have equal forces but they might not all be orientated ideally. .... they will not all be orientated in a certain way etc etc Mazuza we are getting in another roundabout. Come see me afterwards (ok). [L4:8-9]

Interpretation:

The questions posed by Mazuza were brilliant questions at that level. They were quite complicated and required more complex concepts to explain and way above the level of the syllabus, though this point should not be an issue. It should therefore be quite understandable that Andrew whistled as an indication that he was not expecting such a question and that he might not have had a direct answer to the question. He avoided the question for a while, but when he eventually attempted to answer it he was not very confident. He further bought time by asking to see Mazuza later, both in the interest of focusing on the lesson and of searching for a suitable way of answering Mazuza's question.

It was also rare that Andrew did not answer a student's question, but there were instances where such occurrences were observed as shown in the example below:

S: What is the concentration of water?

A: The concentration of the water remains constant. Um If the concentration of the water remains constant then we make the concentration of the water to be equal to some constant k. [L3:8]

Interpretation:

Andrew's response does not answer the student's question. But because the student did not persevere like Mazuza, s/he did not get the answer s/he deserved. The actual answer would not have made much of a difference in the understanding of K_a but it would certainly have been helpful to show how and why the concentration of water does not change despite some acid dissociation. The evidence available does not however qualify a conclusion that Andrew did not have the correct response to the question because the question was not pursued to exhaust Andrew's knowledge in this aspect.

Other strategies Andrew used to keep students on track during lessons included questions like:

"Xolani what do you think I mean by that ....."

"You see that Laura?..."; "Does that make sense?....." You understand that? ...." "Is it logical?...."

5.12 Profile summary

Andrew came from a church run private school which did not have much to offer in teaching science through inquiry and discovery. He did not have any particular recollections of good teachers. His expectations of the physical science methodology course were based on his own teaching experiences. He was looking for ways to improve his teaching styles and address problems encountered in teaching content, such as deficiencies in explaining science concepts.

Andrew holds the process-product conception of science. Initially this conception was dominated by the science as a process view. That is science is a process of establishing facts though investigation and experimentation. He was not convinced that science facts were science but that they can be related to science. By the end of the year he appeared to bring the two together and expressed , conception that knowledge established through science processes is also science and that it tries to explain natural phenomena. But none of his lessons gave the impression that he believed that science involved observation, experimentation and investigation. He focused only on the knowledge aspect during these lessons, and possibly how such knowledge changes with time when discussing theories of acids and bases.

Underlying Andrew's views of science teaching and teaching in general is the conception that teaching attempts to get students to change, improve their knowledge and enrich their experiences and skill either by simply presenting knowledge or guiding the students in the process. Describing teaching without anchoring on learning was difficult for Andrew, particularly in the first interview. But later his theory of teaching appeared to have expanded. Andrew views teaching as transmitting knowledge, facilitating the learning process by providing opportunities that allow students to discover what is intended by the teacher. These conceptions portray the polymorphous nature of teaching and its dependence on learning (Hirst, 1971). Thus extending these theories to learning, he sees learning as knowledge acquisition and construction, realising and understanding what is taught. He also demonstrated a belief that students must be actively and mentally involved, and therefore be aware of the process of accumulating knowledge. The views he expressed regarding learning, at the beginning of the study were more theory based (considering that he had just attended lectures on theories of learning though he believed he had these ideas prior to entering the programme). Later they were more practical. The ideas that learning is a mental activity and that students must be engaged actively was also demonstrated in his teaching practice lessons.

Andrew taught for about three years before professionalising his teaching career. He also taught part time while undergoing his training. The preservice training thus served as inservice training as well. However he could not put his newly acquired skills into practice because the students rejected student centred learning where they were required to do more work. They were more willing to accept what he told them rather than take an active part in their own learning. This frustrated and discouraged Andrew particulary because he was confident that he was a good teacher. His only problem was that his didactic teaching style conflicted with the advice from the science methodology classes. He also believed that changing from teacher oriented teaching would make him a better teacher. This rejection of his efforts to change his style meant limited applications of student centred strategies. The other contributing factor was that the situation in the school was geared to drilling students towards matriculation exams and there was therefore no time to try out different teaching methods. Furthermore the school had no facilities for discovery learning which depended on equipment.

Andrew experienced personal problems leading to absenteeism and even thoughts of withdrawing from the programme. Regarding the programme itself Andrew appreciated its practical nature and the insight it provided even though he was unable to try out many of the suggestions from it.

He was teaching physical science to std 10 and mathematics to std 9 and 10. Apart from lessons designed to have students working individually or in groups, his lessons were mostly expository. During the lessons he used low level questions to promote student understanding and get them involved in the class discussions. The lessons were also very theoretical with no practical activities. Students had no opportunity to construct knowledge from their own observation/discovery. They relied on him as the main source of knowledge. Though the school did not provide him with opportunities to test his beliefs about science teaching and learning, he made efforts to lead students to think towards desired answers. Andrew compromised his reliance on theory for his lessons by structuring his questions to lead students to a "correct" answer. He also tried to get students to give their opinions before he gave an explanation. He also encouraged students to ask questions. Most of the time he was successful in answering students' questions. Andrew's teaching style also reflected his belief that the students in the school had limited knowledge of physical science concepts. He was very patient with them as shown by his frequent use of cues, repetition and rephrasing of questions in attempting to lead them to desired responses.

As far as knowledge of chemical concepts was concerned, Andrew was confident in his subject matter knowledge. This confidence was demonstrated by his claim that the use of different resource materials did not add to his knowledge of science but showed him different strategies of explaining the concepts. However, despite having spent much time and possibly consulting references when answering the pretest on chemical bonding, Andrew still scored below the class average in the multiple choice questions. His post test was also below the HDE class average but better than that from the pretest. He was absent when chemical bonding was discussed and his test results on this topic demonstrated that he possessed several erroneous conceptions on the topic. His understanding of acid base concepts was better, though weak in the area of microscopic representation.

CHAPTER 6

CASE STUDY 2: FERRIAL

CONTENTS OF CHAPTER 6 PAGE

6.0 Introduction

This case study focuses on "Ferrial", a young woman enrolled in the HDE programme. She is training to become a junior secondary physical science and matric biology teacher.

6.1 Brief background:

Ferrial had no school experience, certainly not beyond that of being a pupil herself. She seemed to have chosen a teaching career as a last resort. She developed the idea of becoming a teacher in her final year of B.Sc study. Her original aspirations were careers in medicine or dentistry.

She attended English medium primary and secondary schools of her own race group in the Northern Province. Both these schools were government schools run by the House of Delegates (Indian department of Education in the apartheid structures). As she saw it, attending a government school and the lack of certain facilities had shortcomings on how things were done. She joined Wits in 1990 immediately after matriculation to obtain her B.Sc degree in botany and zoology in 1993. In 1994 she enrolled for the HDE programme.

6.2 Reasons for becoming a teacher

As stated above, teaching was not Ferrial's first choice. As for many other students her first application for medicine was unsuccessful. She settled for a B.Sc degree, but did not give up her dreams. As she proceeded with the B.Sc degree she submitted another application to the medical and dental schools and was again unsuccessful. She then completed her B.Sc studies majoring in biological sciences because she apparently had a keen interest in environmental studies. She describes her real reason for joining the teaching profession as:

> After I finished I realised there weren't many jobs-job opportunities as far as B.Sc was concerned. I was doing BSc. And then err when in my final year of BSc um teaching became a bit more plausible err I mean to say teaching is quite important and things like that. [I1:238a]

Becoming a teacher was an afterthought. Her eventual decision to become a teacher was, accompanied by some reflection about the profession and her experiences as a student at school. Ferrial saw another challenging opportunity this time directed at school children. She had an ambition to provide the students she would teach with what she had missed as a student herself. On recollection of events leading to career choice, she expressed the following positive thoughts on teaching

> [...] When I looked today and I thought of the opportunities I didn't have while schooling. May be I could introduce them you know. And reflecting on what I've been through, teaching is quite plausible and now with the new changing education system and stuff like that it would be a lot more challenging and different and (Mh) I would want to go into teaching. [I1:238b]

She soon lost interest in medicine and dentistry as alternative careers. She apparently had no intentions of remaining a school teacher, but hoped to pursue a career in environmental education in the near future

> I will be dealing with you know education as such, environmental education, dealing with schools, introducing environmental studies in schools. [I1:238c]

Interpretation:

Ferrial's decision to become a professional teacher was dictated by practical circumstances, i.e. the lack of other employment prospects in other fields for ordinary BSc degree holder. It seemed easy for Ferrial as for many others before her to pursue studies in teaching and to secure employment. A similar view is reported by Book, Byers and Freeman (1983). Ferrial is also not convinced that teaching in a school could be a lifetime career for her. However, she seems to have accepted the possibility of remaining in the educational field.

6.3 Perceptions of the teaching profession

The fact that she opted for teaching only after realising that holding a BSc degree had limited employment prospects indicated that initially she did not think highly of teachers and teaching. After some reflection on what teaching could offer, her attitude changed slightly. These are her perceptions of the teaching profession:

> I always thought now why do you want to be a teacher, but I realised the importance of it. I mean we all come having been educated I mean going through schools and surely teaching is important. But err as far as it compares I mean it seems is a non-profession which is unfortunate. I mean we [..] work under somebody, [...] we do not take an active part, we are given the syllabus and told this is what you teach, we have deadlines to meet, we have to complete the syllabus, you know run tests and things like that. As far as the teaching and learning process is going on I don't think teachers are that involved you know and they don't have that much say in the structuring of these processes and what's been taught and things like that. So I think teachers should be given more of the leeway in structuring what's being taught and how it's being taught and stuff like that. And the content of .... (Ok.) I think we should be paid more. [...] After all it seems like a 24 hour job. You've got to think about what you're doing the next day you've got to take stuff home you know, you've got to be working at it all the time. [I1:239a]

Another reason she felt teaching is not considered a real profession was the attitude of her peers who preferred the more prestigious profession of medicine and engineering was that:

> [...] you know you're always confronted with why is it that you wanna teach, why teaching, (From who) From people around you know basically people around [...]. Generally when you speak to peers and other students, stuff like that, student who are doing engineering, medicine and stuff like that .... try to do teaching? [I1:239b]

Interpretation:

These perceptions displayed in the above excerpts seem to indicate that Ferrial herself has a low concept of the teaching profession and is supported by many others. Ferrial was aware that teachers lack autonomy in their work place and as such teaching lacks professional status.

6.4 Characteristics of good teachers

Ferrial could not recollect any particular teacher whom she could consider to have been a role model for her. She had this to say concerning a teacher she initially disliked .. the time but later appreciated his actions.

> [...] as far as high school is concerned there was a teacher that really put me off maths at the time. But um his attitude was such that he really put me off the stuff. But when I came to matric the final term I realised you know that I learnt a lot in that process because he made conditions difficult for me, er he really gave me a tough time, he really gave me much work, he gave us ridiculous things to do. But I did learnt quite a bit you know, I was quite amazed by that and things worked. [I1:239c]

This particular teacher's teaching strategies appear to have influenced her conception of teaching and learning as will be illustrated below. She felt she learned a lot because she did almost everything herself. The teacher discussed in excerpt [I1:239c] seemed to have neglected his students and as a result Ferrial developed a strong belief that a teacher should be more of a facilitator, address problems and be more available to the student. These were some of the things she did not experience as a student.

She demonstrated this belief during teaching practice. In her own right she tried to facilitate rather than tell, help students rather than leave them to do things on their own. This point is discussed further in section 6.10 on teaching practice observation.

6.5 Conceptions of Science

A summary of Ferrial's ideas about science and related matters as expressed in the interviews is given in Table 6.1 below.

Table 6.1: Ferrial's views about science.

Initail Interview [I1]	Final Interview [I3]
Science: • relates to research, technology • something up to date, factual and relevant • makes people aware of why things happen • For some it is far fetched, for more intelligent, carries the image of scientists	**Science:** • something that is always changing • something that helps define and describe the world around us, to make sense of what is going on. • *encompasses social, political, economical aspects,* • *involves a lot of skill: cognitive, psychomotor, affective*
Scientific knowledge: • in school it is taught as science, chemistry, physics, basic laws. • produced by research	**Scientific knowledge:** • any kind of research, any kind of knowledge whether strictly science or social anthropology • broad knowledge about science like the subject, • produced by observations, our theorising, experimenting, practical activities, over years of accumulation and progress:

At the beginning of the study Ferrial held the following ideas about science:

> Just from the top of my head? Um {pause} research ok if you think in a few words. Research, technology something up to date, something relevant, something factual, things like that. [I1:239d]

This view is different from those she expressed in an assignment she wrote in March, prior to this interview, shown below.

> I defined science as a discipline attempting to explain various phenomena in our physical world and greater universe. [...] Science stemmed from people's curiosity and the need to structure and organise his/her surroundings. It all begins with theory, assumptions or hypothesis which is explained or attempted to be explained via objective, precise, practical observation, investigations and experimentation. The results if workable and acceptable to the scienti[illegible] world become norm and the theory is then stated as factual. [Assignment material March 1994]

It will be observed that these views conform to some of those that can be found in the literature, as this was an assignment for which Ferrial researched before writing. The assignment also followed a class discussion or workshop on the nature of science. Later in the year she presented a more open and somewhat broader view of science as shown by excerpt [I3:254a] below:

> [...] it *(science)* encompasses a whole lot of things um socially, politically, economically as well.

Talking strictly of science as we know it in teaching I think it's a lot of things. It involves a lot of skills, a lot of thinking, [...] all the cognitive, affective and psychomotor skills, and it's something that's ever changing it's always changing ... Um it's just something that helps to define the world and describe the world around us [...], to make sense of what is going on [..] [I3:254a].

Underlying this exposition is the dynamic nature of science and its ability to bring about understanding of the world. The idea that science is related to research and is something up to date is presented again in the last interview in terms of science being ever changing and as knowledge accumulated over a number of years. The view presented in excerpt [I3:254a] also betrays a conception that science can explain a whole array of disciplines. An almost similar belief is presented by Goodwin (1995) that science is a network of ideas, perceptions and processes which constitute the explanatory framework of science.

In the assignment Ferrial mentioned human curiosity as the origin of science and in the last interview she acknowledged the social and political aspects of science. Both these ideas show that Ferrial is aware that science is human based.

During the initial interview she did not display knowledge of the terms 'scientific method' and 'scientific knowledge'. But what is interesting to note is the way science was taught and presented to her in her school years has made her feel that

[...] for some it would seem that science is a bit of far fetched thing. I mean its for the more intelligent, its for those who are ...... it, things like that. Dealing with-I mean you've got this image of scientists dealing with research all the time. [I1:239]

In the final interview she described scientific knowledge and its production thus:

F: ... Scientific knowledge is [...] a broad um knowledge about science, science like science the topic, the subject science (ya). But again any kind of research any kind of knowledge whether it is strictly science or in *the* field *of* say social anthropology I would think it's some kind of scientific knowledge. [I3:254b]

I: Now how do you think er this (this knowledge has been produced?)

F: Well its by our observations, by our theorising by our um er doing you know experiment and practical activities (mh) over the years accumulating these and going further progress and so forth. [I3:254c]

Though she seemed unable to link the two concepts she knew the importance of the "scientific method" (observations, experimentation, theorising) in accumulating knowledge in science and the amount of time it takes. She also holds a general view of scientific knowledge, which extends to and includes areas of research outside the natural sciences. It appears her views have changed. Her conceptions seem more well defined and expanded. They appear to have extended from a convergent view demonstrated in the first interview to a more open and inclusive view later in the year..

6.6 Conceptions of science teaching

Conceptions of science teaching and teaching in general are discussed together with learning here. This is because during the interviews the two terms, science teaching and teaching were treated synonymously. Like many other teachers, Ferrial had difficulty discussing teaching without falling back on learning. The claims she made later on in the year for her being in favour of learning were that:

> [...] I don't really like the word teacher or teaching. I believe it is learning that happens. I learn and they learn at the same time. [I3:256]

A summary of Ferrial's views about teaching as gleaned from the two interviews are given in Table 6.2 below. There is very little change or elaborations of her views between the two interviews. New ideas are shown in italics under the final interview column.

Table 6.2: Ferrial's Views of Teaching Science.

Interview 1	Interview 3
teaching involves/requires: . prompting/probing/inducing someone to think about a situation . the presence of a teacher . the transfer/imparting of content/factual knowledge/information . the interaction between the source of knowledge and the learner . facilitating and guiding learners along . attempts at developing skills by the learner	**Teaching involves/requires:** . prompting/probing thinking in a certain direction . the presence of a teacher . transferring of concepts that learners are capable of internalizing . interaction between teacher and taught . teacher assuming a facilitator role . *encouraging group work* . *setting up an environment that will encourage student participation.*

Three themes about conceptions of teaching emerging from Ferrial's interviews will be described under the following headings:

- teaching is the transfer of conceptual or factual knowledge;
- teaching is facilitating and guiding students in the learning process
- teaching is providing and developing skills and abilities.

6.6.1 Teaching is knowledge transfer of conceptual and factual knowledge

This is the transmittalist view of teaching. In this portrayal of teaching she regards the teacher as a source of knowledge and skill, though not the only source. The teacher should have knowledge, particularly specific content knowledge such as that in science and maths in which learners might not have taken interest. So in teaching

> [....] there's a lot of like content and-and factual knowledge and stuff that we have to transfer, [....] what we as teachers are doing is directing them, um we are giving them knowledge about maths and science and things like that and which probably otherwise wouldn't have taken interest in. .... I think it would be good to get pupil's own conceptions before you begin the lesson and then try and construct from there. [I1:241a]

She based the latter idea on the conviction that we all construct our own theories on how things work. From her experiences as a school pupil she formulated analogies to help her understand how things worked and whenever she identified faults in her conceptions she rearranged her thoughts. To illustrate this view which also has a bearing of her views of how learning occurs, the extract below is given. However, the possible influence of the HDE classes on the views she had before the initial interview cannot be disregarded.

> [...] I do believe we do form our own conceptions and sometimes they may be misconceptions which can be [...] frustrating when you come to school and then learn that you are a bit way off or something. But-but then again you will re-align yourself in your in your thoughts in what you gather from the teacher and what you have been taught.[I1:241b]

She also places exceptional emphasis on the importance of teacher sensitivity to students' pre-existing theories, and that teaching should build on to these theories. Excerpt [I1:241c] below shows how she would tackle ideas brought to class by students:

> Try to assess [...] what their concepts are by [...] making them work with things that makes me aware [...] the way they are thinking-their way of thinking. Introduce-yes the-the concepts that I want to teach and see how they formulate that from-for themselves. And if they're way off then try to bring them by a process-I don't know test or maybe making them see a different way, well seeing different views from the classroom and so on. But being aware surely that people form their own concepts [I1:241c]

So while Ferrial believes the teacher should be knowledgeable and have the skill of imparting that knowledge, as does Hollingsworth (1989) she prefers the teacher

> [...] to play the facilitator (ya). Um so um-Well I have a certain amount of knowledge over them and maybe-maybe practical skills that I've learned over them. Um er I believe yes I maybe a source (mh) in-in-in some in .... them wanting further information or knowledge and skill. (Mh). But I see myself as a person for - to whom they'll come when they do encounter a problem or they can't get any further with what they are busy with. (Mm) So um yes a source of knowledge and skill but not the source. [I3:259] *(In response to question on how important she thought serving the students as a source of knowledge and skills)*

Though not ascertained, there is a possibility that she got the strong inclination towards skills from the biology methodology.

Ferrial attempts to assess and work from students' ideas about the concepts discussed in class will be noticed in the section on teaching practice observation described (see section 6.10).

6.6.2 Teaching is facilitating and guiding students in the learning process

While Ferrial acknowledged that some knowledge has to be transferred during teaching, she has a strong belief in the facilitator role of the teacher. She views teaching as more than the mere transmission of formal intellectual content.

Ferrial's experience as a student seem to have had a significant impact on her views of the teacher and teaching. The behaviour and attitude, both affective attributes, of her most memorable teacher, though not popular with her as described in excerpt [I1:239c] on page 127, appears to have played a crucial role in shaping her views about teaching. The manner in which he conducted his lessons developed in Ferrial an urge to see herself as more of a facilitator and guide for her students, and being more available for their needs while enabling them to do most of the work.

> [...] teachers should be there as their *[learners]* full guide and as a facilitator. [...] as someone [...] they can come to [...] have their problems sorted out. [...] But if they have a problem dealing with science processes and they come back to you (mh) they can you know er re-address and stuff like that. So [...] I don't think its er like er solitary and I know all that I know all the skill so you come to come to me and I'll tell how or-this is how you should do it. Ya sure enough you develop skills and stuff like practical skills and use things but you are there you know as a facilitator. [I1:245]

She was convinced that the facilitating teacher role is very important. She maintained the same view throughout the study, as the following excerpt illustrates. Notice also in this excerpt the emphasis she places on student participation and students doing things for themselves, as she did when she was at school. As far as teaching is concerned

> I think we should be taking more er-er facilitator role (ok). Um ok we can give students some facts, ok, but dealing with problems and stuff like that in order to see how these things actually work. (Mh). they should indeed do it themselves, or discover it for themselves [...]. [I3:255]

Ferrial seemed to find a compromise between the two seemingly conflicting views viz. the transmittalist and teacher as facilitator conceptions of teaching science. Her preference for teacher as facilitator is, however, very evident. It seemed if she had things her way learners would be involved in decisions on what they should learn so that the teacher would only direct and guide the learning process.

6.6.3 Teaching is providing and developing sk ls and abilities

The dislike for the word 'teaching' by Ferrial apparently stemmed from her previous experience with some of her school teachers, especially the maths teacher she describes earlier. In her final year of BSc she became aware how severely limited she was as a result of what she missed as a student, as shown in excerpt [I1:241d] below:

> [..] I became aware of teaching and what was lacking in my schooling and stuff like that. I became aware of it because like skills that-in other words I hadn't developed the art of writing or thinking critically or writing down arguments and doing thi-analysing things like that had become a bit of a problem for me. And I-and I de-decided that had I been taught those skills, I mean I excelled in science and maths, I knew all of it, but I wasn't-I couldn't deal with problems beyond that. [I1:241d]

As mentioned earlier, in her final year of BSc degree Ferrial realised what had been missed from her schooling. She felt she had not developed certain skills she desperately needed in her university career. As she describes in excerpt [I1:241e] below she had not developed the

> [...] art of writing or thinking critically or writing down arguments and [...] analysing things [...] it had become a bit of a problem for me and I decided that had I been taught those skills I mean I excelled in science and maths but I knew all of it, but I couldn't deal with problems beyond that. I realised that and became a little bit more err when-while doing my HDipEd now I realised "Hhe! this is what I've been thinking" and it became a bit more concrete for me. [I1:241e]

Her school experiences and the teacher referred to above shaped her conceptions of teaching to a large extent. As a result of the many unpleasant experiences due to her limited skills she was convinced that skills were more important than factual knowledge because

> ... if they have those basics, the ability to think to think abstractly, and stuff like that. With that as a life skill (Mh) they can go ahead and um deal with problems as they come along. [I1:241f]

She believes that teaching should therefore strive to develop and equip students with skills to deal with problems in different situations, skills to gain knowledge from other sources and life skills. She seemed to resent the limitation she had suffered regarding her own skills. Thus in addition to guiding students in the acquisition of specific content knowledge what teachers should be doing during the teaching process is

> [...] providing them with is in fact skills, skills such as the ability to-doing-I don't know how you assess those but the ability to interpret, to understand, skills such as that-that would bear on dealing with the scientific problem, to conceptualise it to interpret the scientific problem (Mh). Since skills like to know that they are more important than teaching them the factual knowledge because if they have those basics, the ability to think to think abstractly, and stuff like that, with that as a life skill (Mh) they can go ahead and um deal with problems as they come along. [I1:241g]

In summary she feels that people do not portray a just view of teaching and that teaching to be good if conducted in certain ways, thus:

> [..] if you define [*teaching*] as parting with knowledge and giving someone else knowledge or the ability to do something for himself then teaching is good if it's done in that way. [I3:256]

6.7 Conceptions of science learning

As the reader might have observed in the above exemplary excerpts, Ferrial's discussions of teaching were linked to learning. A similar feature was observed in both Andrew's and Mary's views of teaching. Discussing these two concepts separately is difficult if not impossible, though this does not imply that they are mutually inclusive. The following table summarises the views identified from the qualitative analysis of Ferrial's interview transcripts.

Table 6.3: A Summary of Ferrial's Views of Science Learning

Initial Interview [I1]	Final Interview [I3]
Learning requires or involves . forming own knowledge from interacting with the environment . internalising information . thinking about or realising something about a situation . active involvement of the learner	Learning requires or involves . knowledge construction . gain/taking in knowledge . realising something about a situation or process . occurs when students work in groups, do their own thinking or work, are actively involved

Ferrial's conceptions of learning will be discussed under the following themes:

- learning is constructing knowledge for oneself
- learning is internalising knowledge
- learning is realising something about a situation.

6.7.1 Learning is knowledge construction for oneself

As can be noted in excerpt [I1:241h] below Ferrial views learning as the process by which knowledge is constructed. She seemed captured by the constructivist's views about learning. In giving her theory of teaching she highlighted aspects of learning thus:

> [...] there's a lot of like content and-and factual knowledge and stuff that we have to transfer. I mean pupils, kids form their own knowledge from the way they interact with the-the society and stuff like that, from their own backgrounds [...] and if left to their own devices I mean they'd be acting spontaneously and form *knowledge on* their own.[I1:241h]

These views also expressed in excerpts [I1:254a and b] on page 129 indicated Ferrial's awareness of the dynamic nature of the constructed knowledge and her belief that knowledge construction and therefore learning is influenced by the background: social, cultural and religious. Accompanying this conception is the perception that teachers need to be sensitive to the background and needs of the students particularly because some of the ideas imparted to the students in their home and community environment may be varied and in conflict with accepted ideas about scientific phenomena.

She viewed learning to be at its best when it is based on experience and interaction between pupils. Children learn best when they do things for themselves and when they work in groups.

> [...] a lot of learning happens in group work. I noticed that a lot of kids communicate with each other, disc-discuss with each other and er a lot of learning happens there um it needs to be more pupil centred and where pupils do much of their own thinking more of their own work. And I'm sur- I believe that is when learning really happens, (ok) and er pupils are actively involved. [I3:255]

What emerges from the above description is that Ferrial conceives learning as knowledge construction by learners. Knowledge construction is a continuous process influenced by what the learner already knows and that the best conditions for learning are those encouraging learner interaction like group work.

6.7.2 Learning is internalising knowledge

Ferrial earlier acknowledged that teaching involves the transfer of knowledge. For learning to occur the transferred knowledge needs to be assimilated and accommodated in the learner's schema. Also mentioned above, for knowledge internalisation to be possible the level of the knowledge should be compatible to the cognitive level of the learner. She seemed very surprised in her responses to the item on a lecture on molecular orbitals given to first grades [Appendix 1C:4]

> Well I don't think they have the foundation or um, it may be too far fetched for them they don't have the-the structures (Mh) to be taught molecular orbitals at that age or you know from what they've already learnt. I don't think that a grade one kid knows anything about molecular orbitals unless it's 1994 and I'm still behind. And err-so I don't think he's teaching them anything or that they are learning anything either because they don't have the foundation structures, they haven't internalised anything about you know as a foundation where they can learn about molecular orbitals. [I1:243]

> I don't understand it and I'm not in grade one. Um [pause] on molecular orbital theory, it depends at what level he's teaching molecular orbital theory. I don't know if he can take it down to grade one level but I do believe in the bit-in the when Piagetian themes that um you know there are stages of development and I don't think grade ones are gonna take any of this in (Mh). I don't believe any science teaching is taking place if he is - he or she is lecturing on molecular orbital theory at the

level we know-we are supposed to know it, to a small group of grade ones. No, he's just probably confusing them. [I2:257

Notice how the teaching and learning complement one another as far as content and factual knowledge is concerned and how she maintains the same ideas between the two interviews.

To facilitate the learning process of taking in knowledge by the learner Ferrial believes that it is important for the teacher to carefully select and adapt whatever is to be presented to the level of understanding of the pupils. She nonetheless, cautions against loss of quality due to excessive simplification and lack of truth thereof as she describes in excerpt [I3:260] below, in response to teaching task on adapting materials to be learned to level of student (see Appendix 1D).

> [...] it's very important because they have to get some kind of understanding and some kind of hope they'll formulate their own pictures in understanding it. But um not to the extent where we don't give them the truth or the real thing so (Mm) Is it you know knowledge as it stands but um I think it's important to-to adapt it to their level so that you know its a stage of understanding (mm). You know we can go further from there. It's the way I have learned using analogies and bringing things down. It's how we learn it's how we read a book or pictures (ok) and images. (But it shouldn't be at the expense of truth) of the-ya of (I mean the truth and both .....) Ya. (ya) .... They should be made aware of those things even though you're not teaching it or telling it to them (ya) they should be made aware of it.[I3:260]

Ferrial also believes that internalising knowledge requires the possession of some knowledge base that can be applied to understand a different situation as indicated in the excerpt below.

> ... they *[students working on problems from textbook]* are applying what they have learnt and from-ok probably taking information from the textbook then applying err that knowledge that they have gained to work out the problem. (Mh) So they are using their ability ...?.... so they are developing something and er what they are now doing is err something that they'll internalise how to do this problem. (Mh) So they are learning. [I1:242a]

6.7.3 Learning is realising something about a situation

Excerpts showing these views have been taken from the section on interviewing about instances and non-instances of science teaching. The instance of focus involved a student watching a TV programme [see Appendix 1C:2]:

> Well what happens well I w-watch most-I can't just put-watch these programmes about how they make plastics or bread and er yes er to an extent where you see the process happening. Ya we are learning about the process it's like er ya "Oh now I know how they make that plastic". You-you kind of learn something, ya. (Mh) ... I know now where my-my can of coke comes from, how it was made. Now that's something. [I1:242b]
>
> Well the pupil is learning something hopefully. He's watching something, he's hearing it and he's visually seeing it. I'm sure if he's interested he's sitting at home watching a program on chemical plants um that he's learning something. [I3:257]

This view is complementary to that of constructing knowledge on the basis of pre-existing knowledge. When something is realised it means that information is integrated with pre-existing knowledge and it makes sense. It also agrees with ideas that in the learning process prior concepts are altered for better ones (Brickhouse 1990). Her views of learning have become enriched, but fundamentally unchanged. The teaching practice experience could be responsible for large part of the expansion of her ideas.

Ferrial's conceptions of science teaching and learning seemed to be stable during the study and only became slightly modified. One possible reason for this stability is that the first interview was conducted twelve weeks after the HDE programme had started. This means that teaching and learning theories had been discussed in their classes. However, a strong influence of prior experiences was also detected. No valid assertions can be made regarding this point.

6.8 Ferrial's Experiences

Ferrial's experiences of the HDE programme were obtained from interview data and a journal she kept for the university based HDE courses and during her teaching practice. Most entries in the journal were of a personal nature.

Before describing Ferrial's experiences of the HDE programme it would be logical to give her expectations from the programme courses. At the beginning of the physical science methodology course she was asked, together with the rest of the class, to write down what she hoped the course would offer her. Ferrial said

> What I would like to gain from this course is to be able to learn and teach science in a less patronising, friendlier manner. To acquire skills that would make learning of science more pleasant, informative, approachable, real and doing so without any misconceptions. [...] I would like to be able to communicate science concepts and language in a friendlier manner, to make science more seeable for the scholars i.e. using everyday known concepts and making them scientific, [....] to make science a more practical experience, dynamic and interesting by various methods, skills which I hope to gain through this course. And I hope to teach myself as well. And also develop my confidence.

As can be seen her expectations from the HDE programme were broad. Below is how she describes the teaching of science.

> Science at school was approached very hesitantly by many. It almost seemed to have the label of 'explosive', 'fragile' and 'do it at your risk'. I for one had a great 'phobia' for science which I until

today seem to be fighting. Perhaps doing this course and being able to teach the subject thereafter would in many ways help me overcome this fear. For some reason or the other science teachers were always so patronising.

The expectation reflects how little confidence Ferrial has about teaching science, how she hopes to alleviate a phobia developed during her schooling and be equipped so that she does not teach science in the same way she was taught, which she regarded as unacceptable.

The description below of Ferrial's experiences is presented in two parts: experiences of the campus based courses and teaching practice experiences.

6.8.1 Experiences of the Campus Based Courses.

Ferrial's experiences were influenced by her expectations of the HDE programme. When she joined the programme she had a number of expectations she hoped would be addressed. Very few of her expectations were met as will be shown in the description below.

Her first journal entry was

> As far as the methodologies are concerned, I believe I expected something different. I don't know actually what, but at the moment I feel as if I'm being treated like a school kid (sic). I mean here I am equipping, informing, preparing myself for the role of teacher but instead I'm being assessed, marked for the charts I put up! [MJ:1]

A similar concern was expressed in the first interview.

> I would have thought that the additional studies would equip me more as a science teacher, like you know dealing with say misconceptions, what these are generally in science, err how to deal with them, how to be more competent in the science classroom as far as setting up experiments, more practical, something applicable. I mean something I can take back when I'm leaving. [....] I thought additional studies would be where I would be given a little more of science coaching (more of the content?) Ya (that you need in the schools?) schools Ya, ya. I mean I'm not, I fear it a bit but I'm doing science up to std 7 and stuff, but I'm in a bit of {pause} fear of it because what if I don't know enough or something that's not in the sciences, I always have that horror but err I-I would have thought that it *(additional studies)* would be more constructive in a sense. [I1:246]

While she acknowledged the importance of the theoretical aspects of the course in enlightening them on the possibilities of what they would find in real classrooms, she also expected to deal with actual classroom situations which she considered more relevant and applicable.

> I think it *[science methodology]* should be a bit more constructive. Um we actually don't even go out to classes, I mean schools and see different schools and things like that, engaging in that. I mean we don't do that. (Mh) We only go to specific schools when we want to prac-teach. But you know actually sitting in on classrooms err seeing what happens, giving lessons. Oh! for biology we got

quite a bit of practice with it giving lessons and critique and stuff like that. I think those were-those were good. [I1:246]

I wish they could have told us a little more of how to do things or to go about and with stuff like that. [I3:261]

The above extracts indicated what teacher training meant for Ferrial. Being equipped, informed, coached in science teaching, being given hands on school experience before actually going out to teaching practice. In a single phrase Ferrial expected the programme to provide her with everything she would need to become a teacher. She did not see much evidence of being trained to become a teacher. Ferrial's perceptions are in agreement with Steinberg's (1985) observation of the tendency among student teachers to regard constituents of courses in relation to perceived relevance. The excerpts presented above also reveal Ferrial's anxiety to become the perfect science teacher, who has sufficient content knowledge, is sensitive to students' misconceptions and competent in practical work. She had hoped for real classroom practice.

Ferrial was more receptive to those sections of the programme which dealt with issues directly related to the role of a teacher. That is those complying with her expectation. Some of the sections she appreciated included

... some mini lessons like in Biology that were very useful. They had emphasis on group work and encouraging skills and practical work that was very useful. [I3:260]

The way the mini lessons were designed and conducted seemed to correspond to her conceptions of teaching and learning as described in sections 6.6 and 6.7 above and her expectations of the programme. She found mini lessons so useful that she did not seem to mind the repetition, which was frustrating her in the textbook analysis and test construction, described later in this subsection.

There were more frustrating experiences for Ferrial than positive ones. One, which could have had resulted in unpleasant consequences came when she was almost halfway through the programme, when she realised the demands the programme placed on her. Excerpt [I1:247] below, though starting on a positive note, shows the extent of the depression that she went through.

Like I said I was made more aware of er more of the idea about teaching and learning process itself and stuff like that, that's good. Um but as far as, like for biology, putting up charts, er running a lab and things like that, {pause}, maybe I'm a bit lazy in that I don't actually want to run a lab. You have to collect animals and things like that. (Mh) Um I don't know it's er it's becoming a bit frustrating after the first few weeks I want to quit the HDipEd. That this is just too much for me. [I1:247]

Ferrial found the biology methodology activities more demanding. Her other frustration were linked to her perception of being treated like a child. Other contributing occurrences were the amount of repetition, lecturers' tendency to be vague, and uncertainty about some issues. These four points are explored further below.

Being treated like a child

Ferrial felt she was ready to become a teacher, an adult. It was early in the study that she entered in her journal that she was not getting what she had hoped for in regard to her professional preparation for teaching. In excerpt [MJ:1] above she actually underlined 'school kid'. The feeling of being treated like a child emerged again in an interview

> I think I'm being treated more like um as a children-a child {Both laugh} a pupil. Well then "Hey, I'm gonna be a teacher soon, (Mh) an adult" you know what I mean. [I1:247]

This feeling of being treated like a school pupil was expressed again:

> I feel as if I'm being treated as a pupil/students and Not as someone who needs to be provided (not dictated to) with the mere basics of education, teaching/learning. Guided is more like it. Helped.
> I just don't feel comfortable in this course
> I've never suffered so many mood fluctuations in a day!![MJ:1]

It is clear from the excerpts above that Ferrial felt belittled by the approaches used by her methodologists and the kind of activities she and the other students had to do. She was also frustrated because the kind of assistance she needed went beyond professional levels, and it was not forthcoming. At times she felt she was being thrown in a situation where she was not getting the help she thought she deserved from the lecturers. She came to this conclusion about the physical science methodology:

> I think this course is lacking personal tutors. Yes that is what it needs. Fortunately this diary has provided a vent.
> But a tutor is required to guide and help the "HDE student" ..... s/he will be stepping into the role of teacher.
> Someone to help with all fears and problems the person may be having as a person/student/teacher.[MJ:1]

Notice how her views of the teacher as facilitator and guide emerge strongly in these journal entries.

Repetition

It must be very difficult for methodologists to draw a line between what is too much, what too little and what is just right in addressing preservice teacher training aims and objectives and satisfying students' expectations. This is how Ferrial felt about some aspects of the HDE programme and the way it was conducted:

> As far as the whole entire HDE course is concerned we are dealing with a lot of repetition. I mean as far as this textbook analysis or text analysis was concerned, we did it in core science, we did it in biology and we did it in science all within a week and it is frustrating and it has happened before with other topics as well [...]. The work was too much. (Mh) There was just so much going on. I mean like it was repetition [...] It becomes-its frustrating me because you spend so much time on little assignments and typing up stuff, and things like that. Er I don't know it just becomes a bit frustrating.[I1:246-7]
>
> I found the lesson "setting test", very useful. But once again the repetition in core science and biology was agonizing!. [...] If core science was meant to address commonalities in all the courses of science like setting a test, lesson planning etc. It has failed!! It has failed to avoid repetition and address common issues in order to cut down work load. [MJ:2]

Ferrial appears pretty upset from these excerpts. Apparently Ferrial's perception was that unnecessary work was created for the HDE students, and this work was more for assessment purposes than to benefit them toward their professional training. Indeed the workload could have been reduced but the reasons behind the repetition should be considered though not explored in this study.

Vagueness and uncertainty

Ferrial had what she perceived as "pretty upsetting encounters" with M1.

As a result of these she became uncomfortable with the course and unsure of what was expected of her. Some sensitive issues entered in her journal were

> Found M1 to be quite vague in instructions. Never quite get what she's aiming at, what the object of the lesson was or is!
> Received my assignment on prac. I've failed!! I still think M1's much too vague.
> I do believe I've addressed the question maybe M1 finds me vague!!
> I also approached her for the curriculum package and I found her quite unhelpful.
> I dread I'm beginning to take "a dislike" toward her!
> She's vague, overbearing, unapproachable. I just don't comprehend her!
> Headed for depression!
> M1 had a problem with my file! Which I think is quite unwarranted. The way I choose to order my file is personal and makes sense to me. I'll be using it and rearranging it if need be! And it is ordered in a way in which anyone could find their way. I don't see the problem! M1 wants it her way. [MJ:1]

There seemed to be some misunderstandings between Ferrial and M1. Ferrial might have had a problem which M1 was not addressing successfully. Maybe the help M1 offered was misinterpreted to portray a domineering and unapproachable attitude. This problem was not explored.

Being "dismantled" by chemical bonding classes

Among other things, Ferrial did not seem content with the class discussion on chemical bonding as the interview excerpt below shows.

> I can understand the *[lack of]* right answe-of the right answers the way to to do things. You know I mean um if-for example the chemical bonding I feel I have been totally dismantled. I had a pictures of chemical bonding and what chemical bonds are, totally dismantled it's not all been put together. You know I think that's one really serious problem that needs to be addressed with the HDE. [I3:260]

These were Ferrial's feeling about the class discussions. But as described in chapter 4 a number of issues were addressed relating to how certain aspects of chemical bonding could be addressed in the secondary science classroom. Ferrial's perceptions could be attributed to the fact that she only had a chemistry 1 background. So her chemical background may not have been sufficient to enable her to appreciate much of the discussions around chemical bonding. Alternatively, she may not have recognised that learning to teach is different from the school learning she had been engaged in and she could not adjust to new learning requirements (Calderhead, 1991).

Preparation for school experience 1995

Part of the aims of core science course was to have teachers who have been in the teaching field for their first year share with the preservice teachers their first year field experiences. Again Ferrial was unhappy in the way it was organised in that

> [...] And there were students who were brought in from *[school]* R and other schools. They talked about teaching and stuff like that, they brought out their documents they talked about you know about their teaching experience, their first year teaching experience basically. But I don't mean to be racist in any way but here I sat at the back, there were only two Indians there in the class and they talked about TED and everybody chatted and laughed about the TED and then they you know teacher's meetings and stuff like that which we were totally excluded from (Mh) as teachers. I'm not a teacher but I know they weren't and I felt you know we could have had people from-from DET and different teaching organisations um or departments to relate their stories as well their triumphs and tribulations as well. And I think -to make us more aware of where teaching has been the last few years and where it is going to as well. (Ok) All we've heard is the TED [I3:261]

Ferrial's school experience and expectations from the HDE courses had an impact on her perceptions of the course and her experiences. Her science teachers portrayed an inaccessible image of science as a mystical subject for only a selected few. As a result she hoped that undergoing preservice training would help her shed some of the phobia she had developed. She had also created a model of the kind of teacher she hoped to become - one who facilitated the learning process without intimidating or patronising the students, one who while making the learner more involved and responsible for their own learning, would be more available to the students, one who would relate scientists science to students' real life experiences.

6.8.2 Teaching Practice

Settling in the school

The period prior to teaching practice was uncomfortable and confusing for Ferrial. She felt she was not getting sufficient support regarding school placement for teaching practice. The experience was reflected in her journal where she said

> I'm not quite sure as to where I'd like to do my prac teaching! I feel unsure and uncomfortable at being at school R.[MJ:1]

And later she expressed her feelings about the whole situation thus:

> I think more should be done to help students decide on the schools they intend doing pracs at. I'm confused. [MJ:1]

Ferrial did not seem to get all the help she needed to feel secure. Apparently she was to do teaching practice in a school she had not selected and where she felt uncomfortable to be.

For Ferrial teaching practice provided the first opportunity "for a close up view of staff relationships, teacher student relationships and school culture from a teachers perspective" as Cole and Knowles (1993: 642) noted regarding field experiences for preservice teachers. The HDE programme equipped her both professionally and personally with some useful skills for teaching practice though the actual practice of teaching was "a new whole cup of tea compared to the HDE course".

Having not taught before, Ferrial was anxious because she was not quite sure what she was going to teach and what her goals as a teacher were. She feared what she might face in the actual teaching process. But she found that the environment in the school was very welcoming and looked forward to the challenges of her first real field experience of teaching practice.

In the first two weeks or so of the teaching practice period she felt she did not fit in well with the system. She couldn't identify with the "flow of the of the classroom, what it was she was getting across to the classroom". Fortunately she was in the reliable hands of two co-operating teachers with whose support and encouragement things became better for Ferrial.

Ferrial was anxious possibly because she felt she had not been sufficiently engaged in real teaching activities prior to teaching practice. But the welcoming atmosphere and support of the co-operating teachers made it simple for her to fit into the system. It appears that the school culture and staff can play a very important role in preservice training by helping student teachers integrate into the system during their internship.

Competence and confidence

Ferrial had majored in Biological sciences and only did chemistry 1 in her junior degree. With this subject matter background, she could teach biology up to matric and physical science in the lower levels of secondary school. Even at this junior secondary level she was not comfortable with her physical science content knowledge. In response to an interview question seeking her confidence in handling content during teaching practice she said

> Well I found myself really learning a lot of things. A lot of things became clearer for me now than they were at school, that kind of thing. Well when I first heard that I was teaching acids and bases and reactions and combustion to std 7's I thought "Oh my God I know nothing about acids and bases". But I learnt as I taught. I'm glad that this has been more that just a teaching experience because I've learnt myself. [I2:251]

At least she acknowledged and accepted her limitations and was willing and motivated to work at them. She was very positive about relearning the subject matter. And knowing that she was not very competent in it appears that she did exactly that during teaching practice. In other words she learned as she taught. Student teaching was indeed another learning experience fro Ferrial.

Teaching practice was also the only time that she could try out her ideas about how teaching should occur and how learning can be promoted. She could also try out anything that she had learned or had been suggested in the HDE programme. In her teaching Ferrial tried to design her lessons to reflect her conceptions of science teaching and learning. It was not easy for her at first to make the lessons student centred or to be fun for the students. This is how she perceived her endeavours:

I really worked hard you know. I spent hours planning, thinking about things, it doesn't come quite easy to me. (Mh) So when preparing a lesson I become quite anxious and it takes quite a while for me to think about something when preparing a lesson, something new and something different something creative it takes quite a while. Er and how to teach etc etc. Er er well as far as that is concer-I'm slowly getting I found that the last few weeks I'm not doing much work it becomes a lot easier to do the lessons and things like that. You more or less assess what the class is able to do the time and things like that.[I2:248a]

What emerges here is the persistent anxiety due to fears that she may not achieve her goals and how she appears to have worked hard at designing her lessons.

When asked if she was made aware of these methods in the HDE programme she said

I never really reflected on my methodology, the teaching methods that I was taught. Maybe I did in a subconscious way, but not with the intention like er I would be doing this as specifically said in my methodology notes, (Mh) that kind of thing like for example like graphing skills a did as a mini-lesson in my methodology which I gave here as well. [I2:250]

What is also fascinating to note is that Ferrial did not seem to make much effort in consciously employing the knowledge and skill that she acquired from the HDE programme. Analysis of her teaching practice observation field notes provide evidence that Ferrial's conception of science is facilitating the learning process by engaging students into thinking, setting up an environment that encourages student participation. Her lack of confidence increased he anxiety throughout the training. But because she was aware of her own limitations, particularly in content, she put extra effort in designing her lessons to her satisfaction.

Critiques

She had this to say about the critiques from all parties concerned:

... as far as the crits are gone I found the science, er, well as far as M1 is concerned she was very supportive and-and er gave lots of good advice er that kind of thing, er always asking what I thought how I would do it differently. I like the idea to be warned that she's coming, which isn't the case in biology. (They just rock up.) They just, they -just rock up and hope to see something innovative when you may be in the middle of a section and just continuing with work. Then you get critted on that lesson which is not as exciting as when you began with it and that's supposed to give them a feeling of where you are (Mh) and you know I don't think that's fair.[I2:248b]

Two issues can be identified from this excerpt. One is that Ferrial seemed to have changed her attitude about M1. The kind of rapport that developed between Ferrial and M1 was healthy and motivating for her. During teaching practice she found M1 "quite supportive" giving "good advice" for what she described as a "terrible lesson". Even when she felt she was being "cut by M1" she still felt it was helpful. The fact that she now found M1's suggestions encouraging and supportive she took the advice positively is enough evidence to suggest she understood M1's strategies in conducting teacher training. I did not ascertain whether Ferrial thought M1 had changed or that Ferrial's attitude changed as she began to understand how M1 operated.

The other issue is that Ferrial appreciated being forewarned about the methodologists' visits. Her regrets about surprise visits were that sometimes assessment became based on a non-exciting section of a lesson which was not reflective of all her efforts in making the lessons innovative. The visit by M2 was not very encouraging for Ferrial. She had this to say to show her displeasure:

> August 9: I did not find M2 supportive. I find myself at a loss. I can't find direction with where I'm headed. Don't feel competent at all. [TPJ]

This sounded like a desperate expression. It could be understandable at this early phase of the first hands-on teaching experience and having to make decisions about what to do, how to do it and live with the consequences. At this early stage of student teaching Ferrial hoped for more and direct guidance on what was expected of her or more constructive opinion on her ideas.

Sometimes she felt the her efforts were not receiving the recognition and reward they deserved particularly because she felt she spent a lot of time planning and designing her lessons. Excerpt [I2:249] illustrates this concern more to the point is quoted below:

> 16/9/94: For instance today I got critted by Ann. I started yesterday with doing data response and skills. Today [...] what I did was-the aim of that lesson yesterday was to get them to work in groups I assigned them to be in and then answering all the questions, give them the time to answer all the questions then gave specific questions to each group. And then they had to [..]consolidate that answer and then one person elected as leader had to come to address the rest of the class which I thought was a good skill, (Mh) which keyed on today, ok, where I left yesterday because they didn't complete. And er (the biology group?) Yes that was the biology group, that keyed up today. And er well the crit that I got was that it was fair it was just average it wasn't good. (Mh) Well I begun that thing with the aim and I you know and er its just that its-the lesson needed to continue it was no other way I could {pause} (ya) do it. I had to finish the work before, that kind of thing. [I2:249]

Ferrial was apparently satisfied with this particular lesson and she expected a comment that it was good but she got less than that. She seemed disappointed, not so much with comment as with the unfairness of the timing for observation. From Ferrial's perspective the lesson was excellent and linked very well to the previous lesson. She had high student involvement and students were successful in what they were doing. Evidently Ann did not see the lesson in the same light as Ferrial.

Ferrial also found the discussions she held with the co-operating teachers quite constructive and led her to improve her lessons.

August 16/94: "Went much better, due to better lesson prep. Well done! [TPJ]

She was improving and therefore becoming more confident and pleased with herself. This is a feeling that could motivate any student teacher at anytime during training. She seemed to have been getting so much assistance that she was feeling suffocated by it. She felt she had to follow their instructions and that she was somehow under their control.

> August 22: Hang on! What am I here for Them or myself. Find I'm not given the opportunity to find my one. I know the guidance is good,. But I need to experience for myself. But I don't wanna mess up. [TPJ]

Though she appreciated the guidance of the more informed professionals gave her she did not want an idealised situation where she did things according to the experiences of the cooperating teachers. She wanted to explore things for herself, explore different teaching styles, go through the process of finding out things and be able to reflect on it later, even if it meant going through an embarrassing ordeal. This should not be taken to mean that she relished the embarrassing process, though she certainly cherished the experience for the future, as will be seen in sub-section on students' reception of her efforts below.

She did, however, acknowledge the importance of the critiques in highlighting strong and weak points and in bringing about improvements in her lessons and instructional techniques. This is particularly true because student teachers are critiqued more than once and their assessment is a cumulative exercise.

Student teaching can provide opportunities to try out various teaching methods and styles. Ferrial while appreciating assistance from the cooperating teachers, wanted to try out her theories and ideas. Sometimes she felt she was presented with restricted and ideal teaching situation in which she had to use well tried teaching methods and miss the challenges of exploring her potential, or her teaching and learning theories. She wanted the freedom to be as innovative as she desired. Unfortunately her efforts and strategies were not received with the same enthusiasm by the cooperating teachers, who criticised her for not teaching, and the students who were not willing to participate in her class discussions. The kind of reaction Ferrial received from the cooperating teacher is a normal occurrence among student teachers. Cooperating teachers (and students) can be suspicious of new teaching methods or drastic changes that may upset teaching routines in the school (Starr and Clark, 1991). Student teachers (and new teachers) need to master the tried methods to which the class is used to before trying something new.

Students' reception of her efforts

From her descriptions of her lessons, it appears that she used student centred approaches in her teaching and she believed the students enjoyed and learned more. The student centred approach to teaching and learning confirms her beliefs regarding the two processes. She was, however, disappointed to be criticised for doing fun activities and not teaching in spite of the fact that those were the lessons she perceived as successful and with which she was pleased. The excerpt below shows her concerns.

> Well I find that a lot of group activity and activities where they were left to fully think for themselves, I'm talking about std six biology (Mh) now the kids enjoyed that and er I was also told today that I do a lot of fun activities instead of teaching which I disagree with as long as there is learning taking place (Ya). I'm quite happy. [I2:249a]

This is how she viewed learning to be taking place in that lesson:

> [..] well the crossword although fun weren't or needed or required that they er use their books for the whole section of what we've done so as to find answers in order to fill it in. So surely revision was taking place there. They were using some words that language skills-in which English was being-vocabulary was being t-propagated there and er working with someone else as a pair (mh). The thing about competition, working within a set time ....{some deletion by mistake) by the pupils in a lesson like that {pause} [...] then I'm really glad they have learned. I've taught something. They remember something. And I'm sure when they get the results of this crossword, the correct answers, it's something they're going to remember. [I2:249b]

What was more frustrating for her was that in some instances her efforts to make lessons more interesting and student centred were received by an unwillingness to participate by the students. One upsetting incident occurred during my first visit for observations. She had this to say about her experiences of that lesson which took place on the Thursday afternoon of September, 8:

> Probably the most embarrassing day. Traumatic and embarrassing. I've had it with 7K. couldn't take it anymore. (Victoria was here) I was real upset. Is it my fault. Beginning to doubt whether talk and responding to emotions really helps with kids! [TPJ]

In this extract it can also be seen that Ferrial began to question her ability and doubt herself as a teacher. Without sounding and being sympathetic towards Ferrial these students appeared to have an attitude problem. They seemed determined to make her feel incompetent in her teaching and she succumbed to their intimidating tactics by showing how upset she was and walking out of the classroom and calling in the principal to 'her rescue'. This is what she revealed during an interview as she recollected the events in unsuccessful lessons:

> Well er I did have a bit of a problem of control at first, (Mh) structuring and timing. Well the rapport got better, the control got better the timing also, the way I gave homework, what I gave as homework. [...] Well er the incidence with the std 7's was er was very upsetting. I've tried very hard with the std 7's. They are known to be a notorious class in the school. So I thought let me do my own work, trying to make the effort with them in technology, as well as in science, preparing good worksheets, let them do the work, would help and let them get involved .... it's a more an attitude thing that kind of stems from them. You know you get stared down, imagine after giving them an instruction and they will look at you like what the hell are you speaking about (Ya) What happened in that lesson was er I just felt like I was in this primary school with kids screaming at me and er no one listening to instructions that were given, and me having to scream and I couldn't handle it (ya) that kind of thing. It was an experience. It was a lot of experience. It's only made me stronger, a little bit harder. I just hope that it doesn't mean I have to be laissez faire about it. It doesn't matter. Sure enough different situation award different er {pause} you know approaches and responses (Mh). And if something like this happens again maybe I'll be able to handle them. [I2:250]

It emerges from excerpts above that Ferrial tried student centred teaching in the hope of getting more students involved in the classroom activities and processes with her participating as a facilitator. These claims complement her initial views (as detected by the first interview prior to teaching practice) that a teacher should make use of students' ideas in teaching shown in excerpt [I1:241a] on page 131. This is confirmed by her instructional strategies observed during her lessons.

What also emerges from this excerpt is that Ferrial saw herself improving with time, which was quite normal. Teaching practice was a learning experience for Ferrial as will have been observed for many other student teachers (Clark and Starr 1991).

Apparently this was the first time things really got out of control and she attributed their unacceptable behaviour to the fact that the lesson was in the afternoon when they were tired. Sympathetic as anyone can be, we cannot disregard the fact that Ferrial knew that this was a problematic class in the whole school. It could, however, be argued that she could have at least anticipated what was coming and prepared herself for dealing with such a situation. She was very upset at the time of the incident but on reflecting she thought positively about it and that it was an unforgettable experience which she would exploit in future. She promised herself that she would not in the future react in the same way as she had done. This encounter provided Ferrial with invaluable experience regard'ng classroom control, she admitted to be having difficulties at first.

Ferrial believes that maximum learning occurs when the activities are pupil centred, when learners are actively involved in thinking and discussing the tasks. Her fancy is that learners have to provide answers and solutions to problems. Only when they are unable to do so, should the teacher guide them to the desired answer. Her experience as a scholar developed in her the belief that one learns a lot from doing all the work herself. She did not enjoy that at the time but when she realised that it paid off, she became convinced that it was the best way learning could occur. She tried to execute this belief during student teaching. Active involvement included practical experience, audiovisual involvement, working with problems preferably those linked to everyday experiences of the students and thinking about the tasks

6.9 Ferrial's knowledge of chemical concepts

The analysis of the diagnostic test revealed the data summarised below in Table 6.4 for responses on the chemical bonding test and Table 6.5A and 6.5B for test on acids and bases.

6.9.1 Chemical bonding

Table 6.4 : Summary of Ferrial's responses on the chemical bonding diagnostic test.

Responses in Pre-test [Class average 4.6]	Responses in Post-test [Class average 7.7]
1. *C: Ionic bonds. NaCl consists of Na^+ and Cl^- ions held together by electrostatic attraction	1. *C: all bonds are formed due to electrostatic forces
2. *A: process of elimination!	2. C: easily broken down
3. *C: (no explanation)	3. *C: a molecular solid is necessarily grey or black
4. C: (no explanation)	4. *B: electrostatic attractions form bonds
5. B: (no explanation)	5. *C: when a bond forms electrons are shared by two atoms and are attracted by the nuclei
6. A: (no explanation)	6. *D: (no explanation)
7. *B: (no explanation)	7. *B: more energy is required to break a strong bond
8. *B: (no explanation)	8. *B: intramolecular forces in I_2 are greater than intermolecular forces
9. C: (no explanation)	9. C: (no explanation)
10. *D: (no explanation)	10. *D: (no explanation)

From Table 6.4 above it will be seen that prior to discussing chemical bonding in the university based classes, Ferrial was unable to explain her choice of the responses. It will be noted that for question 1 though the chosen option is correct her reason portrays a conception of electron transfer in bonding in a sodium chloride crystal. Her response to question 4 (exploring student's knowledge of bonding in carbon monoxide) shows that she views sharing of a pair of electrons (option C) is responsible for the bond in carbon monoxide. And her response to question 5 (on reasons for bonding between two atoms) illustrates that she sees achieving an octet of electrons by an atom as the reason for bonding between atoms. In the post test she reflects some positive changes in her conceptions about the reasons for a bond forming.

Her response to question 2 does not show much understanding of the microscopic structure and properties of brittle solids even though she chose the correct option. It seems the discussion of chemical bonding did not bring about a better conception of this aspect of the topic. From her response it seems she could not differentiate intermolecular forces which are easily overcome and thus responsible for the brittle properties of simple molecular solids and the much stronger chemical bonds which are intramolecular.

Her response to questions 6 in the pretest showed that she was possibly unfamiliar with atomic and molecular dimensions. The question stated clearly that a molecule was represented in the diagram. If she was familiar with representations she would have interpreted the illustration as that of a homonuclear diatomic molecule but still she thought that the distance between the two nuclei of such a molecule is the atomic radius. This view changed but was not supported by any statement.

Question 9 on melting of network solids was a problem for her in both tests. The same incorrect response was chosen that ions move from their positions when a network solid melts. This response is not completely incorrect though it is not the best answer to the question. It may be surprising that she did not change her views despite this concept being discussed and illustrated at length during the class discussion (see Chapter 4).

In conclusion it could be said that Ferrial had some erroneous conceptions about the nature and origin of the chemical bond in both network and simple molecular substances (exemplified by sodium chloride and carbon monoxide). She initially could not effectively differentiate causes of bonding and effects of bonding (electron sharing). She also appeared to believe in the octet rule as the cause for bonding. All these apparently changed after the discussion. It could thus be said it was beneficial for Ferrial to discuss chemical bonding during her preservice training.

6.9.2 Acids and bases

Analysis of Ferrial's responses to Part A of the questionnaire on acids and bases is given in Table 6.5A.

Table 6.5A: Ferrial's responses to Multiple choice questions.

Question*	1D	2A	3E	4E	5B	6C	7B	8A	9E	10A	11A	12E
Response	D	A	E	E	C	C	B	B	E	A	A	E

**Correct responses are given with the question number.*

Ferrial expressed the belief that the most significant property of aqueous solutions of acids is good electrical conductivity. It is also very surprising to note that in the multiple choice she chose ammonia as the conjugate base for hydrogen chloride but identified it correctly in Part B. A more serious point is that she did not seem to be aware that the acetic acid and ethanoic acid were the same substance. She even gave a slightly different formula for acetic acid as shown for question 3 in Table 6.5B below. Note also that she did not show the representation of aqueous hydrochloric acid. Her reasons for not showing a microscopic representation were not explored. It is worth noting that during the physical methodology workshops some handouts on the acids and bases and their microscopic representation were given. These discussions also focused more on practical skills and less on content.

Table 6.5B: Ferrial's responses to structured questions: Section B.

Question #	Response
1	Yes: release of H^+ ions in solution
2	$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$; $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$
3	(i) Cl^- weak conjugate base; CH_3COO^- strong; ii) —
4	$HC_2H_3O(aq)$ (sic) $\rightleftharpoons H_3O^+ + C_2H_3O_2^-$ Acetic acid
5	a) Colour: presence of H_3O^+ ion static equilibrium b) i) A ii) B iii) C
6	concentrated → less H_3O strong acid → H^+ readily available in solution, weak conjugate base b) Not so, concentrated refers to amount of H_2O; strong referring to the H^+ ions
7	No microscopic representation of aqueous solution of hydrochloric acid was given.

6.10 Teaching Practice Observation

6.10.1 The school

Ferrial conducted her teaching practice in a multiracial school located out of town. This is one of four private schools which were recently established through a trust fund and set up to specifically to reflect racially the population of the country. The majority of the students in the school reside in hostels. There are 15 teachers for a student body of about 160 students distributed in two streams of std 6 to 10. The number of students range from 13 to 28 per class. With such a small pupil teacher ratio any teacher should be able to give individual attention to students. It is also not surprising that Ferrial described the school as "one big family where the teachers know the students like parents know their kids". The students do not have to wear any uniform though they may have school jerseys and blazers.

6.10.2 The laboratory

The school laboratory is fairly small but adequate for the small number of students it serves. There are three wooden movable work benches and twenty-four stools. It has a number of fittings necessary for a laboratory: a fume cupboard, elevated instructors bench, chalk board, gas taps and water taps at the back. An overhead projector and screen at front and posters on the walls. All science lessons are held in the laboratory.

6.10.3 Classroom observations

General features

Ferrial taught physical science to std 6 and 7 and biology to std 6 and 8. I observed only four std 7 physical science lessons. Transcribing the tape recordings of all four was made difficult by the high levels of noise during Ferrial's teaching practice lessons.

It was not possible to observe consecutive lessons as was done for the other two case studies. The first lesson to be observed, on acids and bases, was disrupted and did not run to the end. Many factors contributed to the disruption of that lesson. Like for example student misbehaviour and not heeding to her attempts to control the class. Ferrial's intolerance of such misbehaviour resulted in her becoming upset to the point of discontinuing the lesson and calling the principal to address the class. As a result the physical science co-operating teacher continued and completed the topic on acids and bases. Another reason was that Ferrial had several clashes with her classes so that her std 7 science class was also taught by the co-operating teacher, as she explained

> Er the sad part about the teaching prac is that I had to share lessons because I couldn't take the full set of three lessons for week for 7K or 6A. You see I couldn't er usually my lesson had to be continued by Stella or completed by Stella. So like where I missed out periodically on a lesson and er you know the thing which is a bit sad.. [I2:251]

Another problem interfering with the study was poor communication so that for some of the lessons I arrived very late because of time changes I was not aware of.

As it usually is the case with many teachers experienced and inexperienced, Ferrial began each lesson by reviewing the previous lesson. For example she introduced the lesson on neutralisation thus:

F: What's the colour of bromothymol blue in acid?
Ss: Blue-blue-black-black-red white pink [students simultaneously calling a variety of colours]
F: Bromothymol blue in acids, what is its colour?
Ss: [students continue calling out various colours] In acid it's purple. It's pink.
F: Take out your notes it's written down in your notes [students continue shouting answers]
S: It's it's milky. [...]
F: Bromothymol blue turns yellow in acid. Ok. What is bromothymol blue?
S: It's an indicator.
F: It's an indicator. We use it to show us .... [students quite noisy] Max please be quiet. Do you understand what I'm saying. What is the purpose of an indicator?
S: It is to show us whether a substance is an acid or alkali.
S: To show that there is acid or alkali. .....
F: Shhh. One at a time must speak at a certain time. To show whether a solution is an acid or an alkali.
Ss: Yes.
F: What are the colours? [students talk at the same time] (Shhhh)
Ss To show that there is an acid or an alkali. [students talk simultaneously]
F: One at a time. To show whether a substance is an acid or an alkali. If a substance is an acid it shows yellow in bromothymol blue, if it turned back to blue what can you tell me about...
Ss: It's an acid; It's an alkali.
F: What would happen if it no longer stays yellow in an acid what would you have?
S5: Alkali.
F: An-alkali. Ok. Bromothymol blue is yellow in (Ss: Acids) acids and what colour is (Ss: Blue) [Handing out work sheets] Ok I'm handing out these worksheets .... [immediately students start talking and cutting and pasting] Please stop your pasting and cutting. These books are handed in at the end of the lesson. There's no time for ..... You are going to detention. [in a threatening tone]
S: M-i-s-s ...[objection] [8/9/94a]

The above excerpt also indicates the general behaviour of students during the lessons and their responses to Ferrial's questions. It further illustrates the general pattern of opening the questions to the whole class. This questioning technique may invite students to call out answers, but also has the advantage of prompting the whole class to think about it (Clark and Starr 1991). Students also seemed fairly free to call out answers despite attempts to have only one student speaking at any given time. Sometimes Ferrial directed questions to specific students as shown below.

F: [...] So what is convection?
S: Convection is the move ...
S2: It' the ...
F: Shhh. Neil?
Neil: It's the way the liquid is heating up ... when liquids are heated ...
F: Come again.

Neil: It's the movement the liquid makes when heated.
F: Is there anything else anybody would like to add? Nancy?
Nancy: ..... movement of heat in water.
F: Ok. Edith.
Edith: It's the movement made when water is heated. When water is heated the movement it makes.
F: Dick?
Dick: The cycle caused by the heating of water.
F: The cycle ..
Dick: Not the cycle but the process caused by the heating of water.
F: Ok. Convection is the process in which....
S: water is heated. [Ferrial continues to explain]. [15/9/94]

Notice how she attempts to get as many views from students about convection as possible before giving the expected response. Eliciting students' views about any concepts discussed in Ferrial's lessons was a common practice as will be noticed in excerpts quoted below.

Ferrial also had classroom management problems with this class. Her skills in controlling the class, however, improved with time. Excerpt [8/9/94b] below shows how her attempts to exercise some authority are ignored as students continue trimming their handouts in spite of her requests to stop. What was more frustrating for Ferrial was that some of the students' verbalisations were in Sotho or Zulu neither of which she understood (which I did). She tried not to be very hard on them and allowed some degree of noise. But she became intolerant of the cutting and pasting that students were so engrossed and which prevented them from paying attention to her instructions as she explained what was expected of them in the practical outlined on the worksheet. She also expected their participation in the process.

F: Paul Khoza, I want you to read the title, we are getting on to the worksheet. [Students chatting] Has everybody got the worksheet so far? [some students say yes others say no]
Paul: Reactions of acids with alkalis.
F: Ok. Can you start reading please the first paragraph. [Paul reads on] Ok Lolly read the next paragraph [she reads. Other students are trimming their worksheets and pasting into their notebooks] (Shhh) alkalis [correcting the Loily]. Can you stop pour cutting please Cathy. [beginning to sound a bit agitated] can everybody please stop cutting please! I've had enough of cutting and pasting you're meant to have your books up to date. [S: shhh] Billy stop. ..... can you put your bag down please. Vusi where's your worksheet? Veronica what's .... Cathy leave everything else and pay attention. (Cindy [students correcting) Sorry what is your name? (Ss: Cindy simultaneously Cindy) Cindy. I want absolute quiet I'm tired of hearing you speak. You can't speak all at the same time. Lolly I want you to carry on reading please. [Lolly continues to read. the students are quieter] neither [another correction]. Sally what is neutralisation?
Sally: It is when...
F: Say it without reading your notes.
Sally: I don't know.
F: Ya. But you haven't listened, have you?

Sally: No. [8/9/94b]

Besides classroom control or management problems, lack of co-operation from the students is displayed by Sally's withdrawal from responding to Ferrial's question on neutralisation. It seems the environment was becoming tense and unhealthy for learning. Sensing that she was too upset to continue the lesson Ferrial decided to discontinue the lesson. She further sought the principal's intervention on the matter. She described this lesson as the most traumatic and embarrassing for her. It made her reflect deeply about her role as a teacher and her interaction with students, as demonstrated in excerpt [I2:250] on page 149.

By her own admissions in the initial interview, class control is important in

> [...] showing you are an authority, that you you're the one who is controlling the class, and pupils should pay attention to you. Ya I think that's important. Ya it er and I mean there should be a bit of er row-er-noise in the classroom that allows for interaction with peers but-but er constructive noise you know. [pause]. To an extent there should be control otherwise you could be sidetracked completely from-from-if you if you want something done [I1:244]

It appears she got sidetracked by students' behaviour which she considered unconstructive. It also seemed that the management problems Ferrial had with this notably problematic class went beyond what meets the eye. The fact that they made comments in languages she did not understand, one of them even saying in Zulu (which I understood) that "she won't make it as a teacher" reflected that there was poor rapport between Ferrial and those students. Some of them did not seem bothered that she walked out of the class because they continued talking and one of the students warned the others thus:

> Hey nine bayasiteipa. Bateip'umsindo nje. [which means Hey, we are being taped. They're taping noise.] [8/9/94d]

Three of the observed lessons were hands-on oriented. Students worked in permanent groups and were given a practical worksheet. Prior to students carrying out the practical activity Ferrial discussed the theory behind the activity and helped the students so that they should have known exactly what they were to do:

> What we are going to do today is I'll be giving you beakers. I want you to break up into the four groups you were working in the last time. Shhh. Before you do that you'll be given four beakers. In this beaker we will have acid and we put in there bromothymol blue. What colour will it be? [....] Then we are to add a substance which we call an alkali to this acid and we will see the colour

change from yellow back to (Ss: blue). When the colour changes from yellow back to blue we call this a neutralisation reaction because the acid probably or the acid is now taken away. So when the acid and the alkali react we call that a neutralisation reaction. [8/9/94e]

The fourth lesson was on graphing skills, which also involved the development of the skill as students were guided on graphical representation of data. Again in this lesson she gave students the opportunity to give their ideas on graphical errors. They had to identify these from a graph she presented to them and they had to say how they would draw a proper graph from a given set of data before drawing it.

Ferrial's approach in conducting her lessons complements a description by Clark and Starr (1991) as inquiry and discovery strategies of teaching. It will be observed in the description above that as a teacher, Ferrial's use of the inquiry approach is displayed by her raising problem issues and guiding the students in the investigation of those issues. She then followed the investigation by helping students draw conclusions from their observation and discussion during the lesson. Her proclamations during the interviews are witnessed by the attempts she made in assuming the facilitator in teaching her lessons. There are no implied notions that she was efficient in this task. There is of course a lot more to inquiry learning than that in which Ferrial engaged her students.

Questioning technique and handling of students' responses

As was done for Andrew and Mary, questioning technique analysis sought to establish the level of Ferrial's questions during her lessons. Ferrial's lessons were designed to help students learn through hands-on activities and demanded more input from the students than merely responding to her prompts. Ferrial's lessons were thus less expository and more inquiry oriented as mentioned above. The excerpt below gives some idea of the inquiry nature of Ferrial's lessons:

> Ok. You know that liquids are not good conductors of heat. We call them insulators. Ok. If you look at the handout that I gave you, has everybody got one? (Ss: Yes). Ok. The problem we would like to solve is "If liquids are such poor conductors of heat why does a kettle of water warm through so quickly?' [15/9/94]

The kind of questions Ferrial asked were a combination of recall/recognition as shown in excerpt [8/9/94b] on page 157 and explanation or comprehension type questions. Excerpt [8/9/94f] is given below as an example attempting to show the convergent nature of some of her questions (questions containing prompts to the answer or requiring recall of what has already been discussed (Clark and Starr, 1991)) and explanation questions (each with simple specific answer).

F: Which materials did we say, consider solids liquids and gas, are the best conductors?
S: Metals.
F: Metals are the best conductors. So in solids liquids and gases ....
S: Solids.
F: Solids are. Ok. Not all because we know that glass is a solid and it's a..
Ss: Insulator.
F: An insulator. Ok. Which is the worst...
Ss: Gas.
F: Gas is the worst conductor. And in the order we find...
Ss: Liquids.
F: Ok. If liquid is such a bad conductor of heat, [...] why is it that if you put a kettle of water on the stove, why does all the water heat up so quickly?
Nancy: It is because the kettle is usually made of metal and metal causes the water to heat up quickly.
F: Ok. The liquid itself is not a good conductor. Why does the liquid then become hot all round ... heat up all over if liquid is a bad conductor of heat?
Rose: The kettle is solid.
Nancy: Because the ...
F: Ok. But I'm talking about the liquid. Liquids are not good conductors. Why then does all the water get hot? Laurie.
Laurie: Because the liquid starts to adjust, starts to vibrate faster and then like .... the heat is sent through each one from one molecule ....
F: Tsidiso what were you going to say?
Tsidiso: ....
F: I'm talking about the liquid in the kettle.
Tsidiso: .....
F: The liquid is not a good conductor. How can the liquid get hot? [15/8/94f]

Notice again how she attempts to get a number of students to express their ideas and avoids telling the class anything until she is convinced that the students can no longer give different suggestions from those already stated. Furthermore the answer was discussed after a demonstration she conducted while students watched closely. Not only did the students watch but they had to make contributions by describing their expectations and observations of convection currents as shown by a stream of coloured water. In the process they also had to explain their observation to draw up a definition of the concept under discussion. All this they did with a lot of guidance from her. These observations complement her claims in the initial interview, see excerpt [I1:241c] on page 131.

Ferrial took time to give students the acceptable answer to her question because she believed students' ideas were valuable in moving from what students know to what the teacher wants them to know. So she seemed to have made every effort to get as much as possible of what students thought about a given situation and even encouraged them explain or defend their responses as the excerpt below taken from lesson on graphing skills, illustrates:

F: Ok. I have two questions, very good questions. The next thing we need to do in drawing of our graph we need to know what goes on the X-axis, we need to know what goes on to the...
Ss: Y-axis.
F: Ok. Which is your X-axis?
S: Internal temperature.
F: Ok. If we call it X and Y which one is it?
Ss: X-axis ... horizontal ...
F: That one [pointing to x-axis on overhead transparency]. Ok. Don't tell me what it should be labelled, just tell me what it is, horizontal or vertical.
Ss: Horizontal, horizontal.
F: And the vertical would be your...
Ss: Y-axis.
F: What do you think will go onto the X-axis?
Ss: [Calling their responses at random] Body temperature; Body temperature; It's er....; No it's external temperature....no the body...external...It's the body temperature and on the Y-axis it's the external temperature [and the debate continues]
F: Ok. Wait. I've got um Lerato (Yes) and Myra. Myra you say we should have the external temperature on the X-axis and Lerato you say on the Y-axis. Why?
Myra: Because that No Miss...
F: Go on go on, hang on we're are almost there [encouraging her because she was on the right track. She continues but is inaudible] Lerato you have an answer? What?
Lerato: I feel that the external temperature should be on the Y-axis ..... and then the body temperature on the X-axis.
F: Why would you want to swop them around in the table and put the body temperature on the X-axis?
Lerato: Miss because....
F: Ok. If you look at this table here ....[13/9/94]

Notice also how she prompts the whole class to think about the situation by initially opening the questions to the whole class before focusing on Lerato and Myra. This questioning technique was common in the lessons I observed.

Ferrial also related the concepts discussed in class to real life experiences. For example after she demonstrated convection currents in liquids and discussed those in air she went on to discuss the domestic hot water system and how a room gets warmed up by a heater. These attempts concur with her beliefs that

> we can teach about everyday science in a way where we make people aware of the things that are happening not using as much scientific terminology and language. [...] Not using the actual science terminology and things like that. But sure enough in order to teach something you've got to introduce those terminologies and that language to a certain degree. Yes you can learn so much about science in a layman kind of way but when you are coming down to pure science that you

> wanna learn then you got to speak the language so to speak. [...] make sure that you use the terms correctly when you're teaching it in school [...] And I think err it's equally important that although these concepts need to be clarified, they need to be used correctly. We should err put them out in a sense where it's more-where people can take them in, I mean it shouldn't be too scientific. So that er you know kids or children at school can grasp it. It should be relevant and applicable. Practical-practical to everyday (Mh). So you can teach science in that way. (Mh) But it should be balanced.[I1:240]

Student Participation

The above extracts also show the high degree of student participation, not just completing teacher generated statements, prompts and cues but also giving their ideas which she elaborated on if necessary. Her use of students' ideas in teaching again confirms her beliefs about exploiting the knowledge students bring to class.

> Try to assess in a way what their concepts are by a form of-making them work with things that makes me aware of that, of how they-the way they are thinking-their way of thinking. Introduce yes-the-the concepts that I want to teach and see how they formulate that from-for themselves, and if they're way off then try to bring them by a process-I don't know test or maybe making them see-see a different way. (Mh.) Well seeing different views from the classroom and so on. (Mh) But being aware surely that people form their own concepts [I1:241]

In addition to recall questions there were also questions which required students to synthesise some definitions from her explanations. An example of such questions is one she posed after a detailed explanation of convection currents has been shown in excerpt [15/9/94] above.

What also emerges regarding teacher directed student participation involved only a selected group of students whose names Ferrial was fairly familiar with. Her reasons for doing that were

> I tried to spread it out but sometimes I get the response that I don't know and no matter how long I wait I know I'm not going to get an answer. (Ok) That has happened with std 6As, you just get a blank stare and it goes on and on. And if you for an answer and you try and prompt they seem to get upset. Um I'm trying to think, er especially with some of the kids in 6A they are a slower class. And because of the pressures of the peers around as well, they seem to laugh at them (if they give an answer) or they don't give an answer or ya. If they don't give an answer they get upset the longer you wait because everybody else gets anxious as well (Mh) And to try and avoid that and to move the lesson up as well because you never finish (ya). Well the knowledge also sometimes of er you know er what the problem areas are and things like that as well. [I2:253]

Student motivation

Student motivation was not a common occurrence in Ferrial's lessons, but when a student deserved praise she awarded it. This happened when Nancy applied her knowledge of convection in liquids to explain why the air above a bunsen burner flame was hot thus:

Nancy: When you light the bunsen burner it warms the air just above the flame and when the air just above the flame gets warm and it rises. (Ok.) And when it gets to this top it sinks and replaces the air that was at the bottom so that the air around it becomes warm.

F: Ok. Super. What happens here again is the air just above the flame is heated , what happens to it? [.....] [15/9/94]

Safety

Ferrial was also safety conscious. She warned the students about hydrochloric acid and sodium hydroxide thus:

> Note very well, we are dealing with an acid and alkali. We are dealing with sodium hydroxide .... very (dangerous) dangerous. I don't want you to consume any of the liquids that I've given out to you. [...] [8/9/94]

Content limitation

One interesting observation about Ferrial's lessons was that there were hardly any student generated questions directed to her. As a result her shortcomings in the topics acids and bases concepts and heat transfer were not exposed. However analysis of sections of her explanations reveal that she seemed to avoid using the terms "dependant-independent variables" when discussing graphing even though she had them in her lesson plan. One other disturbing aspect was her explanation of neutralisation displayed in the excerpt below:

> Ok. We saw that an acid has a specific colour in bromothymol blue. It's yellow, ok. When we add the substance to it we [pause] deun-we de-we de-acid basically the acid. So the colour of the indicator will change to blue. Ok. We de-acid the acid that we are using basically in simple terms. This substance that de-acids or neutralises the acid is called an alkali. Ok. And the reaction of an acid with a base or an alkali is called a neutralisation reaction [...]. [8/9/94]

She explains what they will do in reacting an acid and a base and continues the explanation of neutralisation thus:

> Ok. Then we are going to add a substance we call an alkali to this acid and we will see the colour change from yellow back to blue. We call this a neutralisation reaction because the acid probably or the acid is now taken away. So when an acid and an alkali react we call that a neutralisation reaction. The acid is no more acidic it's now neutral, and the only thing that can make it neutral is an alkali. [8/9/94]

This reason was given to std 7. It was also suitable to discuss acid-base reactions in qualitative terms. The only danger of Ferrial's explanation of neutralisation is that students could develop the conception that neutralisation reactions of acids and bases all the acid reacts leaving some excess base giving a blue colour with the indicator.

6.11 Profile summary

Ferrial came from a government school where science teaching was poor. It appears her science teachers presented science as something mystical and dangerous and not to be pursued by anyone. She claims to have been responsible for most her own learning. At the time of entering the HDE programme she had well defined expectations from the courses aimed at preparing her to be a science teacher. These expectations were quite diverse and the opposite of the way science and its teaching has been portrayed by her science teachers at school. If these could be achieved she would certainly be an ideal science teacher. She also disclosed that she was fighting against a "phobia" towards science and its teaching developed during her school days and which seemed to be responsible for her feeling incompetent and anxious throughout her training.

As she progressed with her training few of the activities offered addressed these expectations. She appreciated those course activities which had direct relevance to teaching tasks or her expectations like the mini-lessons, setting tests, discussing chemistry concepts and exposing and addressing errors in her content knowledge. She felt those activities for which she could not identify any direct relevance to developing her teaching skills like word processing of the many small assignments, were a waste of time and frustrating. She also complained that certain activities like preparing charts and text analysis, though relevant to teaching, were overdone. At some point she felt students were unnecessarily loaded with work at the expense of proper training for teaching. She felt there was too much work that she found it hard to cope.

At one point during the HDE she contemplated withdrawing from the programme. She did not feel comfortable with certain aspects of the courses. She felt she was not given enough guidance but dictated to and that personal tutors were needed in the course to help the student teachers in the transition from student to teacher. Ferrial seemed consumed by the idea that she would become a teacher soon, that she is an adult, and was frustrated by what she perceived as being treated like a child during the methodology courses or not given the respect she deserved by her std 7k class during teaching practice.

Ferrial's conception of science is quite broad and is that science

- has a human origin,
- is factual, implying it has a knowledge base,
- has been researched over years and therefore changes to keep up with the times
- defines, describes and explain natural phenomena.
- is research related and as such includes other areas of knowledge such as social anthropology
- is generated through the science process (experimentation, observations, theorising) over many years.

Her initial views did not include a clear understanding of the words "scientific knowledge" or " scientific method/processes". Her ideas changed slightly by the end of the year. During her teaching practice lessons she managed to show the importance of the science process in deriving explanations and definitions for concepts like "convection" and "radiation". She also tried to make the science done in class relevant to their everyday life by discussing its applications. Examples were seen in her lessons on "heat" transfer.

Her own experiences of teachers seemed to shape her conception of teaching to the point that she disliked the term "teaching" itself. She realised her own limitations resulting from her own teachers' teaching styles. She thus developed the belief that teachers should always be available to guide and help their students and that teaching should be more student centred. Her conceptions of science teaching did not change much during the course. They were modified slightly to include the idea of increased student participation. She views (science) teaching as an activity in which the teachers

- transfer factual knowledge to students who are capable of learning it;
- help the students develop life skills and ability to do things;
- facilitate the learning process by probing students to think about a situation or in a desired direction, encouraging group work, interacting with the learners and creating an environment that will promote student participation.

Ferrial's conceptions of (science) learning did not change either. She views learning as knowledge accumulation either by construction, restructuring of existing knowledge or taking in knowledge. The knowledge to be internalised must however be compatible to the cognitive level and background knowledge of the learner. She also believes that learning occurs when learners make links between what they know and what is presented to them. Ferrial's experiences as a scholar were that she learned more from doing all the work first hand. Thereafter she became convinced that it is the best way in which learning can occur, that is maximum learning occurs when the activities are pupil centred, when learners are actively involved in thinking and discussing the tasks. She was also convinced that learners have to provide answers and solutions to problems and only when they are unable to do so should the teacher guide them to the desired answer. The beliefs she developed from school experiences moulded her teaching styles so that her lessons were designed to

- maximise student participation through practical experience;
- encourage students to think about the learning tasks;
- encourage students to work in groups; and
- encourage students to work with problems and preferably those linked to their everyday experiences.

School experience can provide opportunities for student teachers to try out various teaching methods and styles. While appreciating assistance from the cooperating teachers, Ferrial wanted the freedom to be as innovative as she desired. Sometimes she felt she was presented with a restricted and formalised teaching situation in which she had to use well tried teaching methods and miss the challenges of exploring her own potential, or her theories of teaching and learning. Unfortunately her efforts and strategies were not received with the same enthusiasm by the cooperating teachers at the school, who criticised her for not teaching, and the students who were not willing to participate in her class discussions.

Ferrial experienced classroom management problems. She was fairly strict and wanted her students to be well behaved by paying more attention to her instructions and only talk when responding to her questions and cues or when asking a question. She really got upset when students ignored her instructions and because also she felt she was not being respected as a teacher. She could not compete with student noise while giving instructions or explaining something. She tried too hard to maintain class discipline but students were not willing to cooperate with her.

Ferrial was unhappy with the HDE chemical bonding classes. She had expected that after exposing her erroneous ideas about these concepts, acceptable ones would be discussed. She was very worried about imparting wrong ideas to students that she assumed that they would discuss right and wrong ways of dealing with these concepts. What is interesting however is that Ferrial's score in the chemical bonding test did not reflect the problems she reported. In both the pretest and post test she actually obtained scores above the class average. Her pretest responses had only two explanations and her explanations in the post test indicated that she understood the concepts. She did not teach this topic in her teaching practice, so I could not ascertain her level of competence in handling it.

CHAPTER 7

CASE 3: MARY

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7.0 Introduction

This case study focuses on "Mary", a young woman enrolled in the HDE programme. She is training to become a junior secondary physical science teacher and a biology teacher up to matric.

7.1 Brief background

Mary attended both primary and secondary school in Mmabatho. For her secondary education she attended a semi-private multiracial school. In spite of receiving a high government subsidy the school was surprisingly autonomous. She described the school as a

> [...] very academic school, *without* things like religious instruction *or* anything controversial like that. [I1:1a]

The teaching style at the school was predominantly didactic. She thought that was different from what she had learned from her HDE courses in that at the school

> [...] they didn't do things like what we have now been taught as exciting and we must teach like this. They also encouraged us to think and not regurgitate stuff which apparently isn't so widespread. [I1:1-2]

The school had very good sporting and library facilities. The school laboratories were also well equipped for teaching school science. Computer facilities were also available but she felt these were under utilised.

The description given above portrays a school with a great potential for teaching science and possibly other subjects effectively. However, some of the things Mary said regarding her experiences as a student were to the contrary. For example she described the status of practical work at the school thus:

> I never actually saw how things happened at school. If we did an experiment or if we did a demonstration more often that not it didn't work and I found that I didn't understand what was going at all. [I1:3]

Being encouraged to understand what was taught and the perceived lack of practical work during her schooling years seems to have had some influence on her conceptions of teaching and learning described below. She also developed the belief that practical work is the key to promoting understanding of science concepts during teaching and learning activities. This influence is also reflected in some of the excerpts quoted in the descriptions given in this chapter.

Mary joined Wits university after matriculation in 1990. She completed her basic degree in minimum time with majors in botany and zoology. She went on to do physiology honours in 1993. In 1994, during this study, she was training to become a professional teacher.

7.2 Reasons for joining the teaching profession

As she puts it, teaching was "the absolute last resort" [I1:1b] career she chose to follow. She had hoped to pursue a masters degree in physiology after her honours but later realised there were no employment prospects in it for the immediate future. It was also becoming expensive to keep herself at the university, though she was on scholarship. So she felt compelled to find employment. It seemed fairly easy to get into teaching, obtain a qualification and secure a job (Cole and Knowles 1993). The major driving force, however, seemed to have been that she

> [..] had to do it because *she* had no other choice [I1:2a].

Teaching became a plausible reality when she considered suggestions on the possibility of her pursuing a teaching career. She was also inspired by realising her potential in teaching during the initial two weeks of teaching practice prior to enrolling for the HDE programme. She went to her old school for this teaching practice orientation and realised this about teaching:

> [...] it's something that I'm fairly good at, and I wouldn't mind doing it. And also if you look at the state of the country, it's really something that we desperately need, is good teachers. So I don't feel so bad about it any more. [I1:2b]

The excerpt above also shows that she now feels comfortable with the choice of teaching as a career. She has not, however, committed herself or made any concrete decisions on making teaching a life time occupation. She felt it would depend on a few factors in the field. For example in response to a question on her future prospects of staying in teaching she said:

> Well it depends. Um people tell me "Oh don't worry you don't have to teach for long. You can get yourself a university post". The fact is if I enjoy it then I'll stay in the field you know. I think it's something that- it's a very important career. So it all depends on how I actually enjoy it, and I don't know. I really don't know. [I1:2c]

Like Ferrial, job availability dictated Mary's choice of teaching as a career. Her lack of commitment to the profession demonstrates this. She is quite undecided whether she will stay with teaching indefinitely.

7.3 Perceptions of the Teaching Profession

From the excerpts above, Mary seems content in the teaching profession, albeit uncertain about its future. As with other prospective teachers, Mary's views of the profession have been influenced by other people. Though she expresses the belief that teaching is a very important career

> [...] people around here don't really see teachers as professionals. [I1:2d]

She also cites the issue of low salaries in teaching as another contributing factor to the undervaluing of teachers and the teaching profession. Excerpt [I1:2e] below shows the kind of issues that are of real concern to her regarding this profession.

> [...] I think because they get so very little salary compared to the other professions. I think that has something to do with it but that doesn't worry me as such. I'm worried about how the schools, you know ... sort of like what do you say um my future employers would treat me as a teacher. [...] from what we learned from theory of education it doesn't sound too great. [I1:2e]

She appears to be more anxious about the relationship she might have with her employers and supervisors. The excerpt above also shows that the expected relationship is not something she is looking forward to. Furthermore she is worried by the fact that she has very limited knowledge about the education system in the country. This limitation will be appreciated considering that prior to deciding to undergo professional training in teaching she had not paid particular interest to educational matters. Another area that seemed to concern her was the amount of bureaucracy involved in the profession.

She naively hopes things will change to give teachers a comparable status to engineers and doctors in South Africa because many things are expected to change. When asked what sort of changes would achieve a recognised status for teaching and teachers she said

> I think they have to allow teachers a certain amount of leeway in how they teach. But now this is also a problem because not everybody is as comfortable or they are not that well qualified. I mean teachers in this country are not well qualified in general. So maybe for them it would be quite unfair, maybe they like [...] being told how to do things because that's what they can cope with. But on the other hand, it might be difficult for somebody wh-who is well qualified like I hope the people

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> from you know who will be graduating from this class will be. [I1:2f]

So while she acknowledges the limited autonomy in the teachers' workplace she also accepts the possibility of difficulties many un(der)qualified teachers in South Africa would experience as a result of allowing more teacher autonomy. She foresees a conflict of interest if such a change would be implemented, viz a situation where one group feels threatened and another group of qualified teachers feels "very frustrated and undermined as teachers." [I1:2g]

7.4 Characteristics of good science teachers

Mary was asked to describe her best teacher at school. What emerged from her description of her std 8 science teacher was that formality in dress and non-academic issues were not part of her criteria for characterising a good science teacher. This is what she said about this teacher:

> [...] he was very interesting. He could explain the subject very well and he was very clued up on the content and you see he read a lot. [...] he used to tell us about fun stuff, you know like .... strange things that [illegible]ld never have ordinarily heard of at that level. And we found that fascinating. When he [illegible] things like the atom bomb, things that er related science to you know what scientists were discovering at the time and also made it a bit more new for us [...] *he* made science just a bit more interesting ..... He-the thing is he explained the course work very very well. [...] He was very informal um, but for some reason he managed to control the class very well, he was very effective, he just had that. I couldn't imagine anyone else having such an informal manner and actually getting away with it. He never had any discipline problems. Maybe because we were all so fond of him and we respected him and we never gave him any problems. ([I1:2-3]

Mary identified the attributes listed below, also reflected in excerpt [I1:2-3], to be characteristic of a good science teacher. These attributes shaped her expectations from the HDE programme.

- being knowledgeable in the content;
- having the ability to explain the subject matter well;
- displaying wide reading in science related issues and relating these to school science;
- making science more interesting by making scientists science real to the students;
- effectively managing and controlling the class; and
- having a good rapport with the students and winning their admiration and respect.

7.5 Conceptions of Science

Table 7.1 below summarises Mary's views about science, scientific knowledge and the scientific method, as gleaned from the interview data.

Table 7.1 Sum. aary of Mary's views about science

Initial Interview [I1]	Final interview [I2/3]*
Science: • a logical study where concrete measurable data is collected; • includes mathematics, biology, physics and chemistry; not sociology; • Scientific Knowledge originates from people's curiosity about the world and explaining it; observe what is going on; deduce something or experiment and conclude; trial and error thing sparked by curiosity • involves experimentations and hypothesising	**Science:** • has to do with the systematic logical gathering of data to find out what happens • *is concerned with discovering how things around us work in the world* • *it has qualitative and quantitative aspects* • method of generating Scientific Knowledge depends on the topic but would involve observations, experimentation, drawing up hypothesis, • there are different theories governing how to do science but results should be accurate and repeatable;

*The second and the third interviews were conducted simultaneously

Mary's views of science are dominated by the "processes of science". Her initial view of science was stated thus:

> It *[science]* would involve some sort of er a study, [...] where one could collect concrete measurable data, so it would include things like mathematics and er biology and physics, chemistry that kind of thing. [I1:3a]

Like Ferrial, the term scientific knowledge seemed to be unfamiliar to her, as shown in her response in excerpt [I1:3b] below.

I: How do you think scientific knowledge has been produced?

M: Where, what do you mean? In general (In general and later I think we will refer to) Like how do we know (ya) what we know about science? (Ya, how it has been generated) for centuries, (Whatever ya) I think er basically people become curious about the world around them, to explain it. (Mh) So they observe what is going on and er perhaps they would deduce something or else they would take something more what we would call the modern scientific approach where and set up an experiment nor something where they could change the circumstances and you know see-see how the phenomenon reacts under those circumstances, do an experiment and then see what happens and then conclude something from that. 'Cos I think its er a trial and error thing sparked up by curiosity, generally. [I1:3b]

Though she appeared unfamiliar with the term "scientific knowledge" she was aware of the human origin of scientific knowledge and that science processes endeavour to satisfy human curiosity about natural phenomena.

Another conception of science that seems to emerge from the excerpt above is the explanatory ability of science. Mary also believes that the data collected from either the natural world by trial and error or experimentation is aimed at explaining how and why things happen the way they do.

In the final interview she described science thus:

> I think it has to do with um er discovering how-how things around us work like in the world .... I really think it has to do with er um- a systematic logical, um gathering of data to find out what happens. [...] it has to be logical (mh). But it's concerned with finding out about the world around us. [I2/3:12]

She does not exhibit a strong change of view in her conception of science during the study. Both the responses displayed in excerpts [I1:3b] and I3:12] above reflect an inclination towards the empiricist conception of science which subscribes to empirical evidence of concrete measurable data.

Possibly the slight change observed in her conceptions is slight because the initial interview to establish prior conceptions was conducted long after the HDE class on the nature of science.

Her conviction that concrete replicable measurable data is fundamental to science is supported by Mary's reluctance to accept other possibly related subject disciplines as science. She feels that subjects like sociology, religion (which she thinks is controversial as reflected earlier (see excerpt [I1:1-2] on page 169), history and philosophy cannot be regarded as science because they tend to be subjective and

> it would be difficult to measure any hypothesis originating in these fields qualitatively or to test any of the hypothesis using repeatable experiments. [assignment material, March 1994]

This could suggest an objectivist view of science as described by Hodson (1981). She did not seem to subscribe to any particular belief about the scientific method. At the beginning of the study her ideas about the scientific method did not seem well defined. She seemed rather doubtful about what the scientific method involved. Later in the year she said that as far as the scientific method of doing science is concerned

> [...] there are different theories about how people should do science. [..] I think as long as you stick to certain guidelines like you have to be accurate, your results have to be repeatable, I don't actually think it matters how you do it. You can do whatever you feel comfortable with. But I don't think you must compromise um your result. They have to be accurate and repeatable, but you mustn't compromise that you know, in favour of your personal method. As long as your method works you

can use whatever you want. [I2/3:13]

This view partially concurs with Hodson's (1988) assertion that science involves a range and variety of methods and the selected method depends on the circumstances. In Mary's case the method is selected according to the topic.

She holds a view dominated by the processes of science, viz gathering concrete, accurate, measurable and repeatable data through observation, experimentation, hypothesising to discover how and why things happen in the world. This view suggests of an empiricist's conception of science.

7.6 Conceptions of science teaching

In both interviews Mary clearly stated that she was still unclear about a concept of teaching. As a result she was unable to adequately describe her theory of how teaching occurs. She attempted to give her theory thus:

> I'm sort of confused at the moment. I think it has a lot to do with how the teacher presents a topic. [I1:5]

> Well to be honest I'm still a bit confused about that [...]. I've never really understood the question 'Does teaching happen?' Do you stand up there and you rattle on to your students. You're teaching them. Whether they are taking anything in is another question. (Mh) But I don't actually know, it's not effective teaching, but it's teaching. I mean that's how we were taught. [I2/3:14]

Excerpt [I2/3:14] shows the link between effective teaching and learning. It also shows the influence of her experience of how she was taught on her views of teaching.

Her views of teaching science extracted from interview material are summarised in Table 7.2 below.

Table 7.2 Summary of Mary's views of teaching

Initial interview [I1]	Final interview [2/3]*
Teaching: . is presenting new information; . is providing answers, explaining and clarifying concepts; . is making sure students know what is going on/ understand content. . is developing students' interest; . involves listening to what students say, getting them to prove their theories, not just telling them they are wrong; . depends on how the teacher presents topic;	**Teaching is:** . presenting new information or knowledge . clearing misconceptions, giving correct answers; . addressing students' problems . making students think about what is going on; . standing in front of students and rattling on about anything (lecturing); . *making abstract concepts concrete for students;*

* The second and the third interviews were conducted simultaneously
NB. The listing does not in any way imply a corresponding change.

It will be noticed from Table 7.2 that Mary's views about teaching changed and became more specific later in the year. The underlying tenet of Mary's conception of teaching science is that it is the presentation of knowledge. The difference in the ideas given in the Table 7.2 is in the way the knowledge is presented during the teaching activity. Mary distinguishes effective teaching from noneffective teaching on the basis of these differences. Thus she believes teaching can occur without learning but

> [...] effective teaching can't occur without learning. I mean he can stand there and teach you whatever he wants but you know I don't know if there will be any fruitful outcome of that. It's like saying is if there is a sound in the forest but there is no one there to hear it is still a sound? [I2/3:15-16]

From excerpt [I2/3:15-16] above it can be seen that Mary believes it is insufficient to just lecture to students. She views effective teaching as producing the intended outcome in terms of a learning outcome in whoever is taught.

Mary's conceptions of teaching will be discussed in terms of her views that teaching is the presentation of knowledge.

Other interesting points about teaching Mary raised and also discussed are that teaching

. is influenced by the cognitive level of the learner;

. depends on the subject matter knowledge background of teacher;

The other ideas expressed in the table will be part of the discussion under these subheadings.

7.6.1 Teaching is the presentation of knowledge

Mary believes that students cannot be taught what they already know. Thus she believes that for an activity to be characterised as teaching, new information must be presented to the learners. This view was reflected in both interviews. In the first interview it was related to an instance where students are working on revision problems [Appendix 1C:3]:

> [...] Are these revision problems or completely new problems or what? (They've been given homework) Oh! They've been given homework. {Pause} I don't see any teaching happening there. They try to learn something by going through the problems but if they are both stuck then the only way they would be able to get some additional information is from the textbook. If teaching is happening then probably it's by using the textbook to teach themselves to learn how to solve the problems. [I1:16]

In the second interview it pertained to an instance where students being asked to label a diagram [Appendix 1C:6]:

> [...] its pretty much just recall isn't it? They've just done the experiment. So they have to just consolidate what they have just did. I don't know if she's actually teaching them or helping them remember or is it the same thing. It's just that this er this is like in conclusion to the lesson to consolidate what they you know apparatus they used or whatever. But she's not teaching them anything new. You know what I mean, she's {pause} I really don't know if we would call this teaching or not. [...] cos' that something they should already know. [I2/3:16]

It is also emerges from these two excerpts that Mary thinks that helping students remember is not teaching.

The view that teaching involves presenting knowledge that students supposedly do not know seems to comply with the "jug and mug" vision of teaching and the assumption that teaching automatically results in learning. But she explains herself that for teaching to be effective students should know what going on and understand the content presented. She believes that understanding of concepts by learners can be achieved by simplifying and concretising concepts.

She further shows this conviction by saying that

> I think *adapting material to level of students* is important. (Your reasons for that?) Well a lot of the stuff in the syllabus I think um it's at a level where a lot of the students are not capable of abstract thought yet. Some of them are, you know but some of them aren't. So you have to try and make it so that they can understand it, or maybe so that it is concrete and so that they are working with something with which they are familiar. [...] so that [...] at least it's a bit more real to them. [I2/3:17-18]

The cognitive level of the learner is revisited in section 7.7 on conceptions of learning.

In describing strategies for teaching science effectively at secondary school, she said:

> Definitely I think inquiry based. [...] I think it has to be more activity based. [I1:4].

and later the same idea though expanded was presented thus:

> [...] you can do it like in an inquiring way. [...] I think it's important as long as they can relate to what they are doing to maybe to things that they know. Like maybe M6 [...] was telling when we were doing bonding to relate it to things like bridges or you know just to make it more clear to them. Because I found they had a problem with bonding, because it's er like it's so abstract. They don't really understand. So you try and make it concrete for them. I think that's good if you keep showing them models or pictures or something just to keep relating it back. [I2/3:13]

The latter view has been influenced by her std 8 science teacher and her teaching practice experiences. It reflects the importance Mary attaches to making science concepts relevant to students' experiences during teaching and also to the teachers' attempts to help students integrate the new concepts with their pre-existing ones. Mary's emphasis on relating the knowledge that is presented to what students know demonstrates further her belief that the knowledge is unfamiliar to the students.

She also has a strong belief in the use of practical work to achieve effective teaching of science at school and enhance understanding by pupils. As she said earlier (see excerpt [I1:3] on page 169) she had limited experience in practical work at school. Thus she is convinced that school science should be taught

> With lots of pracs. [...] Because it's fun, because it's er I think the students understand more. I don't think I saw a single chemical during my schooling. So it's very difficult to try and relate, it's very theoretical (ya) and then if you don't see anything you really have no idea of what is going on. And also it teaches them a lot of stuff you know. It teaches them how to do practicals. It teaches them how to use the equipment. I didn't know how to do anything like that until I came to-I got to varsity. I think it teaches them a lot. I think they get a bit more confident. So I think through practicals. [I2/3:13]

Unfortunately she did not display this conviction in the lessons I observed during teaching practice.

Mary's belief about the importance of practical work in science teaching is common among many science educators and teachers, as this quote shows:

> The predominant ideology among science educators is that hands-on experience is at the heart of science learning. As important as laboratory experience is thought to be, there has been little systematic analysis of just what can be achieved in the science lab. (Nersessian quoted in Hodson, 1993:85)

Practical work in school has been acclaimed to motivate students, imparts manipulatory skills such as techniques in measuring and handling apparatus, enhance their acquisition of science concepts, give insight into scientific knowledge and develop expert use (Hodson 1990; Clarkson and Wright 1992). However the design and implementation of practical work by teachers have been found not to meet the claims made in favour of practical work (Hodson 1990). Clarkson and Wright (1992) support Hodson by asserting that there has been research that provide evidence that lab work does not necessarily improve subject matter understanding because very often students fail to link the practical activities with the rest of the subject. There has thus been extensive literature (Hodson 1990, 1992, 1993; Johnstone and Wham 1982; Clarkson and Wright 1992) advocating a rethinking of the value of practical work so as to design it to meet the claims made.

A view which seems to have influenced her experiences in the university based preservice training is that of teaching as involving giving students answers together with explanations and clarification of misconceptions. She felt that sometimes during physical science methodology lectures problems were identified but no ideas given on how to address these in school was given.

> I still don't see what that chemical bonding did for me. I really got very little out of it because we were told this is what they do at school we don't think it's correct, what do you think you should be doing to address this problem, though we never came out with any solid concrete anything. [I2/3:21]

This view influenced her perception of the HDE in that her responses to an instance where a teacher questioned a student's statement (see [Appendix 1C:5]) were similar in both interviews. An example of her response is given in excerpt [I2/3:16] below.

> I think she's [...] trying to clear up any misconceptions the student might have. So I think, ya she will be getting there. I need to-but I don't think the question is enough. [...] I think we need to hear the next step. [...] She hasn't cleared up any of his misconceptions, she hasn't told him what the correct answer is or what the wrong answer is or anything. [I2/3:16]

What she apparently wanted was for the teacher to provide answers for the students in this instance for it to constitute a teaching activity. It was insufficient as it was without the answers.

7.6.2 Teaching is influenced by the cognitive level of the learner.

In addition to transmitting new unfamiliar knowledge to the learner Mary is convinced that other factors have to be in place for an activity to be considered as effective science teaching. One factor explored below is the matching the cognitive level of the learner with the concepts presented. This belief has also been supported by Head (1982), Strike and Posner (1982). This factor emerges in excerpt [I2/3:15] below in response to an instance about a lecture on a supposedly difficult concept (molecular orbital theory) to grade one children [Appendix 1C:4].

> Obviously he's trying, I assume science teaching is taking place but I don't think any learning because I think it's hard enough for first years to grasp. [I1:6]
> Well it's certainly not effective. [..] They must be at a certain level of development to be able to understand what he is saying. I mean we have only just grasped this concept this year. [I2/3:15]

Here Mary shows the importance of this match for meaningful learning and therefore effective teaching.

7.6.3 Teaching depends on the subject matter background of teacher

In her transmittalist view of teaching Mary acknowledges that it is important for the teacher to have a good background knowledge of whatever is to be presented during teaching. This idea is again influenced by her own school experiences. This view was given in both the initial and the final interviews and is based on students' perceptions of teachers. An illustrative excerpt is taken from the final interview to represent her most recent ideas. It was in response to the teaching task about a teacher serving students as a source of knowledge and skill [Appendix 1D:4].

> [...] students think you know everything. Because you are the teacher, you know everything that there is to know about everything. And they lose confidence in you if you don't know everything for one thing. And for another thing you can always tell that they must look up things in books and well that's fine. But you should also know how to do something or you know can go and look it up yourself and that's fine. And I think it's important for the teacher to have fairly good background knowledge of what it is that s/he's teaching. (Mh) Students can pick up when you don't know what's going on. I mean we did that at school too. Kids are not stupid.[I2/3:18]

While holding that the teacher should be fairly knowledgeable, she does not believe in telling students everything all the time. But she feels it is important to be in a position to assist students whenever it is necessary. While it can be frustrating for the students not to get any assistance when required, it should be extremely embarrassing for a teacher to have severely limited knowledge in what s/he is presumed to be an expert.

In summarising Mary's views on teaching it will be noted that though she seemed to accept "standing in front of students and rattling to them", her conception of science teaching seemed to be more learner centred and to require that:

- presented knowledge is adapted to the corresponding cognitive level of the learners before presentation.

- presentation is in such a way that students understand and know what is going on;
- the knowledge is made more concrete, familiar and real to the students and
- the teacher holds a good knowledge of what is presented fairly well;

7.7 Conceptions of science learning

Expressing her views on learning was a fairly easy task for Mary. In most cases they corresponded to the factors identified to be influencing effective teaching. Table 7.3 below is a summary of Mary's views about learning. The views which were not given in the initial interview, and therefore appear to be new are given in italics in final interview column.

Table 7.3: Summary of Mary's views about learning.

Initial interview [I1]	Final Interview [I2/3]*
Learning: • depends on cognitive level of learner; • depend on interest of the student/learner; • students have to believe in what they learn; • is understanding what the teacher is giving; • occurs if concepts are not too difficult; • depends on student background knowledge.	Learning: • occurs if students understand what is being taught; • occurs if material taught corresponds to level of cognitive development of the learner; • student must have background knowledge. • is taking in knowledge;

* The second and the third interviews were conducted simultaneously.

As mentioned above the conceptions of science teaching that Mary favoured were more learner centred. And though she seemed uncertain in giving her theory of teaching, she found it fairly simple to describe learning. It is therefore, fitting to show Mary's viewpoint regarding learners and their learning before engaging in a description of her views on learning science.

> I think that students really have to believe in something before they learn it. I think *that is* important. [...] Um but I'm not exactly sure whether I'm sort of leaning towards Piaget or Vygotskian theory. They sound pretty good [...] The thing is I definitely think that children have um a knowledge base from what they learn around them. I mean they don't just know nothing until they pour it into their heads. They have something. That's probably how they get these preconceived ideas of some physics theories that are completely wrong. [...] And they have their own interest we can't just deny that (Mh) and we have to sort of try to just help them develop it. [I1:5a]

The ideas presented in the excerpt above show a high input from theories of learning.

I was therefore curious about the influence of the HDE programme on the development of these views. Her claims indicated that she was not convinced that the HDE had much influence. The excerpt below helps illustrate this assertion:

I: So when did you start having this idea that they are not empty heads?
M: I think I've always thought that. I don't know I-I ever since I've started thinking about it I've never thought that children have empty heads. It's something that's never been a problem for me.
I: I was just um making sure that it's not something that you only got to know this year after the theory of education course.
M: No definitely not. It's probably why I cant stand ...[inaudible] [I1:5b]

There is insufficient evidence to debate Mary's claim because again the initial interview was conducted long after the programme had started. She may not have been consciously aware of any such influence. Whatever the case may be Mary seems fairly comfortable with constructivist views of learning.

From the table it is clear that two views have not changed while two new views seem to have developed. As was the case with her views about teaching, there is one underlying idea that can be extracted from this table. That is learning as the process of knowledge internalisation which can take place only if students are able to integrate the presented knowledge with preexisting knowledge as reflected in excerpts [I2/3:14] as well as [I2/3:15] below.

> [...] how learning occurs, one could say if the student can understand the theory not only just you know to regurgitate or what but actually to understand what-understand the theory to work with it and to apply it you know. Then you can say ok that the student has actually learned what's going on and he understands why something is happening. [I2/3:14]

The excerpt above also illustrates Mary's belief that when a learner understands and can follow what is going on, then learning is taking place. This complies with Mary's conceptions that learning involves acquiring concepts meaningfully and showing that the concept is understood by applying it in novel situations. This conception is illustrated further in the description of her experiences of teaching practice described in section 7.8.2 below.

7.7.1 Learning as internalising knowledge

Mary stated very clearly that she rejects the *tabula rasa* conception of learning. Though she believes that children develop some knowledge spontaneously, she also believes that some knowledge can be transmitted from the teacher as a source to the learner as a recipient. This view agrees with that described for teaching as presenting knowledge. The fact that there are other factors that should be in place before an activity can be classified as effective teaching or meaningful learning bears witness to Mary's belief that the presented knowledge is not internalised verbatim. An illustrative example is taken from her response regarding an instance of learning science from watching a TV programme [Appendix 1C:2]:

> If it's aimed at students you know at that level, then I think it's great. [...] If it's on TV then it should be pitched at the lay person so he should be able to understand what's happening. If it's TV then it is pitched at the lay person so he should be able to understand what is happening. [...] if it's completely over his head then no teaching, well maybe teaching is taking place but he is not taking anything in. (In other words he is not learning anything?) No. Definitely not. [I2/3:15a]

And responding to another instance of a students baking [Appendix 1C:8], she said

> [..] if this student had to think about what was happening to this fruitcake when she was baking it or when she is mixing it or whatever then ya I think she would be taking in a significant amount of science or at least be able to think about what is going on. [I2/3:16]

She felt that for any learning to take place students

> [...] must be at a certain level of development to be able to understand what *the teacher* is saying. *And if they* don't have the background knowledge then no learning occurs. [I2/3:15b]

The cognitive level of learner seems important for both learning and effective teaching. This confirms Mary's conception of the inclusive nature of these two stated earlier in excerpt [I2/3:15-16] on page 176.

7.8 Mary's Experiences

Before describing Mary's experiences her expectations as she gave them at the beginning of the HDE programme are given. These are given on the assumption that their influence will be reflected in her experiences of the HDE programme. The degree to which these expectations influence her experiences will become clearer as the description progresses. Mary's expectations at the beginning of the physical science methodology were:

> As I am not as comfortable with the thought of teaching science (especially physics) as I am about biology, I would like to <u>increase my confidence</u> with this subject. I am a bit apprehensive that I won't be able to <u>explain physical science</u> very well to my students, or that I won't be able to <u>hold their interest</u>. I really want to be abe to <u>relate physics to real life examples</u>.

It should be noted that the four key expectations underlined in the excerpt above correspond to four of the characteristics Mary described about her best std 8 science teacher listed earlier. She seems to have selected attributes and practices from this particular teacher and created a model teacher she wanted to be become (Cole and Knowles 1993). And being a biology major she was not confident in dealing with science concepts.

The description and analysis of Mary's experiences given below was obtained largely from orally described data derived from all three interviews and from a very brief journal she kept for the campus based HDE courses. The journal was very brief, with entries for only six days. The content of most of the entries in the diary were also repeated during the interviews.

As was done for Ferrial, the description of Mary's experiences provided here is divided into two parts. The first part relates to experiences of the theoretical aspect of the HDE programme, viz the campus based courses. This description is mainly on the physical science methodology and the physical science additional studies. The second part of the description is based on the field based practical part of the programme, the teaching practice.

7.8.1 Experiences of the campus based courses

Mary's oral descriptions and journal entries reflect an influence from her expectations of the programme, with a bias toward negative experiences. When she was specifically asked for good points about the physical science methodology she said

> Um let me think. This is really a tough one. Well um some things that um that they did cover better than biology like, like M3's *[the other physical science methodologist]* topic on evaluation and assessment and we had to set a test for him. (Mh). That he did in the core science and he also did it with us. And that was covered very well. I used that to set my biology test. You know that was very good. I found that lecture particularly useful. [I2/3:19-20]

Despite this apparent difficulty for Mary to identify good experiences, I have attempted to describe such experiences first. This means that excerpts illustrating her experiences as she perceived them will not be chronological.

There are four aspects of the campus based part of the programme that she seemed to appreciate. These are

- the workshop format used in presenting physical science methodology themes;
- test design and assessment;

- mini lessons;
- content addressed in additional studies.

Workshop format

She liked the workshop format of the physical science methodology classes. She felt that this approach was very effective in presenting the kind of material dealt with in the course. Examples taken from her interview data and journal entries reflecting this appreciation are given in the excerpts below:

> Well I like that almost everything is in a workshop type format. (Mh) I think that with this kind of material I think it's a very effective way of doing it. But I'm not happy about the assignments I have been given, very unhappy about them. [I1:9]

> Wednesday 18/5/94: Today we did a skills workshop - acid/base experiments. It was fun doing experiments again, and it was interesting to think that students do these at school level. [MJ:1]

Besides allowing the student teachers to engage in practical activities suitable for school level science, the workshops allowed discussions with colleagues and lecturers on science teaching related issues and practising some teaching methods thought to be effective. She seemed to have found this format of presentation relevant because she could apply whatever she acquired from there relatively early during teaching practice. It also had a direct bearing on her training as a teacher. She also got a change to conduct some practical work relevant to school science.

It was however unfortunate that sometimes she missed the main theme of the workshop as the excerpt given below shows:

> Sometimes I went to lectures and I felt lost throughout the lecture and at the end of the lecture people would ask me 'so what did we do' and I wouldn't be able to tell them. [I2/3:19a]

It could be argued that it is a common experience for people to be lost in lectures. But in Mary's situation it had undesirable effects on her perceptions of other aspects of the course, as will demonstrated in this description.

Test design and assessment

The excerpt below shows how Mary felt when given an assignment which she understood and found relevant, something that seems to have been a rare occurrence for her.

> 8/6/94: Another assignment - design a test paper. At least this is relevant and useful. About 4 of us

- mini lessons;
- content addressed in a[illegible]litional studies.

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> 8/6/94: Another assignment - design a test paper. At least this is relevant and useful. About 4 of us

are going to do different sections of the syllabus and swop tests. So we all have tests covering the entire std 8 syllabus for our resource files. I even understood the assignment. But then M3 did explain it rather well. Things are looking up!! [MJ:4]

It will be observed that excerpt [MJ:4] complements excerpt [I2/3:19-20] quoted earlier on page 184. These two excerpts show that this skill could be applied immediately during teaching practice. It was also pertinent to her training as a teacher and she therefore appreciated it.

Mini lessons

The mini lessons were another aspect she found stimulating and relevant. However, the most beneficial mini lessons were those she did in the biology methodology. She found these to be more focused and other students more critical of the presentations. But for the physical science mini lessons she felt

> [...] those mini lessons that we did I got very little out of you know. I mean the content was a bit interesting and the things that people did were very interesting [..] But with the science we just walked in there and we did something and people said well what did we think, no it was fine let's go on to the next thing. It-they didn't use it to it's full potential, I didn't get as much out of those mini lessons as I did with those in biology. [I2/3:19b]

Again she appreciated the knowledge and skills acquired in the mini lessons because she found immediate use for in teaching practice and it improved her skills in lesson preparation and implementation.

Content addressed in the additional studies

As mentioned earlier, Mary majored in the biological sciences. She last did physics and chemistry in her first year, 1990. So naturally she was not very confident of her knowledge of subject matter in the physical sciences. She acknowledged this limitation in her expectations and journal as well.

> 18/5/94: I don't feel very confident about chemistry - I received a very poor chemistry education at school and did not cover a lot of the material at university. So the foundations are quite shaky. I probably have just as many misconceptions regarding chemistry as my future students. [MJ:1]

She later described how additional studies boosted her confidence in content in a short space of time, by addressing concepts which she found difficult and others which she thought she knew very well, but did not.

> [...] well M3 did a lot of stuff with us. He did those pulley things (levers and pulleys). Ya levers and pulley stuff. That I found very interesting. And also electromagnetism which is really difficult for me to understand, you know. I found that good. And you know M5 played lot of games with us and everything was just fun. But she also asked us what do we want to do. And then we-she gave

another lecture on chemical bonding, and um she did redox reactions with us and equilibrium reactions. And what I found was good is she gave us the questionnaire, we had to do it and then we gave it back. Nobody did-knew anything and all that. We didn't remember anything from school. So the second time she gave it to us she said read over redox reactions and electrochemistry and the lot. So we went home and we read over it. Because our misconceptions wouldn't disappear by just reading over that stuff, I mean they are fairly, much deep down. And she gave us the questionnaire. You find that you really don't know, you think you know what is exactly going on but you don't. And I found those extremely useful. [...] But we knew exactly what the misconception was and how it arose and how to deal with it. And what more can you possibly ask for. That was fantastic. So now I actually understand what's happening redox reactions. We only had one lecture on it. One double lecture on electrochemistry. But I feel so much more confident about it. And I think that maybe if we had replaced or spend less time on those philosophical things the physical science methodology maybe it would have been good to do something like that you know. Because ultimately that's what-I think that's what helps you to become a better teacher. [I2/3:20-21]

The excerpt also shows her appreciation of having her own misconceptions identified, explained and cleared. Also reflected in the excerpt is an appreciation of addressing subject matter issues during teacher training, something she feels makes one a good teacher. It is obvious by now that she found those parts of the additional studies which addressed her expectations on subject matter relevant and useful.

Mary appeared concerned by her limited knowledge of science concepts. She also acknowledges that her own misconceptions are deep seated and cannot be eradicated by merely reading text books. Furthermore school textbooks were shown to perpetuate misconceptions among teachers and students, despite their powerful effect on teachers as the main resource material in schools. Dealing with subject matter issues improved her confidence in science content knowledge, and this effect overshadowed any benefits that could have emerged from the philosophical issues discussed.

As mentioned in the introduction to this section, Mary also had some unpleasant encounters. Some of these have already been mentioned in excerpts [I2/3:19a] (page 185) and I2/3:19b] (page 186). The most tormenting experience was vagueness by the lectures and in particular assignments. As a result she was generally unhappy with the course as excerpt [I2/3:20] below will indicate. This excerpt is a continuation of excerpt [I2/3:19-20] quoted above (page 184). It describes how she and her colleagues proceeded with the design and implementation of a curriculum package, the confusion experienced and other frustration that followed.

There were things there which are apparently good, but I found them a complete waste of time because I didn't know what was expected of me, I didn't know where we were going and I didn't see the use for myself. Like this curriculum design, it was this huge assignment and for much of the another lecture on chemical bonding, and um she did redox reactions with us and equilibrium reactions. And what I found was good is she gave us the questionnaire, we had to do it and then we gave it back. Nobody did-knew anything and all that. We didn't remember anything from school. So the second time she gave it to us she said read over redox reactions and electrochemistry and the lot. So we went home and we read over it. Because our misconceptions wouldn't disappear by just reading over that stuff, I mean they are fairly, much deep down. And she gave us the questionnaire. You find that you really don't know, you think you know what is exactly going on but you don't. And I found those extremely useful. [...] But we knew exactly what the misconception was and how it arose and how to deal with it. And what more can you possibly ask for. That was fantastic. So now I actually understand what's happening redox reactions. We only had one lecture on it. One double lecture on electrochemistry. But I feel so much more confident about it. And I think that maybe if we had replaced or spend less time on those philosophical things the physical science methodology maybe it would have been good to do something like that you know. Because ultimately that's what-I think that's what helps you to become a better teacher. [I2/3:20-21]

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There were things there which are apparently good, but I found them a complete waste of time because I didn't know what was expected of me, I didn't know where we were going and I didn't see the use for myself. Like this curriculum design, it was this huge assignment and for much of the time we were so in the dark that in the end it had very little use for me, although apparently it was great assignment to do. I missed the point. So we did it and you know we reported back and only in the end did I actually realise sort of more, not only what was expected but what kind of value this was to have for us. But only like at the very end. It resulted in four very frustrating months [...] because I really didn't know where I was going, [...] nobody knew what was going on [...] and then we were so confused. Then we did the analysis and we came back and said look we don't understand the second part of this thing. And M1 got very upset. And said you people are really post grad and you know I shouldn't really spend so much time explaining. But she did because she was not clear before [...]. I think more often that not I think I was more frustrated with what we were doing because usually I didn't know what we were doing or why we were doing it and then we had to do an assignment which just compounded the problem. (Yes) So I don't know (How did you fare in these assignment?) I did great but it was a complete surprise to me always. .... [I2/3:20]

It seems that Mary could not reap all the benefits of the HDE programme as she would have liked. She seems to have been lost most the time, unable to figure out what was expected of her in the physical science methodology. Since she could not link whatever she had to do with anything immediately useful, she simply regarded the activity as a waste of time.

Mary's perceptions as demonstrated in the excerpts above seem to indicate the importance and the need for Mary to know exactly what was expected of her by the teacher trainers. In this way she probably would have seen the relevance of the activities they did.

7.8.2 Teaching Practice

Like Ferrial and many other preservice teachers, teaching practice was the first test of Mary's expected roles as a full time teacher, though it was for only eight weeks. Teaching practice also provided her with the opportunity for real field experience of testing the theories she believed prior to training and those developed during training.

Mary taught physical science to std 7 & 8 and biology to std 7 and 9. Her first few days of teaching practice were enjoyable because the staff members were very helpful and supportive. As far as teaching went she described her teaching practice thus:

I surely found that I enjoyed teaching the science because of all the wonderful experiments we could do. (It's a pity I didn't see you) Doing experiments? (Ya. you were doing mostly the chemical bonding and so on.) Ya. [...] Afterwards we did about three lots-four sets with the std 8s and lots with the std 7s and we enjoyed it. So I enjoyed that part and this-I got this one page and I had something that I had to give to M1, we were doing these experiments of reactions of metals in water and the thing exploded all over this page and smudged this page all these holes, but it was great fun. [I2/3:10]

Notice how she is captured by the opportunity of doing practical work in the science lessons. She was convinced that this approach enhanced understanding and learning of science content. It was unfortunate that I was unable to observe her conducting practicals.

Staff support was not only moral but it extended to professional and academic areas like providing resource material, teaching tips, students' worksheets, notes and teaching aids. She found all these very helpful. Often when the co-operating teacher was present in Mary's lessons, at the end of the lesson he would discuss with Mary good points about her teaching and areas where students were likely to misinterpret what she said. Some of these discussions were for example, the possibility of students taking the 2s and 2p orbitals as being of different energy levels in the atoms from the way she displayed them. Another was the use of charges and cross multiplication of these to derive the formulae of compound. In deriving the formula for water she used charges as in (a) instead of valencies as in (b), below.

(a) H^+ O^{2-} $\underline{H^+}$ H_2O as opposed to (b) H^1 O^2 $\underline{H^1}$ H_2O

The teacher felt that approach (a) does not reflect the normally accepted view of the actual reaction that takes place when water forms from hydrogen and oxygen, while approach (b) is a better representation.

Her good experiences during teaching practice also included some successful lessons. In describing her successful lessons she sounded convinced that what

> [..] made those lessons successful is that they *[students]* were really interested and they really enjoyed it. (Mh.) Although ultimately they missed the point at the end Ok. [I2/3:11]

> When I got the students involved in the lesson (ya) and when I think they were interested in the lesson it generally went well. And I found that they learnt from that lesson you know. Like when we went back to the material later they knew what was going on. [I2/3:23]

Emerging from these excerpts is Mary's associates teaching by involving students, getting them interested in the lesson and to enjoy to meaningful learning. This observation is in agreement with her conceptions of teaching and learning described earlier. Her attempts to promote student participation was also observed in her lessons during teaching practice and is discussed in section 7.10 on teaching practice observation.

Another good experience was the realisation of a positive link between successful lessons and adequate preparation for that lesson.

> I think one of the things is that if it was a particularly successful lesson (ya) was when I was particularly well prepared and I had like teaching aids and you know whatever. I mean like there was one practical I couldn't set it up *[for a variety of reasons]*. So I had to set it up between lessons you know. And I was a complete mess. So that was quite bad. And also there was like this one practical I thought I knew what I was doing and I actually didn't, because there was one, I can't remember what it was, but there was one experiment that I actually didn't realise what was going to happen. And of course I was confused and the kids were even more confused than me and it just didn't work. [I2/3:11]

As will be seen in excerpt [I2/3:11] Mary also experienced disappointments during her teaching practice. Sometimes these were related to lesson preparation as seen in excerpt [I2/3:11] above. At other times they pertained to her assumptions about and expectations from her students. These assumptions were apparently the cause of the mismatch between Mary's expectations from the students and their actual performance. This mismatch can be observed in excerpt [I2/3:10a] below. The excerpt also shows how she misinterpreted students' positive behaviour towards the learning tasks to signal meaningful learning.

> Well there were a lot of lessons which I thought were successful. Um and in the end it turned out that they weren't. Like for example when we did um I had to try and teach them how to balance equations. But the std 7s-we couldn't talk about valency and stuff like that. It was very difficult. So I tried to do it with them and I thought that they clicked because we started of with like um a certain number of marshmallows you know and they enjoyed it and some of them came up with the right answers. Little did I know that the rest of them didn't. They were close but um just um-when they wrote the test it was quite clear that none of them had any idea of what was going on, and none of the I-mean none of the classes, it wasn't only my two, it was all five of the classes. I think out of all of them three people got the right answer, you know. So it was really terrible. And then a lot of them came back to me and I like explained it again all and this time I got it right. But I really thought that the first time was enough you know, and obviously it wasn't. Um nearly-like that what I tried to-like they all say, you know, go from the known to the unknown so they got from a certain set of marshmallows and then you'd relate it back. M3 thought it was fantastic, unfortunately the kids didn't click. So um I don't know, now I don't actually know. That was right at the very end that I realised that because they were writing the cycle, the last day that I was there. So um now I don't know if they actually understood anything that I told them. [I2/3:10a]

Her strong belief about the role of practical work and hands-on activities in enhancing the understanding of concepts during learning made her believe that whenever learners were engaged in hands-on activities meaningful learning was ensured. Instead she found that hands on activities or practical work or involvement of students did not guarantee learning.

Also reflected in excerpt [I2/3:10a] is that sometimes she thought she was engaged in effective teaching because the students displayed signs of understanding, interest and enjoyment. It was disturbing to Mary to realise later that her students had not really learned the concepts. She could have avoided this had she put into practice some of her prior ideas about the task of monitoring students' progress (see [Appendix 1D:2]). Her strategy to tackle this in future is

> [..] I think I would give them a little spot test the next day you know, just so that someone can see if they can do it. And if they can not then I know I have to re-do it or do something different or whatever. [...] I have to be a bit more clear in what I'm trying to get across because I think it was still a good idea but maybe I just didn't do it well enough, you know. The idea was good but I didn't make my instructions clear and I didn't maybe follow it up. There was a very-very little time in which to do it. [I2/3:10b]

Excerpt [I2/3:10a] above also shows some difficulties Mary went through in teaching without the necessary concepts like 'valency', which she considered useful background knowledge to balancing equations. An element of self-doubt also emerged as she wondered if they understood any of the science concepts she discussed during the entire teaching practice period. A further disappointment followed as she realised that nothing had been learned after two hours of what she thought was effective teaching. Her assumptions seemed to have compounded the problem. These assumptions were based on her previous experience as a student and also on some teaching tips given by the co-operating teacher. These are illustrated in excerpt [I2/3:10c] below.

> Well I assumed it *[balancing equations]* was a fairly easy concept to grasp because I've never ever had a problem with it (as a student) Ya, you know. I mean I had a lot of problems with physics and chemistry concepts but it was never one of them. So I assumed that it was very simple. And also the teacher told me this is really easy, just glance over it, don't spend a lot of time over it. Even though the chemical bonding section for the std 8s I was supposed to only spend 30 minutes on it and I ended up spending about 2 hours and they still didn't understand what was going on. So you know I think I overestimated them. [I2/3:10c]

Some consoling moments followed six weeks later when she realised how widely dispersed the problem was and that other students besides those in her class were experiencing similar problems with the concepts.

Mary was also disappointed that her efforts to prepare thoroughly for physical science went unnoticed. In excerpt [I2/3:11-12] below she describes her experiences relating to this disappointment and lesson preparation.

> [...] sometimes if I had-if I had this gut feeling that my biology lecturer was going to be there the next day then I devoted a lot of time to biology. But you see like in biology they placed a lot of emphasis on preparation, which they didn't for physics *[physical science]*. I mean it was sort of-M1 said as long as you write something even on the back of a cigarette box, as long as I can see you've written something, that's fine, you know. Whereas our biology lecturers were not like that, you have to write every single thing that you are going to do in the lesson and when and why and everything you know. And so I did that for physics as well because I didn't know what to do. (Yes). Like I was so in the dark about that so I did everything that I would have done for biology I did it for physics

as well which I think is -is good. But I was so frustrated M3 didn't want to see my file once. [I2/3:11-12]

Excerpt [I2/3:11-12] above also shows that there were some discrepancies regarding lesson preparation between the physical science and biology methodologies. Mary experienced a problem understanding these discrepancies. This could possibly explain why she wanted to be informed what they were doing during the lectures or assignments and why they were doing it, as illustrated in excerpt [I2/3:20] on page 188

It would also seem for a teacher trainee who had 'shaky' physical science foundations, like Mary, would have needed closer supervision and more support from the physical science methodologists. This appeared not to be the case with Mary as she describes in excerpt [I2/3:12b] below.

> I prepared probably more for biology, I wrote down more for biology because I knew M3 was not going to look it at anyway. But I ended up preparing the same way, you know. I made sure I had objectives for each lesson and I had overhead transparencies, whatever I had to have for biology I would have had for science also you know. If I hadn't-if I didn't know it was expected of me in biology then I would have laid back for the science. I'm glad I did though (ya) because you know I think I should have needed more preparation for science than I did for biology. (Why is that?) Because biology I know more. So {pause} (chemistry you feel a bit uncertain?) Physics I feel even more uncertain. [I2/3:12b]

The above excerpt also shows how she felt about her science preparation but she lacked the extrinsic motivation to work harder at it. She also admits that she experienced more difficulties with science. Some of the difficulties related to subject matter knowledge, some she felt were related to lesson preparation and others to a lesser extent with classroom control. She recounted her difficulties thus:

> [...] sometimes I thought that I had prepared properly but my content wasn't that good. Like they'd ask me a question and I think "Ehh!" I had no idea what they are trying to say. So that was sometimes the problem. It didn't generally happen because I had good resources to work from and Willy *[one of the cooperating teachers]* gave me you know good worksheets and good notes. So it was generally ok. It wasn't great. I know in biology if they ask me something I could answer it, usually, I mean a couple of times I could. But it wasn't as bad as with science. But also the problem was with the pracs. I would do the pracs and it would work perfectly, no problem. When I did it with them and it was a flop and I was in a loss [...] I was very frustrated because I knew that with me when I did it by myself the thing worked. And when they did it or when I did it with them or I demonstrated it to them I mean it didn't work any more. (Actually that was discussed in one of the *physical science methodology* lectures) Ya. But you see after having it done once and it worked the first time, then I didn't expect it not to work again. And that was very frustrating. But then there were some which worked much better than I had expected them to work and I liked it. [I2/3:25]

Though she managed to get round the problem of failing experiments it was been embarrassing for her to be put in the spotlight for a while. Also emerging here is the effect of limitations in content on understanding students' questions or answering them satisfactorily.

She appears to have found her own teaching strategies in science rather limited compared to those in biology in that though it was possible to do a lot of practical work in science, sometimes she used chalk and talk, like when she was teaching chemical bonding. She also said that

> I found that in biology I used an inquiry approach most of the time. But for science often I couldn't do that because I didn't feel that comfortable with the subject (ok). So I didn't need that. Whereas I really could have but with biology I did it a lot more. Um especially with the std 7s I found that I was just telling them stuff and they were just writing it down and if they asked questions we -we would discuss it (Ya). But I wouldn't really you know ask why do you think this happens, this happens this happens and they wrote it down and I was kind of [pause] (Ok. Was that due to your discomfort in the subject matter) and also lack of time because I realised that I had spent too much time balancing equations and I had to like finish the section. (Ok). Ultimately at that school you have to get through the syllabus. I'm sure it's like that at most schools (mh) and you know [pause]. So ya if I had had more time then maybe I could have felt [pause] ya. Ya as you say I was not that comfortable with the material. [I2/3:12]

From this excerpt the effect of limited familiarity with the subject matter can be observed. She acknowledged that her classroom discourse was predominantly didactic, without much exploration of why things happen the way they do. This limitation was also observed in her teaching practice lessons as described below in section 7.10.3 on questioning style and handling of students' questions. Similar observations to those experienced by Mary with regard to restricted discussion of students' questions in unfamiliar territory, have been reported by Carlsen (1993).

> When addressing unfamiliar topics, teachers will restrict opportunities for students to ask questions. They also will limit the topic of classroom conversation to areas where their special status as subject matter authorities can be maintained (Carlsen 1993:471).

Mary also experienced problems reconciling what she had to do in the school with what was suggested in the methodology lectures. An example to illustrate how she perceived her predicament regarding chemical bonding is given in excerpt [I2/3:21] below.

> I mean we understood what the problems were, but we didn't know how to solve them. And um I don't know, I think maybe if we had spent more time. I don't know maybe if the aim was to try and come out with something concrete on how to actually then teach chemical bonding we would be better. I mean I'm in no position to now decide this is how I'm gonna teach it. [...] She *[M1]* doesn't come up with anything on how you should, considering the fact that they now have to write a certain exam at the end and how you can teach it. The thing is they have to do things like the Lewis structures, they have to do all these different things, that are prescribed to them by the syllabus. And then she wants to teach them something completely different. Great you can teach them something completely different, but how are you going to reconcile that with them having to write a standard exam at the end? I still don't know what to do about that. And I'll probably go and teach them exactly what everyone else has been teaching them. If they all wrote the same exam you

know that I was solely responsible for, at least I would be quite happy. But then what happens when they get to std 8 and they and std 9 and they don't know how to draw a Lewis structure? And they have to know that. You know um what do you call it an "ionic bond is a transfer of electron". Now if they've never met this before their std 9 teachers can come and hit me. [I2/3:21]

As will be seen in this excerpt, the physical science methodology lecturer helped identify problems of misconceptions the preservice students were likely to encounter in the schools. Even though some hints on how to deal with some aspects of chemical bonding at school level (see chapter 4 and Appendix 4) as far as Mary perceived those class discussions no concrete and applicable solutions were proposed for addressing these in the field. In this respect Mary's expectations of the course were not fully met. Some areas of content were addressed and she developed confidence in that. But sometimes, as in the case of chemical bonding described in [I2/3:21] above, she felt she was left hanging and was very unhappy. The frustration was aggravated by the fact that she was given school notes which she had to follow closely and which did not comply fully with those acquired from the methodology lectures. The resolution to maintain the status quo by teaching chemical bonding the way every body does it is an indication that the discussion held did not reach her.

These difficulties were again confirmed in the teaching practice lessons as she tried to emphasise ionic bonding in accordance to the school notes and possibly the syllabus in light of what she knew as discussed in the physical science methodology.

> Right now when we are talking about sodium chloride you have to remember that in ionic bonding the electrons spend more time around the one element that the electron has been donated to. That element has accepted the electron. In the case is the (calcium) chlorine (sorry ma'm). Ok. Have you all got this down? (...) Got it? Ok. What about those molecules remember these three, one you've got covalent bond which ... equal sharing. At the other extreme you've got ionic bonding, which is a transfer even though the electron does move around the other element which has donated the electron, it is still a transfer. Ok. The sodium is giving up the electron to the chloride [sic]. That is ionic. What about all those molecules in between those two? Ok. Those are called polar covalent bonds. (polar covalent bonds). Ok, this is an unequal sharing of electrons. [30/8/94:21]

7.9 Mary's knowledge of chemical concepts

Mary's concepts of chemical bonding were obtained, together with those of the other student teachers in her class, by means of a diagnostic tests (see [Appendix 2A]). Attempts to do the same regarding her concepts of acids and bases were unsuccessful. An admission she made in an informal discussion and then repeated in an interview set up provided information on the status of her knowledge of acids and bases [Appendix

2B].

I: I think before we get onto that remember I said I wanted evidence to show that you were unable to answer those questions *[on acids and bases test]*. You say you haven't [pause] go back and say what you said to me (when?) Today

M: Today. I said that I'd forgotten it, that it didn't really matter because I couldn't answer the questions anyway. Ok, I maybe could answer just two, let's be honest here, and the ones at the end were the worst. At least the multiple choice I could guess.

I: Ya, but guessing wouldn't have really given a true reflection of your ideas or views about ....

M: Well if I really haven't a clue well I'm just gonna guess

I: It is true. If you guess when I start analysing then I would say this one has these misconceptions, yet it is not really a misconception it's a guess. May I ask how much time did you spend?

M: Well I took it and I was thinking about it and I looked at it. It was just that I got so discouraged that I couldn't answer any of ....

I: When was the last time you did acids and bases?

M: Well we did them in what May with M1, but then we didn't really go through the material, you know actually covering content. She just- we did experiments ok. But didn't like cover any content. The last time I did anything to do with acids and bases was in first year. (How long ago?) 1990. .... (ok) [I2/3:23]

Something similar could be said for chemical bonding. As far as the chemical bonding questionnaire was concerned her responses were not impressive either as reflected in Table 7.4 below:

Table 7.4 Summary of Mary's responses for the chemical bonding diagnostics test

Responses in Pre-test (Class average 4.6)		Responses in Post-test (Class average 7.7)	
1.	A: (no explanation)	1.	*C: (no explanation)
2.	C: (no explanation)	2.	C: weak chemical bonds can be easily broken
3.	*C: (no explanation)	3.	B: (no explanation)
4.	C: (no explanation)	4.	*B: (no explanation)
5.	A: (no explanation)	5.	*C: (no explanation)
6.	*C: (no explanation)	6.	*D: (no explanation)
7.	*B: (no explanation)	7.	D: (no explanation)
8.	*B: (no explanation)	8.	*B: (no explanation)
9.	C: (no explanation)	9.	B: intermolecular "bonds" are broken during melting -> this is a physical process (as opposed to breaking intramolecular bonds which is a chemical process)
10.	*D: (no explanation)	10.	C. (no explanation)

From Table 7.4 one obvious and important feature is that in both tests she barely gave reasons for her chosen responses. On the bases of her scores on the multiple choice responses she did not undergo much conceptual change towards a better understanding of the concepts discussed in class as shown in Chapter 4.

One obvious pattern of change to a better understanding of the nature and origin of the chemical bond is reflected by correct responses to questions 1,4 and 5 in the post test, which was not the case in the pretest. Her response to questions 4 and 5 in the pretest are actually complementary. Both display a conception that electrons sharing results in bonding between two atoms. Of concern is the change from correct to incorrect responses for questions 3,7 and 10. It will be noticed from Chapter 4 that questions 3 and 7 relate to understanding of intermolecular and intramolecular forces. Her performance in the diagnostic test is consistent with her verbal statements about the sessions dealing with chemical bonding, (see excerpt [I2/3:21] on page 193-4).

7.10 Teaching practice observation

7.10.1 The school

Mary conducted her teaching practice in a very formal boys school. The school is located just outside of town. It is a model 'C' school and is historically a white government school which started admitting other race groups in 1992. Sporting and learning facilities are very good. It is academic but accords significant status to sports. The school runs classes from std 6 to std 10.

7.10.2 The laboratory:

A brief description of the laboratory is given to show the environment in which the lessons were conducted. The laboratory was about 8m x 6m. There were four long benches arranged parallel to the instructor's table at the front. Each bench could accommodate up to 8 students. The last two benches at the back were fixed and fitted with electric terminals. There were two double gas taps and two single water taps. The teachers' desk was fitted with sockets, a double gas tap and a water tap. There was one overhead projector and screen at the front on the left. Two periodic tables were available, one hanging on the front wall and the other on the back wall. The walls had paintings of previous scientists from about 300BC and the solar system and atoms in three dimensions. Water molecules, magnets and magnetic fields demonstrated by iron filings were painted on the ceiling. I did not visit the prep room, but with this description it can be assumed that the school had good facilities to teach science at secondary level.

7.10.3 Classroom observation

General features

Ten lessons were observed two of which were thirty minute lessons and the rest, one hour lessons. Only four of these lessons, representative of her teaching style are used in describing Mary's lessons. The observed lessons started five to ten minutes late because students were generally slow in coming into the lab. They also remained noisy until she asked them to settle down. Even then there was some noise throughout the lessons. She had problems with classroom control. This was something she was aware of long before teaching practice as stated in the excerpt below regarding controlling the class [Appendix 1D:1].

> I think it's crucial [..] otherwise they're going to take advantage of you and you're not going to able to teach them anything and they wouldn't be able to learn anything [....] You have to be able to maintain a certain amount of control over the class. [...] I have no idea *what I would do* but when I look I'm going to try and teach at School Z in August I don't know how I would fare with 30 little boys (Mh) We'll see how they tune in. [I1:7]

Students in her classes appeared fairly playful, chit chatting most of the time particularly when the co-operating teacher was absent. The only time she obtained reasonable silence was when the students engaged in individual exercises like quizzes. However, she did not seem to be disturbed by the noise. Only when the it became unbearable did she try to exert some control, though not to get absolute silence. She used various ways of dealing with the noise in the class. To draw their attention she would bang on her bench or clap her hands or call out like

> You at the back shut up! Or [...] Shhh. Boys I'm sick and tired of waiting ... (...) Shut up and listen. [...] First break Monday *[Detention]*. Now can we carry on. [26/8/94:9]

At other times she dealt directly with the problematic student thus

M: Ned please come and sit in front. [students continue talking] Ned! [the noise is too much] Boys! Did you hear the question here?
S1: Ya Ma'm. He's got the answer.
M: Ned come and sit here. Take your stuff and move!. Boys! Shut up. I don't wanna (Noise reduce slightly]
S2: We can't hear you ma'm.
Ss: Shhh Shhh.
M: Ya that's because you are making too much noise. [30/8/94:19]

The numbers 1 and 2 in the excerpt above simply denote that different students spoke. They do not denote that all the students in subsequent excerpt bearing the subscripts are the same students. Consistency could not be maintained because of the high noise levels during the lessons and also the fact that as an observer I was not familiar with the students to keep track of their verbalisations and behaviours by specific individuals.

With regard to students' responding to her questions, there seemed to be no established order of responding to teacher posed questions. Sometimes she asked the students to show by raising hands that they were ready to respond, but it did not work because they were apparently very used to calling out answers, very often simultaneously. This kind of student behaviour, shouting of answers at random, could be attributed to the fact that Mary frequently did not direct her questions to any particular student. This meant that her questions were open to anyone or everyone. Students also followed the same procedure of just asking questions at random or interrupted her whenever they desired. These assertions will be illustrated in more specific excerpts quoted in the description of her teaching methods, questioning technique, handling students' questions, given below.

Teaching method

Parts of the topic, chemical bonding, observed while Mary taught during her teaching practice were very theoretical and abstract. The cooperating teacher acknowledged this and the difficulty students tended to have with the topic. He was thus willing to help Mary deal with these difficulties efficiently but also possibly so that he was not left to "unteach" incorrectly taught concepts.

So even though Mary believed that science at secondary level should be taught "with lots of pracs" she was unable to put this into practice in this case. However, She tried to involve her students in the teaching and learning process. Sometimes she used individual activities like exercises, but mostly she engaged in whole class interactions where all the students participated in class discussion, posing and answering questions. She also used audio visual aids like charts. In this way she made her lessons less expository, despite her inability to conduct practical work for this section. Student involvement in Mary's lessons took several forms such as the high frequency of questions directed to the class; sending students to the board to present their ideas or make corrections on others' presentations; procuring the opinion of the class regarding other students' responses; frequent class quizzes and exercises. For example:

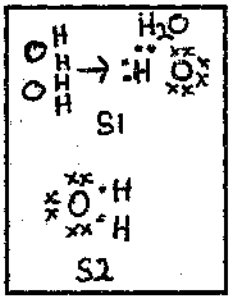


Figure 7.1 Lewis structure for water

M: How are we going to represent the water molecule in the course of drawing a Lewis structure? How can we do it? Yes. [to S1]
S1: One hydrogen plus two oxygens or one oxygen and two hydrogens.
M: How are you going to do it? Right come up here and draw a water molecule in the form of a Lewis structure. ... Shut up and pay attention. [students continue talking as S1 draws as in figure 7.1] Is that how we draw a Lewis structure?
S2: No.
M: No. I want a Lewis structure ...... Come and help him please, (S: Me ma'm.) and you better watch .... if anyone is asleep and so you better watch.
S3: Shhh.
M: Ok. Look at this. (Yes) This [representation drawn by S2 in figure 7.1] is wrong and why is it wrong?
S4: Because the two atoms are supposed to be the other side of that.
M: Can the hydrogen have two have four electrons in one energy level?
S5: No. [26/8/94:11]

Questioning technique

The description of the questioning style will include both her questions and her handling of students responses to her question. As already mentioned above Mary, generally left her questions open to the whole class and rarely directed it to specific students. As mentioned in previous two chapters this technique can be advantageous. Questioning style was also analysed in terms of the type or cognitive level of the question posed. The analysis reveals that most of the questions Mary posed were recognition or recall. Mary's involvement in this kind of questioning is shown by the high frequency of questions which required students to draw on their previous knowledge and give direct correct answers. The excerpt given above illustrates this point fairly well.

There were also teacher posed questions which required more than recognition and recall from the students. Such questions are described by Avalos (1991) as process/explanation questions. These question allowed students to think about the situation, give explanations or draw relationships from available information. Answering this kind of question by students was usually partially successful. Thus these questions required Mary to probe students' ideas further to enable her to elicit the desired response. For example:

M: Robert, [pause] what is a bond? If we know how to represent it, what is it?
R: When two atoms combine.

M: When two atoms combine. How can they combine?
S1: Reaction.
M: Reaction. Ok. But think about ... pretend you have the strongest microscope in the world to see them. What is a bond made of? Why are these atoms together? What keeps them together?
S2: Electrons.
M: Electrons. What about the electrons?
S3: Forces.
M: What happens to the electrons, remember your definition of valency. What is the definition of valency? Everyone keep quite so that Mark can read it to us. [Mark reads definition] Ok. What is the valence electrons? (...) Let me give you a more complete definition. [30/08/94:20]

In addition to showing Mary's probing, the above excerpt is revealing regarding Mary's limitations in her knowledge of chemistry such as chemical bonding. Note how her biological background influences her thinking that it is possible to see a chemical bond through a microscope. Also imbedded in this suggestion is that a chemical bond and electrons have a physical existence. Her questioning style in directing students to the response she wanted seemed appropriate. The problem was that she did not exploit students responses to her probes. For example she does not pick up on the issue of forces and relate it to bonding as was done in the university based HDE courses. She was apparently rigid and stuck to the particle model of electrons, which was probably what she prepared for her lesson. This conviction of the particle model of the electrons and that a bond is a pair of electron also based on the same belief were demonstrated in the classes on chemical bonding held before teaching practice. This was described in Chapter 4.

The excerpt above also shows how she handled students' responses to her question by probing or rephrasing the question. Sometimes she simply re-explained the concepts to help the students understand them better. One such example relates to the students thinking that the spd notation could be used to represent bonding. This may be easy for advanced levels but quite difficult at school level. For example:

M: Ok boys. Remember I told you a bit about bonding. [..] What is the easiest way for you to represent a bond? Hands up. [...]
[students call out a number of ways: Lewis structure, auf bau diagrams, magic spectacles diagrams]
Formulae. What else? spd notation.... [indicative of some doubt]
S: Why?
M: spd notation is when you [...] write the auf bau diagram (S: in short) in short. Remember you have the (S: Lewis structure) you have for example hydrogen that would be {H $1s^1$} because in the first energy level in the s orbital you have one electron. Remember that's (S: yes) the spd notation. [30/8/94:15]

It will be noticed that her questions were generally of low cognitive level, demanding very little from the students. The questions were mainly serving as attempts to keep the students' attention and interest. Her responses to students' answers were fairly restricted to the topic.

Handling of students' questions

Mary's shortcomings in chemical knowledge were further exposed during her attempts to answer students' questions. Students posed a range of question types: such as simple knowledge questions answerable with a direct correct answers like "What is a neutron?" "Does it have a negative charge?" to those which required her to explain certain concepts and phenomena. For example:

M: Anything ending in -ate shows there is oxygen present. Naming HSO_4^- hydrogen sulphate.
S1: What does the minus mean?
M: It means there is one extra electron in the compound ion. [17/8/94:2]

Her responses did not always demonstrate a deeper understanding of the concepts she was attempting to explain. The excerpts below are included to support of this assertion.

M: You don't write F^{-1}. (Why?) That's not how it's written.
[...]
M: Write down the chemical formula for the following compounds. [Again she goes through the list with the students but allows students to select the compound they want to respond about. They start with (g) Calcium carbonate]
M: Symbol [Writes Ca Ca^{2+} as a student calls out the formula, fig. 7.2] Let's work it out just in case somebody does not know. [She goes through the rules, asking leading questions] What's the charge on the CO_3 ion?
Ss: negative.
M: Ya. but how much?
Ss: 2 negative.
M: Why?
Ss: Because the charge on CO_3^{2-} ion?
M: Why because it says so. Memorise these. [18/8/94:5]

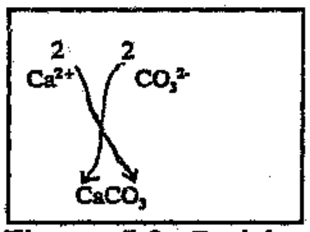


Figure 7.2 Deriving chemical for calcium carbonate

It is surprising that in the case of HSO_4^- above she explained the presence of the minus sign using an excess electrons while in the case of CO_3^{2-} she does not use the same explanation and actually does not explain it at all. She was not consistent in her explanations. This inconsistency was also observed by the students regarding chlorine, thus:

M: You know that chlorine exist as a diatomic molecule. Right. You know that chlorine exists as a diatomic molecule. Remember.
S1: But when you done (sic) with HCl it wasn't a diatomic molecule.
S2: Ya.
M: My mistake it was supposed to be diatomic. [26/8/94:12]

She apparently had problems explaining why iron (II) nitrate was $Fe(NO_3)_2$ and not FeN_2O_6. This could have been a difficult question for many teachers at that level. Her attempts are demonstrated in the excerpt below.

M: [...] What is the valency of Fe in iron (II) nitrate? [They go through the steps of determining the formula]

S: Why don't we say NO to the power of 3;

S_5: Why not NO_6?

M: For NO_6 it means that there are 6 oxygens and 1 nitrogen.

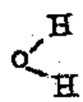
S_6: And N_2O_6?

M: This is a molecule form. We can say theoretically that it is N_2O_6 but it would be difficult for you. For FeN_2O_6 are you going to know that this represent the nitrate ion (Ss: No). You will not know what is going on. You will have confusion and chaos.[18/8/94:6]

Sometimes she acknowledged the difficulty of answering certain questions as that of explaining the polarity of certain bonds such as in the water molecule. An episode to illustrate her attempts is presented below:

M: So how can we represent this *[water molecule]* without crosses or circles? How did I represent the methane?

Ss: Auf Bau. ....

M: Is it a minus sign, it's a line and I can draw it like this. [Writes ] (....) those are not minus signs, it is lines. Ok. That is how I can also represent this. (...) Why's there an unequal sharing. Because just like with your sodium chloride the electron spends most of the time around the oxygen.

S1: Why?

M: That is difficult to answer. (...) I'll find a simple explanation. (...) So what happens is the electron spend time around the oxygen. What do you think that will do to the oxygen?

S2: It will make it electronegative.

M: It will make it more negative and the hydrogen, what will happen to the hydrogen? What will happen to the hydrogens?

Ss: Positive.

M: They will become more positive. You gentlemen at the back ... on to this. Ok. They are more positive because the electron that usually travels around the hydrogen now moves up to the oxygen and spend a lot of the time around the oxygen. But remember this is not an ionic bond. This is not a transfer. The four share them but they just don't get them equally. So that's why these two young man have to decide that one will get the textbook for four days and one will get the textbook for three days. That is unequal. The electrons spend most of it's time up here on the oxygen. [30/8/94:223]

Notice again how she does not pick on the key word "electronegative" which is fundamental to the polarity of certain bonds such as that in water. Electronegativity, though raised slightly later than when it was needed, could have been used to also explain why the electrons tend to "spend more time" around the chlorine in sodium chloride. Instead she used an inappropriate concept to explain this as shown in the excerpt below:

M: [..] Can you explain what I said for Peter's benefit. Peter listen to what Ned is saying.

N: Right electrons are transferred from the Na to the Cl and they spend most of the time around the Cl.

M: That's right. They spend most of their time around the Cl.
S: Why?
M: Why? Because it has to do with ionisation energies as you move across the table. Ok. If-remember your ion, ions on this side *[left]* are usually positive and those on that side *[right]* are usually negative. [30/8/94:20]

Some of the difficulties she experienced could be linked to her limitations of her subject matter knowledge as she acknowledged earlier (see excerpt [I2/3:12b] on page 192) As will be observed in some of the excepts above her response reflected shallow understanding like telling students that "it does not happen like that" or "because it says so" and encouraging them to memorise things. It may be advisable to memorise in this case because the students are going to be using these formulae fairly frequently, but if they request an explanation it could have been more profitable for the students to get one, which was not always possible for Mary to give.

Other difficulties Mary experienced also raised in the third interview, included integrating the conceptions of chemical bonding discussed in the university based classes and those presented in the school notes. The following excerpts will show that while she emphasised ionic bonding involved the transfer of electrons as expected at the school, she also informed the students that the supposedly transferred electrons still spent some time around the donor atom as discussed in methodology classes. The emphasis of electron transfer during ionic bonding was further illustrated by means of an analogy involving a small statured person and person of large structure, like Arnold Schwarzenegger. Unfortunately students seemed to enjoy the analogy rather than the concept it presumably illustrated, as shown in the excerpt below.

M [..] Who knows Nick Moralis?
S1: He was a scientist
M: He was a scientist in ..... Ok. He's this little blimp. Who knows Arnold Schwarzenegger.
S2: Me.
S3: My brother.
M: Right he's this mean dude with lots of muscles and he wants .... Imagine Nick Moralis and Arnold Schwarzenegger have to share something. Right. And Arnold doesn't want to share and he will just grab it and Nick will have absolutely no say.
S: ...
M: Did you get the metaphor picture [students continue talking and she draws their attention by clapping her hands three times] Can I have your attention please. I have explained the sort of thing that happens in ionic bonding. Right. You have certain elements which bond together. The one will give up an electron and the other will accept it. Right. that's the other extreme of covalent bonding. Covalent bonding is perfect bonding, perfect sharing sorry.
N: Who can see this ...?
M: Ok. In covalent bonding, Ned you have perfect equal sharing, in ionic bonding one atom gives up an electron to the another atom. [30/8/94:17]

Another area which demonstrated further the influence of her limited chemistry content or problems in reconciling expectations from the school and from the methodologists was in the discussion of the covalent bond. During those episodes she emphasised that covalent bonds were characterised by the equal sharing of electrons. Though equal sharing of electrons is true for bonding involving identical atoms as she mentions, she also stressed the idea that diatomic molecules are homonuclear. For example:

M: The electrons spend the same amount of time around each of the atoms. So pure covalent bonding is absolutely equal sharing and can only occur in diatomic molecules. What do you need to know about the diatomic molecule. Both atoms are exactly what? What is nice about diatomic molecules?
S: ....
S1: They share equally.
M: What is so special about the atoms in the diatomic molecules?
S2: Equal sharing.
S3: Valency is one.
M: What is special about the atoms, is hydrochloric acid a diatomic molecule [probably meant hydrogen chloride]
S4: Ya.
M: No. The atoms in a diatomic molecule are exactly the same. Right. So they can share equally. [30/8/94:17]

Mary was faced with the difficult task of merging the two, viz electron transfer and electron sharing in bonding. This was further complicated by her inadequate knowledge of chemical bonding concepts. Considering that her students' notes categorised bonding into three types covalent, ionic and polar covalent, she could not then portray concepts which appear to be in direct conflict, i.e. that bonds are the same and only differ in the degree of polarity.

Also worth mentioning is that throughout her lessons on the chemical bond she emphasised the conception of the bond as being constituted of a pair of electrons. This conception is dominated by the particle model of the electron she also displayed in university based classes.

Inadequate knowledge of subject matter can be a barrier to effective teaching (Lee 1995). In the observations of Mary's lessons it was found that she presented and possibly passed on erroneous ideas to her pupils. Sometimes these were identifies and corrected by the cooperating teachers and remained unidentified when he did not attend the lesson. For example that bond polarity has something to do with ionisation energy. Observation of Mary's teaching practice lesson and her own acknowledgement bore witness to this assertion. She was not sensitive to students' questions in that she was unable to understand the questions posed by the students or was sometimes not ready to answer. Of course teachers are humans and susceptible to errors (Goodwin 1995), but there is a limit to such errors. Also she could not apply inquiry approaches when teaching physical science as she claimed to have done in biology, her major.

7.11 Profile summary:

Mary came from a school which had adequate facilities for teaching secondary science, but students still did not do practical work. She felt she went through secondary science without much understanding of it. This experience seems to have influenced her belief that science should be taught in an inquiring way and with a lot of practical work. Unfortunately she did not demonstrate either of these approaches during the teaching practice lessons I observed. She, however, encouraged student participation in her lessons through questions.

Her expectations of the physical science methodology course were based on her description of her best science teacher. Like Ferrial, she appreciated those course activities which promoted her teaching skills like organising practical work, mini lessons and test design. She disliked those where instructions were unclear, were time consuming and bore no apparent relevance to helping her become a science teacher.

Her views of science were dominated by processes (observation, experimentation, hypothesising) reflecting an inclination towards the empiricist or objectivist conception of science. She also believes that science involves discovering and explaining how things work. Her views on the nature of science did not appear to change much during the year of study. She seemed convinced that there are different ways of doing science which depend on the topic though end the results must accurate and repeatable. She thus rejects classifying other disciplines which cannot meet this requirement as science. There was no evidence in the teaching practice lessons observed that she demonstrated this belief, though she may have in other lessons.

Mary views science teaching as presenting knowledge which is unfamiliar to the students, explaining and clarifying concepts, clearing misconceptions, giving correct answers and getting students interested in the tasks. Mary believes in inquiry based learning and the teaching of science by engaging students in practical work. Her school experience provided her with the opportunity to try these beliefs. She found that the inquiry approach worked very well for biology but not for physical science. For physical science she tended to adhere to brief answers to student questions. Also her questions to students were largely recognition and recall with very few explanation questions. Students' responses to explanation questions were partially successful. In such instances Mary followed up with some probing to elicit more complete answers. In the process she sometimes failed to recognise and use suitable responses from students indicating an inadequate knowledge of the concepts to allow sensitivity to appropriate responses.

Mary also had problems reconciling the school notes, which in some instances conflicted with the way concepts were discussed in the physical science methodology lessons on chemical bonding, with the recommended discussion of the concepts. Faced with this dilemma she taught these apparently conflicting ideas alongside each other. For example, when discussing bonding in sodium chloride she told them that the ionic bond was formed by the transfer of an electron from the sodium atom to the chlorine atom as required by the school notes and also told them the electron spent time around the sodium atom as discussed in the HDE classes. She appeared to have only partially understood the discussion in the HDE class, so she had problems applying the recommendations on how to handle conflicting ideas of this nature. She did not appear to have modified her particle conception of the electron even though this aspect was addressed at length during the class discussion on chemical bonding.

As an observer I thought Mary had class management problems. Her classes were generally noisy. The only time she had reasonable silence was when she had them working individually on a quiz, class exercise or test. But even then some students would be throwing things around and asking questions without seeking permission. She did not seem to mind the noise and only stopped the lesson when the noise became excessive.

Mary acknowledged that her knowledge of chemistry and physics concepts was limited. She did not return her diagnostic test on acids and bases because she felt she could not answer the questions. On the issue of the chemical bonding classes she felt that only problems relating to the topic were raised but no strategies were presented on how to teach chemical bonding. The results of her diagnostic test on chemical bonding apparently confirmed these limitations and feelings about the HDE lessons on this topic. Her scores in the multiple choice sections were below class average. In the pretest she did not give any explanations for responses and in the post test her attempts were limited. In general Mary's understanding of concepts in chemical bonding was poor.

CHAPTER 8

DISCUSSION AND CONCLUSION

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8.0 DISCUSSION

In this study I set out to explore and describe as case studies the following aspects of three higher diploma in education secondary science preservice teachers:

- their experiences of the HDE programme with particular emphasis to the physical science methodology;
- conceptions of science, science teaching and learning;
- and aspects of their knowledge of chemical concepts in chemical bonding, acids and bases of the HDE class.
- how these relate to the instructional behaviours of the three participants during teaching practice

Background

During the process, their background and prior experiences were also explored. The three students were found to have varied background and prior experience. Mary came from a school with a great potential for teaching science effectively, Ferrial came from a government school without much to offer in way of science teaching. Andrew came from a church run private school with its own limitations in science teaching. From what they said none of them had a good science background prior to tertiary education.

The three preservice teachers held different views about good teachers. Andrew's perceptions of a good teacher were humanistic based (enthusiasm and discipline) but also being knowledgeable about the teaching tasks. Ferrial viewed a good teacher as one who facilitates learning, one who is available for the students when they need her/him and one who makes the students more responsible for their own learning. Mary agreed with Andrew about the teacher being knowledgeable in his/her subject discipline and in possession of management strategies for effective class control. At the beginning of the HDE programme all student teachers were asked to state their expectations from the programme, particularly the physical science methodology. While Mary selected attributes and practices of one of her former science teachers to model her expectations, Ferrial's were in direct conflict to her former science teachers' practices. The three students shared similar expectations in certain aspects such as acquiring the ability to explain concepts effectively and confidently and to deal with misconceptions. There was also a strong influence of their school experiences on all their expectations. Ferrial's and Mary's expectations exhibited influence from their previous experiences. This study provides supporting evidence that prospective teachers enter teacher training programmes with well formulated views of what being a teacher means and about the training they are to receive (Carter 1994; Aguirre and Haggerty 1995; Cole and Knowles 1993).

Motivation for choice of teaching profession

Ferrial and Mary were novices in the sense that they did not have any teaching experience. Both had other careers as their first choice and teaching was an alternative career after realisation that their first choice careers were no longer plausible. The motivations of the three students for joining the teaching profession were different. Andrew wanted to be in the profession from the time he was a school student and did not show much interest in careers outside education. Ferrial and Mary joined the profession simply because they had no choice. There were no immediate employment opportunities in their preferred careers. Ferrial felt she would stay with the profession though not necessarily at school level, but Mary was undecided. These findings reflect realistic intentions as was also found by Steinberg (1985). They all acknowledge that teaching is an important profession despite the lack of autonomy, lack of responsibility for teachers' actions and the low status. Both Ferrial and Mary thought that allowing autonomy in the teachers' work place could improve the status of teaching.

Conceptions of science

The student teachers showed both similarities and differences in their conceptions of science. Mary's statements suggested that her conceptions of science are inductivist oriented. According to her, science is concerned with the logical gathering of concrete measurable data, which should also be repeatable; discovering through observation and experimenting. Ferrial sees science as doing research over several years and believes that scientific knowledge does change. She also acknowledges the importance of observation and experimentation in the advancement of scientific knowledge. Andrew's initial conception of science was dominated by the process view and excluded the factual knowledge aspects. These views became modified during the HDE course so that he later viewed science both as the process of generating knowledge and as the knowledge itself. He also acknowledged that the knowledge thus generated is not always complete or satisfactory which could imply an awareness that scientific knowledge changes. However the idea of science as a human construction and the importance of consensus did not emerge. Though Ferrial mentioned it in her assignment it did not seem to be an important point for her to remember. Ferrial and Andrew both agreed on the changing nature of scientific knowledge. Ferrial and Mary both acknowledged the role of human curiosity in science.

All subjects displayed a similar conception of science in its ability to explain how natural phenomena occur and the involvement of observation and experimentation.

They all displayed the importance of science content knowledge by discussing science concepts in their lessons. Andrew and Mary demonstrated that scientific knowledge changes over the years, when discussing the Arrhenius and Bronsted-Lowry theories of acids and the history of the atom respectively. Whether they successfully conveyed the message to their students cannot be established. No evidence was found to demonstrate other views of science such as its explanatory power, human origin, reliance of science on processes in Mary's and Andrew's lessons. If these aspects of science and scientific knowledge were demonstrated I did not observe them in the lessons I saw. Ferrial, on the other hand used some inquiry approaches and practical work showing the use of the science processes to arrive at explanations for certain phenomena. I feel that I should have observed more teaching practice lessons to obtain sufficient data to be able to describe any relationship between classroom practice and student teacher's beliefs about science. Zeidler and Lederman (1989) have also noted that many studies have been unsuccessful in demonstrating that teachers conceptions of science can be passed on to the students they teach. There is no conclusive evidence from this study to support or oppose this assertion.

Conceptions of science teaching and science learning

The findings from the three case studies show that the student teachers' conceptions were similar regarding the interdependence of teaching and learning. They all expressed (science) teaching in terms of learning. This observation supports Hirst's (1971) arguments on the dependence of teaching on learning and attempts of teaching activities to bring about learning, though not always successful. Other common features are that they all saw teaching as an activity which prompts student thinking a particular and desired direction and that teaching is knowledge presentation or transfer to learners. However, there were some differences regarding the nature of the knowledge presented and the manner in which it is presented. Andrew did not consider the presence of a teacher a prerequisite for an activity to be classified as teaching. Ferrial thought it necessary to have some interaction between the source of knowledge and the learner, indicating the need for a teacher. However, computers could be regarded as teaching in this respect. Mary believes that learners can only be taught what they do not know.

Both Mary and Ferrial believe that it is important for the presented knowledge to be compatible with the cognitive level of the learner and that background knowledge is necessary to allow understanding and assimilation of what is taught. These ideas are consistent with those of Head (1982), Hodson (1985), and Hewson and Hewson (1988) and Clark and Starr (1991).

Both Andrew and Mary conceived (science) teaching as an activity involving explanation and presentation of the science concepts to remediate students' misconceptions. The underlying point is that in teaching science concepts are presented in such a way that learners understand and are able to assimilate.

While all three subjects acknowledged that the teacher should be conversant with subject matter, they also share the belief that the teacher should also facilitate the learning process by creating an environment that is conducive for learning and which encourages student participation. This implies that teachers must try at all times to make students comfortable with the learning process. Andrew seemed to succeed in achieving this goal as was shown by the many challenging questions he was asked by his students. Mary was also successful, but her students were not as persistent as Andrew's. No evidence that shows similar success in Ferrial's lessons could be found. Her students only responded to her instruction.

All three students found it fairly simple to describe their views about (science) learning and learning in general and complements their views about teaching. All see learning as a process of acquiring knowledge whether by constructing it or simply taking it in. They also recognised the important role played by learners' prior knowledge in knowledge acquisition. The importance of background knowledge is further supported by the assumption that learning builds on previous learning. The background knowledge allows learners to understand and integrate new knowledge in order to alter student's current knowledge (Strike and Posner 1982; Brickhouse 1990; Clark and Starr 1991). They all regarded the active involvement of the learner in the learning process as important. Ferrial feels that learning is best when students do their own thinking and their own work. Observation data show that Ferrial tried to put her beliefs into practice. She had her students work in groups and posed problem questions which they had to try to solve through practical work. Andrew, on the other hand sees learning as some kind of discovery, when the learners begin to understand what they are being told in the learning situation. Ferrial shared Andrew's belief that learning manifests itself in realisation of something about what is presented or taught.

Another common feature of Andrew's and Mary's conceptions of learning is that learning is a conscious and active process. This demands that the learner be aware that s/he is accumulating knowledge and be interested and willing to engage in such an activity.

All the views described above suggest that the conceptions of teaching possessed by these three subjects agree with those of

- teaching as a way of bringing about conceptual change of learners proposed by Strike and Posner (1982) and Hewson and Hewson (1988):
- learning as adding knowledge to one's store of concepts as well as transforming that store of concepts (Hewson and Hewson 1987; Strike and Posner 1982) to accommodate the incoming knowledge;

Practical manifestations of these during teaching practice were evident only to a limited extent.

Experiences

Both Ferrial and Mary had no teaching experience prior to their teacher training. And as such they both appreciated those aspects of the HDE courses which appeared to have direct relevance to being a teacher. For example, both regarded the mini lessons to be very useful. While Mary thought they allowed positive criticism and improvement of pedagogical skills, Ferrial thought that they encouraged what she believed science teaching was about, that is group work, practical work and skills development.

One common feature of Ferrial's and Andrew's experiences relate to contemplating withdrawal from the programme. However, the reasons for this were different. Andrew was subjected to stress through his personal circumstances. Ferrial's reasons were more related to the HDE programme. Sometimes she felt they were made to do a lot of unnecessary work and she found some of the activities irrelevant. Ferrial expected activities more in line with real teaching experiences to prepare for teaching practice. She also felt the need for a more upgrading of her science content.

Ferrial and Mary found the discussion of physical science content particularly helpful in clarifying concepts which they had either forgotten or did not know. The discussion also corrected their own erroneous ideas and made them more sensitive to students' misconceptions. Being biology majors, both found that discussing these concepts increased their confidence in their weaker subject. Mary appreciated the content that was offered. On the other hand, Ferrial expected more. As far as the chemical bonding was concerned they both expressed similar feelings of dissatisfaction about the class discussions. Ferrial felt her concepts of chemical bonding were taken apart but were not put back together, though this was not reflected in her responses to the diagnostic test. Mary still felt fairly uncertain about her understanding of chemical bonding and this was reflected to some degree in her diagnostic test responses. They felt that problems were identified but that there were no discussions on how to address these problems in the classroom. However, field notes (see Appendix 4) reveal that teaching tips were given and appropriate conceptions of chemical bonding were discussed. In addition chemical bonding was further addressed in the physical science additional studies class and in another physical science methodology lecture which focused specifically on misconceptions found in school textbooks and in the teaching practice experiences of those who had taught the topic. There is no evidence from direct observations of classes to support Ferrial's and Mary's claims. Their problems appear to have been deeper. It is possible that the lecturers assumed so much that they overlooked foundation concepts which these two lacked in order to follow the discussions, contrary to the position they presented on teaching and learning. They clearly wished for more "spoon feeding".

It is clear that Mary had serious problems with the topic of chemical bonding and other chemistry topics. Her acknowledged failure to respond to the questions in the acids and bases diagnostic test is one indicator of the intensity of these problems. It is disconcerting that even after attending two class discussions of chemical bonding and teaching the topic in student teaching that she still felt uncomfortable with the topic.

Other aspects that both Ferrial and Mary felt uncomfortable with were that sometimes instructions, particularly relating to assignments were not always clearly defined. They were also not happy about the amount of repetition regarding text book analysis, which they did in both the biology and physical science methodologies as well as in core science. They felt this created unnecessary work for the students. Another problem was that reasons for doing some of the activities were not given making it difficult for them to see their relevance.

Andrew felt the programme was very informative, practical and teacher specific. He had no complaints. One possibility of this apparent satisfaction with everything was that he was frequently absent so that he might have blamed himself for whatever negative outcome. His problems thus lay outside the realms of the campus based activities of the HDE programme.

Teaching practice experiences, too, were similar for Ferrial and Mary. Both taught in normal schools and were experiencing real teaching for the first time. The positive support from the rest of the teachers made their student teaching a fairly pleasant teaching experience. Andrew, on the other hand was not given any special treatment.

He had to carry out all his teaching responsibilities like the rest of the other teachers in the school.

All three student teachers expressed some concern regarding their teaching practice assessment and critiques. Andrew felt he did not receive adequate assessment and feedback as he was observed only once. Mary seemed satisfied with the assessment as a whole. Her only disappointment was that in spite of thorough preparation her lesson plans were not checked. Ferrial was happy with her physical science critiques but not with the biology ones.

Andrew's experience in teaching was displayed in his ability to maintain good classroom control. His lessons were very organised but very theoretical as well. Ferrial and Mary on the other hand experienced classroom management problems which they handled differently. Mary did not seem to mind the noise unless it became excessive. Ferrial wanted the students to be quiet. She could not accept having to compete or continue her instruction while the noise level was high.

A common problem for all the cases related to the rejection of some of their efforts in teaching. Mary and Ferrial found that the cooperating teachers were a bit doubtful about their teaching strategies and intervened to give advice. Ferrial felt that the input she received was excessive. She felt she was not being given any opportunity to experience things for herself. It is a fairly common occurrence for cooperating teachers to feel sceptical about students teachers' "new" ideas. Sometimes the school students themselves reject an unfamiliar approach leading to some degree of restriction in student teachers' endeavours (Clark and Starr 1991) as was certainly the case with Andrew's students and possibly with Ferrial's.

Both Ferrial and Mary doubted themselves at some point because they perceived themselves to be failing to achieve their teaching goals. Mary tended to spend a lot of on discussion of the topics in the hope of ensuring that her students were interested, and involved. However to her disappointment, she found that on testing students had not understood these concepts. Ferrial felt that she learned and improved as she taught during teaching practice, both the content and classroom management.

As far as their conceptions of science teaching and learning are concerned there were only slight changes. In most cases these were elaborations of the ideas they had at the beginning of the study. No substantial changes were found as was also the case in Aguirre and Haggerty (1995).

To a large extent Ferrial demonstrated her beliefs about science, teaching and learning during teaching practice. Andrew was unable to do so, possibly because of the conditions in the school. In Mary's case it is difficult to say because the lessons I observed did not display much of her beliefs in inquiry and practical work. Both Andrew and Mary's observed lessons did not show much in the way of demonstrating their views about science.

In many respects Ferrial and Mary had common experiences between themselves than they did with Andrew. In some cases these were quite sensitive. Andrew appeared to be indifferent. Initially Ferrial did not appreciate M1's strategies but these changed during teaching practice.

Subject matter

This study has shown that prior to discussing the chemical bonding topic in physical science methodology classes the student teachers had erroneous ideas regarding chemical bonding and other associated concepts like

- the nature of the chemical bond,
- its origin,
- the hydrogen bond,
- similarities between ionic, covalent and polar bonds.
- the relationship between macroscopic properties and microscopic structure.

Identifying ideas on this topic and discussing these during the methodology and additional studies classes appeared to have helped the student teachers understand these concepts better and change their erroneous ideas, though not necessarily eradicating them. This was demonstrated by the positive change in the class average scores based on the multiple choice responses, from 4.6 in the pretest to 7.7 in the post test. Statistically this may not be a significant change, but in context of the explanations accompanying these responses there was a qualitative change for individual students. Possible misconceptions among science students in secondary schools were also discussed. The discussion was further helpful because it also gave some hints on how to cope with these concepts at secondary school, though these were apparently missed by Ferrial and Mary. The test scores in both tests do not show that possession of a degree in chemistry implies better knowledge of chemical concepts. Mosimege (1995) was also unable to find any evidence that students with higher level chemistry were any better than those with something less. Such findings are common occurrence among prservice teachers (Gunstone et al. 1993).

8.1 CONCLUSION:

The three students involved in the case studies had well defined expectations already developed regarding their professional training. Their expectations exhibited a strong relationship to their experiences prior to entering the HDE programme. Their expectations also influenced their perceptions of the activities they engaged in and therefore their experiences of the programme, both positively and negatively. Andrew thought the courses were excellent in training him to be a professional in teaching. Ferrial and Mary appreciated those activities directly related and relevant to actual teaching tasks or in line with their expectations, for example the

- mini-lessons,
- test design,
- discussion of chemistry concepts,
- exposing and addressing their erroneous ideas.

Activities which had no apparent direct relevance to teaching or those which were repetitive, were considered a waste of time especially.

All three subjects experienced some frustrating moments like when their attempts to implement their newly acquired knowledge and skill or learning and teaching theories were not accepted by the cooperating teachers and or students.

Ferrial and Mary were also disappointed when they failed to meet their teaching goals and began doubting their competence as future teachers.

Their conceptions of science, science teaching and learning were similar. The views that emerged regarding science were that

- science is sparked by human curiosity,
- science discovers and explains how the world works,
- scientific knowledge changes,
- observations, experimentation, hypothesising, theorising are all important in generating scientific knowledge.

Some views about science teaching that emerged were that engaging in the following activities constituted teaching:

- presentation and transfer of knowledge in ways that learners can access it,
- facilitating the learning process: getting students involved either by thinking about the teaching task or
- leading students to the discovery of something,
- explaining science concepts to students and clarifying students' misconceptions

As far as learning was concerned they all acknowledged the interdependence of teaching and learning. They all conceived learning as

- knowledge construction;
- knowledge acquisition (taking in, accumulating or adding to one's store of concepts);
- discovering or realising things for oneself.

They all acknowledged that learning requires the active involvement of the learner and depends

- on various aspects of the learner such as background knowledge, cognitive level of development, interest and motivation;
- the learning situation and
- how the knowledge is presented.

There were observed attempts at implementing their teaching and learning theories during student teaching though not always received by both cooperating teachers and school students with the same enthusiasm as the student teacher. It was difficult to find sufficient evidence regarding their conceptions of science.

Student teachers in the HDE class were found to possess erroneous ideas regarding chemical bonding and acid-base concepts. Students with a degree in chemistry did not appear to have better understanding of the concepts in these topics. They did not show better improvement after discussion of chemical bonding either. Identifying students errors in chemical bonding conceptions and discussing them helped reduce these errors, though not necessarily eliminating them.

8.2 PROBLEMS AND LIMITATIONS OF THE STUDY

The factors stated below were limitations and problems encountered in the study.

(a) The major limitation of this study was that respondent validation not used. This step would have improved triangulation of data obtained from the participating student teachers. This would require the rigorous process of writing out the analysis and getting the subjects to react to and then record these reactions.

(b) Participants were not conscientious in keeping diaries.

(c) Return rates of diagnostic tests was low limiting data available on the status of subject matter knowledge.

(d) Selection of the Andrew's std 10 class for observation was a poor choice. This was a matriculating class whose concern was more with exam preparation. Andrew's teaching style may not have been a good reflection of how he would teach under normal circumstances.

(e) The study was set to investigate conceptions of science teaching and science learning. During interviewing these were treated in a general way without any distinction from ordinary teaching and learning.

(f) Communication problems and timetabling at the schools led to observation of lessons constituting only parts of topics.

(g) Sharing of classes by Ferrial and the cooperating science teacher resulted in lack of continuity in the lessons observed.

(h) The second lesson of Ferrial's lesson on acids and bases was observed. But the lesson was disrupted and discontinued. The physical science teacher continued with the lesson later and I could not continue my observation.

(i) Time clashes between Mary's and Andrew's lessons led to changing classes observed for Andrew (though from one std 10 class to another). However those initial observations have not been used in this report.

(j) Initial data collection (interviewing) was conducted twelve weeks after the programme had started. Student teachers' responses may have been influenced by the course even though they believed that this was sometimes not the case.

8.3 SUGGESTIONS FOR FURTHER RESEARCH

The case studies reported in this research project are unique instances. But again there may be other cases with similar expectations, experiences and conceptions. The findings are specific to the three cases studied and maybe the other seven students who responded to the diagnostic tests for content knowledge. The study had no intentions to make generalisations from its findings. I therefore find it inappropriate to make recommendations that can or would affect a large group of preservice teachers or the HDE physical science methodology or any other course. The study has, however, given some directions to possible further research in the areas of preservice teacher education such as their experiences which sometimes determine whether a student complete training or not, and their subject competence. So suggestions are further research in the areas explored here on a larger scale.

Two of the cases were found to be unhappy about certain aspects of the physical science methodology, such as unclear instruction, repetition, poor structuring of the mini lessons, lack of help in the transition of the student teacher into a teacher. More research into these perceptions and maybe reviewed over a few years may be useful to the methodologists and other prospective teacher educators.

Teacher education is faced with the challenge of developing preservice teachers' pedagogical content knowledge to allow them to sustain activities that promote meaningful learning. And for programmes like the one year HDE programme, which has to convert graduate students into a teachers knowing both content and pedagogy in

physical science from std 6 to std 10 this task is even more difficult. The literature surveyed for this study indicated that research in the area of student teachers' knowledge of specific chemical concepts or topics is scanty. Results from the diagnostic tests in this study show that there is need to explore on a larger scale the relationship between student teachers' chemical background and their knowledge of secondary school science concepts, particulary post graduate teacher trainees for whom it is assumed they have the necessary knowledge of the concepts in their subject disciplines to teach them. This study did not provide sufficient evidence to validate or refute assumptions of this nature but recommendations are that further investigations be conducted in this area in part of the world. These recommendations are echoed by Mosimege's (1995) study who was also unable to find evidence that higher level chemistry student teachers were better than those with less chemistry content.
Mary is a single isolated case who acknowledged her limitations of chemical concepts and demonstrated the limitations during teaching practice and the physical science methodology class discussions. Her experience indicate another possible area of research into aspects of knowledge of chemical concepts for teaching purposes at secondary school, among non-chemistry majors in post graduate preservice training and finding ways of assisting them overcome barriers that may interfere with the teaching of these concepts.

Initially I wanted to conduct this study with students from a DET background. The two students selected at the beginning of the study withdrew from the programme sometime during the year. What seemed to emerge was that the programme may not be accommodating for the new type of student who was entering the programme, bearing in mind the history of the university. There is need for further research into the experiences and the problems these students, who have previously not been accommodated by the programme are experiencing and how the HDE programme at Wits can be restructured to adapt to the new type of student (provided subjects can be found).

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APPENDICES:

APPENDIX 1: Interview schedule

Interviewee: Date: Venue: Interviewer: Time:

Thank you for coming to the interview session. It may be pretty long (1-2 hours). I am sorry that it will take so long and I hope you will be patient. For all the questions, please answer as honestly and as best as you can. There are no right or wrong answers. The interview is not intended to inform you about anything but to find out what ideas you have about the questions asked.

Before we go much further with the task can you please tell us about your academic background (type of school attended, the university, science subject majored in) up to and including what you are doing now (and your part time teaching)

A: <u>GENERAL IFORMATION</u>

1. Why do you want to be teacher?
2. When did you decide to become a teacher? Any particular reason that made you make that decision?
3. Describe the best teacher you ever had.
4. *How do you think the profession of teaching compares with other professions?
5. How you foresee your career as a teacher? Why?
6. Tell me about the courses you are doing this year?
7. How helpful are the additional studies? Any alterations that you feel could benefit better student teachers?
8. How do you feel about the way the course topics are handled so far? Can you explain?

(*Gunstone, et al. 1993)

B: <u>QUESTIONS ON SCIENCE AND TEACHING</u>

Please respond to the following questions:

1. What is your understanding of the word science? What does the word mean to you?
2. What do you think is meant by scientific knowledge?
   How do you think scientific knowledge has been produced?
3. Do you think the scientific method is the only way to do science?
4. What teaching strategies would you consider to be more effective for teaching science to secondary students?
5. What do you think of the suggestion that many students develop their own 'theories' to explain nature, and sometimes these theories can be substantially different from the so-called scientific theories.
6. How would you consider the student's own theories in your teaching, if at all?
7. If you can, briefly describe your own 'theory' about how teaching and how learning occurs.

(Aguire, Haggerty and Linder, 1990)

C: <u>INTERVIEW ABOUT INSTANCES OF SCIENCE TEACHING</u>

Protocol: Below are instances and/or non-instances about science teaching.

a) In your view, is there science teaching happening here?
b) If you cannot tell what else would you need to know in order to be able to tell? How would this information tell you? Please give reasons for your answer.
c) If you answered 'yes' or 'no', what tells you this is the case? Please give reasons for your answer.

Items

1. *Handing out crystals*
   Teacher in a STD 6 class at the start of a topic on crystals, asking the class, "What can you tell me about the crystals I've just pass around the class?"
2. *Student watching TV*
   A student at home watching a TV programme on chemical plants which produce new plastics from coal.
3. *Students in library doing problems*
   Two STD 8 students in library working on a set of vapour pressure problems from the chemistry textbook given for homework.
4. *University Lecturer*
   University lecturer lecturing on molecular orbital theory to a small group of

grade ones.

5. *Teacher questioning student's statement*
Teacher reads STD 8 chemistry student's statement that 'Ideal gases have no volume' and asks, "Were you referring to the gas particles or the gas as a whole?"

6. *Teacher asks students to label a diagram*
Teacher at end of a demonstration of the electrolysis of water distributes a drawing and asks students to label the apparatus used in the experiment from memory.

7. *Students ask question*
Junior secondary student in class, watching an experiment on the electrolysis of water which has been going on for some time asks the teacher, "Do you think you've got all the oxygen out of there already?"

8. *Student baking*
A student at home follows a recipe for baking a fruit cake

(Source: Hewson & Hewson, 1989)

D: QUESTIONS ABOUT TEACHING TASKS:

Below are some tasks related to teaching. Rate each aspect in terms of "how important do you think it is to know it to do it well" ('crucial', 'important' and 'desirable but Not Important') and "your present competence in the task". The tasks are:

1. Controlling the class.
2. Monitoring students' progress.
3. Selecting material to be learned.
4. Serving the students as a source of knowledge and skill.
5. Adapting material chosen to the level of the students.
6. Instructing students on the demands and procedures of learning.
7. Constructing experience for the students to interact with the content.

Gunstone, et al. (1993)

....

How do you feel about the way the course topics are handled so far? Can you explain?

These questions were adopted from previous studies on preservice science teachers' conceptions of science and teaching and learning. After the first piloting some alterations were made to reduce the length of the interview and eliminate questions that were inapplicable or which could result in unecessary duplication.

APPENDIX 2: Diagnostic tests

A: TEST ON CHEMICAL BONDING

You are provided with a question paper and an answer sheet. Do not write your name on either the question paper or the answer sheet.

Please answer all the questions by circling the letter which correspond with the answer on the answer sheet. DO NOT mark the question paper. Then give reasons f.. either choosing a particular option or for not choosing the other options.

Your co-operation during the course of the my study is greatly appreciated by my Supevisor, M1 and myself. **Thank You very much**

QUESTIONS:

1. The chemical bonds in a sodium chloride crystal are primarily due to:
   A attractive forces between oppositely charged ions
   B van der Waals forces between molecules
   C electrostatic forces between protons and electrons
   D hydrogen bonds between the sodium and chloride ions

2. A solid which is brittle is likely to:
   A be composed of simple molecules
   B be an electrical conductor
   C have weak chemical bonds
   D have strong intermolecular forces

3. Which of the following is an INCORRECT conclusion? Relatively weak forces between molecules account for fact that a molecular solid ....
   A breaks apart when scratched with a pin
   B can be dissolved without chemical reaction
   C has a grey or black appearance
   D melts at a comparatively low temperature

4. The force holding atoms of C and O together in a molecule of CO is a result of :
   A orbital overlapping
   B electrostatic attraction
   C the sharing of electron pairs
   D the stable octet of electrons that each atom acquires

5. A chemical bond forms between two atoms because:
   A the atoms may share one or more electro pairs
   B each of the atoms may achieve an octet of electrons
   C the electrons are simultaneously near two nuclei
   D the kinetic energy of the two atoms decreases

6. The distance, X in this molecule is called:
   A atomic radius
   B covalent radius
   C interatomic distance
   D bond length

7. A high melting point of a pure solid substance definitely indicates that:
   A the substance is ionically bonded
   B there are strong forces between the atoms
   C the molecules are close together
   D the substance is not very reactive

8. The distance between neighbouring non-bonded nuclei in an iodine crystal is greater than the bond length in an iodine molecule because:
   A the molecules are further apart in the gas than in the solid
   B the attractive forces within a molecule are great.r the attractive forces between molecules
   C iodine forms diatomic molecules
   D iodine molecules are covalently bonded

9. Which of the following is always correct for the melting of a network solid:
   - **A** a chemical reaction takes place because chemical bonds are broken
   - **B** a chemical reaction does not take place because melting is a physical process
   - **C** ions move from their fixed positions is the lattice
   - **D** positive and negative ions dissociate

10. The term "molecule" refers to :
   - **A** covalently bonded substances only
   - **B** ionically bonded substances only
   - **C** a specific number of atoms with fixed proportions of each element
   - **D** two or more atoms held together by chemical bonds.

(Harris, 1992)

ANSWER SHEET. Your Code ________

1.	A	B	C	D	Reason:......................................
2.	A	B	C	D	Reason:......................................
3.	A	B	C	D	Reason:......................................
4.	A	B	C	D	Reason:......................................
5.	A	B	C	D	Reason:......................................
6.	A	B	C	D	Reason:......................................
7.	A	B	C	D	Reason:......................................
8.	A	B	C	D	Reason:......................................
9.	A	B	C	D	Reason:......................................
10.	A	B	C	D	Reason:......................................

B: QUESTIONNAIRE ON ACIDS AND BASES.

Introduction:

The purpose of this questionnaire is to ascertain your views, as preservice teachers, on acids and bases.

Instructions:

1. Please answer all questions. Answer the multiple choice questions, 1-12 in Section A, by circling the letter of your choice.
2. For Section B use the spaces provided under each question 1-8 to write your answers.

You do not need to write your names.

General Information:

The information required here will inform the researcher of your academic status and experience in the area of chemistry.

What is the highest level of chemistry you have acquired, institution and year of acquisition? (e.g. Chem I; Wits University; 1990)

How much teaching experience do you have?:.....................

Did you teach the section/topic on acids and bases during teaching practice?

If you did teach it, at what class level/std(s)?

SECTION A: MULTIPLE CHOICE:

Circle the letter of your choice.

1. Which of the following substances can act as an acid or a base?

   A HCl **B** NH_4Cl **C** HCN

   D H_2O **E** H_2

2. Which statement regarding the reaction shown below between hydrogen chloride and water is CORRECT?

$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

A Water acts as a base towards HCl.

B Water is a conjugate base of HCl.

C The water molecule is a proton donor to the chloride ion.

D Water does not act as either an acid or a base but merely as a solvent, in this reaction.

E The water molecule is an electron donor.

3. Which statement is INCORRECT?

A Acids may comprise positive ions, neutral molecules or negative ions.

B An acid-base reaction consists of the transfer of a proton from an acid molecule to a base molecule.

C Bases may comprise negative ions, neutral molecules or positive ions.

D The strength of an acid or a base is correlated with its tendency to donate or accept protons respectively.

E Aqueous solutions of all salts are neutral.

4. In the equilibrium reaction represented by the equation:

$$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$$

the Bronsted-Lowry acids (proton donors) are

A NH_3 and H_3O^+ B NH_4^+ and NH_3 C H_2O and NH_3

D H_2O and H_3O^+ E NH_4^+ and H_3O^+

5 Which one of the following is a property of an aqueous solution of an acid?

A Solution turns red litmus blue.

B Solution tastes sour.

C Solution is a good conductor of electricity.

D Solution has a hydrogen ion concentration 10^{-13} mol dm^{-3}.

E Solution has a slippery feeling.

6. An older theory (Arrhenius) about acids maintains that acids in solution dissociates to form hydrogen ions (H^+).

An important objection against this theory is that

A the number of acids would be very large

B hydrogen ions would not react chemically

C hydrogen ions cannot occur freely in an aqueous solution

D hydrogen ions would form hydrogen gas

E the number of acids would be very small

7. Which of the following is <u>NOT</u> a property of aqueous solutions of bases?

- **A** Aqueous solutions have a slippery feeling
- **B** They change the colour of blue litmus to red.
- **C** They change the colour of red litmus to blue.
- **D** they taste bitter.
- **E** They react with acids to form salts.

8. The conjugate base of hydrogen chloride is

- **A** the chloride ion. **B** ammonia.
- **C** water. **D** potassium hydroxide.
- **E** the hydroxyl ion.

9. Hydroxides such as $Al(OH)_3$, which can react with strong acids and strong bases, are

- **A** diprotic **B** dibasic
- **C** donors. **D** binary compounds
- **E** amphiprotic

10. Five beakers contain solutions (separately) of equal concentration made from dissolving the following substances in water: NaOH, Na_2CO_3, HCl, NH_4Cl and NaCl. If the pH of these solutions is tested (with universal indicator or pH meter), it is found that

- **A** both the NaOH and Na_2CO_3 solutions have pH values above 7.
- **B** the HCl solution has the highest pH, well above 7.
- **C** the NH_4Cl solution has the lowest pH value.
- **D** the NaCl solution has no pH whatsoever.
- **E** only the HCl and the NaOH solutions register pH values.

11. A student has been given a number of aqueous solutions and he has determined the pH of each, using indicator paper. Here are the results.

Solution	A	B	C	D	E
pH	3	4	6	7	9

Which solution is the most acidic?

12. The following substances have been arranged in an increasing order of acid strength. Which order is <u>CORRECT</u>?

- **A** Nitric acid; Acetic acid; Water; Ammonia; Ammonium ion.
- **B** Ammonium ion; Water; Acetic acid; Ammonia; Nitric acid.
- **C** Water; Acetic acid; Ammonium ion; Nitric acid; Ammonia.
- **D** Acetic acid; Water; Nitric acid; Ammonia; Ammonium ion.
- **E** Ammonia; Water; Ammonium ion; Acetic acid; Nitric acid.

SECTION B: DISCUSSION QUESTIONS

Answer the following questions in the space provided under each question. If the space is not enough use the back of the sheet, but be sure to number the response with the corresponding question number.

1. Ethanoic acid (CH_3CO_2H) is dissolved in water. Would Arrhenius have considered the resulting solution acidic?
   Explain:

2. Write an equation for the chemical reaction which occurs when
   (i) ethanoic acid (CH_3CO_2H) reacts with water.
   (ii) ammonia (NH_3) reacts with water.

3. HCl is described as a strong acid, while ethanoic acid is described as a weak acid in aqueous solution.
   (i) What can be said about the strengths of Cl^- and CH_3COO^-?
   (ii) What can be said about the pH of the solutions of the two sodium salts of these acids? Explain.

4. Give an example of a weak acid (other than ethanoic acid) and show how the acid dissociates in an aqueous solution by means of a chemical equation.

5. (a) How does an acid base indicator function? Explain fully.
   (b) The range of colour change of indicator A extends from pH 3 to pH 5; that of indicator B extends from pH 6 to 10; that of indicator C extends from pH 9 to 10.
   Which of the indicators is suitable for titrating
   (i) a strong acid with a weak base? ....
   (ii) a strong acid with a strong base? ....
   (iii) a weak acid with a strong base? ....

6. (a) Distinguish between a strong acid and a concentrated acid.
   (b) Is a concentrated acid necessarily always a strong acid?
   Explain.

7. Draw a picture of an aqueous solution of hydrochloric acid at the molecular level. Show the molecules and ions that are present. (Mosimege, 1994)

APPENDIX 3: Interview transript for Ferrial.

Venue: Room C409/104: Humphrey Raikes Building: 11.30 am

On transcribing Andrew's interview tape I realised that C104 was quite noisy. I had intended using one of the lecture rooms in the building but only used it for a while before I was asked to move out. So we transferred to C104 again.

This interview started with an informal discussion about myself.

I: .... What we are saying is that there's no harm in (talking) ya. You want to know more about me? Ok. I did my BSc, completed in 1986. (Mh) Went to teach for for about three and half years, joined the In-service department of the University of Swaziland on secondment. That is I still had my te ching post (Mh) I was there to help them out of a situation (Mh) and then another job cropped up and I applied and joined the pre-service teacher training. And er, th-ok, the post entailed training teachers in chemistry. We have somebody in biology (mh) somebody in physics who is also training here as well, and I'm doing chemistry. So I'm actually doing this study to get to know more about the teacher training because I didn't have time to-to do it there and I hope at the end of it all I would be in a better position to-to train teachers {both laugh} (oh).

R: What is this interview and what follows entail, I don't know what I have to do?

I: Ok. For this one you just have to answer the ques ons as they come. (Mh) And maybe I should start by saying that thank you for-for honouring this (Yes) interview. I think it's more polite to put it that way, that you made it to the interview. Err one thing you should bear in mind is that whatever you say will not necessarily be right or wrong. (Mh) Actually there are no right or wrong answers. We are interested in your opinion (sure) regardi he-the questions that I'll be asking here. So feel free to say whatever you feel you know (Mh) (Ya) And err like I said what you say here will not be pinned to you people-people will read about it and only you will know that you are the one who said it. The other people I will be interviewing might say Ah! that's not me I wonder who-who it is because its not only you, there are a couple of you (mh, mh) that are eng[illegible] in the study. So in that sense it will be sort of anonymous (ya, ya). I [illegible] not be associated with you directly, and err I-I hope that even my-your lecturers when they see it they won't interfere. Like I said before I will also be following you up in you-in your teaching practice (Mh) and making observations during that time. Ok. Er I would like Ok the questions are in four parts, I think {check}. The first section will be knowing about-about you, the schools (The background) Ya, th-the your background academic I mean your academic background. Then I've got questions relating to science teaching, then I've got questions on interview about instances of teaching and non-instances. You'll see when we get to that and some questions on teaching tasks. Ok. So maybe you could start by telling me and the others who will be reading this, about the types of schools you went to the universities you went, what courses you did (Ok) and so on.

F: Er I went to a school in Potgietersrus that's in the Northern Transvaal (Mh) Ok. I went to school at a primary school, it was an Indian Primary school, up to std 5. Thereafter I had to travel to school in Pietersburg high school because there was no English medium school in Potgietersrus. (Mh) Ok. So I travelled to Pietersburg everyday, for 5 years until I finished my matric. And then I came to Wits where I got my BSc. and now I'm doing my HDipEd and I did zoology and then botany.

I: Ok, for your-for your BSc you did zoology and botany. (Mh) Ok now you're doing your (I'm doing my H. Dip Ed). Ok. Mmm the-the schools you went to (Mh) were they private schools or

F: No, err government schools. (Government school) run under the House of Delegates, a separate schooling body, Indian schools so to speak. (Ok) Err ya which has had quite a bearing on actually err opportunities and stuff like that and at the school things like facilities which were lacking quite a bit. (Mh)

I: So they were not as equipped as the other schools (No not science) Ok. I would like to request you to raise your voice because I might get problems when (Oh ok) when I transcribe here. (Ok) try to strain. Ok. The next

Background:
Schools attended: - Northern Transvaal
- English medium
joined Wits after matric;
did BSc: majors Zoology + botany
. type of school; govt: under House of Delegates
govt influence: lack of facilities + opportunities

question relats-relates to why you want to a teacher.

F: Why do I want to be a teacher? Ok. Err when I did start of at the university I applied medicine and dentistry and I didn't get in. So then I did my BSc. When I did my BSc first choice I decide I was going to try and I apply for medicine and dentistry then I couldn't get in as well. So err then I figured I'd do botany and zoology because I have quite a keen interest in the environment and environmental studies. So I did that. Mmm After I finished I realised there weren't many jobs-job opportunities as far as BSc was concerned. I was doing BSc. And then err when in my final year of BSc erm teaching became a bit more plausible err I mean to say teaching as quite important and things like that. But I looked today and I thought of the opportunities I didn't have while schooling. May be I could introduce them you know and reflecting on what I've been through and teaching is quite plausible and now with the new changing education system and stuff like that it would be a lot more challenging and different and (Mh) I would want to go into teaching. (Mh)

I So you-you decided during your final year (Ya) that (that it is teaching that I want to do) Ok (not before hand). Mh. And err the reason for you to decide that is that you couldn't get what you really wanted initially (Mh) that is going into medical school (Mh) and dentistry (Mh)

F: Ok if I look back now I don't think I'd want to go into medicine and dentistry. I like err I'm bit settled with teaching. But teaching with a bias towards the environment, education (So could you be meaning that your-your you'll stick with teaching for) For always, I don't think for always (For-for a while?) For a few years, ya (A few years) for a few years, ya. But like I said I want to get into I will be dealing with you know education as such, (Mh) environment education, dealing with schools, introducing environment at schools studies. (So you-you figure that you will be more on the educational) Ya (aspect) Background Ya (Alright).

I: Erm, How do you think the teaching profession compares with-with other-other professions?

F: Err I always thought now why do you want to be a teacher, but I realised the importance of it. I mean we all [illegible] having been [illegible] surely teaching is important but err as far as it

Career choice:
medicine + dentistry first choice

tg as alternative: job opportunities
: tg is important
: new + changing education system - lot more challenging

no wish to return to medicine and dentistry - settled in teaching
. environmental education

tg compared to other professions
why teach . important

compares I mean it seems is a non-profession which is unfortunate, I mean we don't-we work under somebody, err we are not given what shall I say we do not take an active part, we are given syllabus and told this is what you teach we have dead lines to meet we have to complete the syllabus, you know run tests and things like that. As far as the teaching and learning process is going on I don't think teachers are that involved you know and they don't have that much saying in the structure with these processes and what's been taught and thing like that. So I think teachers should be given more of the leeway in structuring what's being taught and how it's being taught-taught and stuff like that. And the content of .... (Ok) I think we should be paid more. {Both laugh at this} After all it seems like a 24 hour job. You got to think about what you're doing the next day you've got to take stuff home you know you got to be working at it all the time.

I: Do you think that err the people in the other professions don't?

F: It seems like it-it would seem like it because I am, you know you're always confronted with why is it that you wanna to teach, why teaching, (From who) From people around you know basically people around (I hope you are not referring to me) Oh no no no {Both laugh} that's -Generally when you speak to peers and other students, stuff like that, student who are doing engineering, medicine and stuff like that ..?.. try to do teaching? (Mh)

I: Ok. Err. Did you have a best teacher while you were at school? (Best teacher?) Whether at school, university, or

F: Er, well at school, primary school not really, I mean you know we all sulk at our teachers when in primary school. But as far as high school is concerned there was a teacher that really put me of maths at the time. But erm his attitude was such that he really put me off of the stuff. But when I when I came to matric the final term I realised you know that I learnt a lot in that process because he made conditions difficult for me, er he really gave me a tough time, he really gave me much work, he gave us ridiculous things to do. But I did learn quite a bit you know, I was quite amazed by that and things worked. (And those ridiculous things) Even if they seemed ridiculous you know I mean at er at the time because I mean who wants to do so much third year assignments for maths over the year you know and things like that and the attitude he had (What kind of attitude did he have?) Like you do the work, I give you the work you do it, you know what I mean. We just had to do work-work-work. And er there was no interaction, he gave us work and I spent hours doing maths (Mh) And I did it by myself. He sort of like facilitated, marked our books. If there were problems we accept-he explained them but I did the work by myse- on my own. And er I developed what I developed and learned and I mean I had from concrete (It was-it was your work) I constructed ya. Which is good because I realised in the end that's a good way.

I: Would you do the same to your (Err would I do the same) students?

F: Err actually he was quite arrogant and I hated that you know and stuff like that well being like more of a facilitator you know addressing problems and things like that being more available would be ya.

I: Did you have a teacher who was like that somebody you would look up and think that-that one was

F: Well No. Not really

I. So you only had-you only had this lousy one (Ya, when you look at it now) {laughing} ya at the time. Ok. Ok now we move on to questions on science and teaching. {pause} What does the word science mean to you?

F: Just from the top of my head? Erm {pause} research ok if you think in a few words. Research technology something up to date, something relevant, something factual, things like that.

I: Mh. Ok now how do you think scientific knowledge has been produced?

F: Has been produced in schools? (It could be in schools it could be anywhere, its up to you) You mean the process in teaching scientific knowledge (Ah well its how do you see or how do you think it has been). Err for some it would seem that science is a bit of far fetched thing. I mean its for the more intelligent, its for those who are ...?... it, things like that. Dealing with-I mean you've got this image of scientists, dealing with research all the time. (Mh)

I: W-would you say that it has all-it has been produced by research? {Pause (Ya)} Ok. Now in the school situation do you think that those children that you teach do lets say acquire some scientific knowledge?

F: Scientific knowledge, ya I would think so in that they have been tea-they've been taught about science and chemistry and physics, basic laws about science (Mh) in maybe abstract in some forms you know around what they know, ..?.. like physics like motion and things like that if they are aware?.

I: What makes up scientific knowledge? wh-wh-what are the constituents? constituent parts or components that you can put it like that, (Of science) Of scientific knowledge? If it does have any? What-what would we say makes up scientific knowledge?

F: Scientific knowledge err, like knowing chemistry or something like that? ([I got the impression that she was not sure as she shrugged her shoulders])

I: Ya. Ok. Erm do you think that the scientific method (Mh) is the only is the only way of teaching science (The scientific method) Do you think its the only way (of teaching science) that science can be taught? Ya.

F: {Pause} Err ..?.. we can teach about everyday science in a way where we make people aware of the things that are happening not using as much scientific terminology and language. But you know like why do why does this happen and things like that. Not using the actual science terminology and things like that. But sure enough in order to teach something you've got to introduce those terminologies and that language to a certain degree. Yes you can learn so much about science in a layman kind of way but when you are coming down to pure science that you wanna learn the you shou-then you got to speak the language so to speak. (And wha-what's the language for the scientific method?) You got to be err {pause} you got to be accurate, you got to be you know make sure that you use the terms correctly when you're teaching it school and things like that. And I think err it's equally important that although these concepts need to be clarified and they need used correctly (Mh) we should err put them out in a sense where it's more-where people can take them in, I mean it shouldn't be too scientific. So that er you know kids or children at school can grasp it. It should be relevant and applicable. Practical-practical to everyday (Mh). So you can teach science in that way. (Mh) But it should be balanced.

I: What do you understand about the scientific method?

F: I thought of you saying how is it being taught, the methods its being taught in school. (I said do you think that the scientific method is the only way that can be used for teaching science?) Ok, what I thought of was erm teaching science in school, making sure that you get all the correctly, using science terminology (Ok).

I: Err {Pause} What are some teaching strategies that you consider to be effective in teaching science in sec-to secondary students?

F: Secondary students? (Yes) Ok, one may be err relevancy, applicable to everyday, (Mh) you know bringing in things testing them out like analysing your school then or something of that sort you know. Err with the knowledge that kids bring to classrooms aware, being aware of that knowledge and then turning that scientific showing them that there's science involved with it that's one way. (Mh) Another way is erm looking at something beyond the syllabus like, say er transport and technology or that sort (Mh) and then you know making them aware of-of science in that way, That-that may be a lot-a little more abstract because you are not dealing with it everyday maybe, but they are becoming more aware of it like mining and things like that (Ya. And er concrete) Concrete? (Ya you are saying that talking about maybe transport and technology may be a bit more abstract because they don't deal with them) Ya (I mean to make it clear hands on. So what concrete strategies would you-would you think could be used?) Taking them out there like you know, like taking them to industry showing them how it works you know um actually bringing them in that environment. (Ok. In other words taking field trips) Fieldtrips, ya. (Ok).

I: Err Some people have suggested that many students develop their own theories to explain nature. (Mh) You seem to agree with that? (Mhh, I do) and sometimes these theories can be substantially different from the so called scientific theories. (Mh) What do you think about this suggestion?

F: Well I do, I mean (Mh) I have like when you go through school err when I like for example working with circuits, and resistance and things like that, I developed my own theories of how the thing works, ok, and err I form my own analogies and stuff like that and my own concepts-conceptions. And I don't know if it is in accordance with what the teacher is saying or what-what it actually is. (Mh) But sometimes its workable and-and while I'm busy with building that things up if I find loopholes in it and then we'd rearrange it again in my mind and things like that. And I think lots of people I mean lots of kids, I work with my nephews and I see they have their own concepts about what-about how things work and stuff like that. Sometimes its not a bit far off you know (Mh) but I do believe we do form our own conceptions and sometimes they may be misconceptions which can be err frustrating when you come to school and then learn that you are a bit way off or something . But-but then again you will re-align yourself in your in your thoughts in what you gather from the teacher and what you have been taught. (Ya) So you-you do form that concept.(Ya ok.)

I: Now going into the position of the teacher how would you consider the students own theories when teaching (How would I consider) Ya. And what would you do. (With the knowledge that everybody is formulating their own concepts, How-how can I get them) how would you take that into consi-what would you do in the classroom situation.

F: Try to 'ssess out in a way what their concepts are by a form of err making them work with things that makes me aware of that of how they-the way they are thinking-their way of thinking Introduce yes the-the concepts that I want to teach and see how they formulate that from-for themselves, and if they're a way off the try to I bring them by a process I don't know test or maybe making them see-see a different way (Mh) well seeing different views from the classroom and so on. (Mh) But being aware surely that people form their own concepts (Mh)

I: So could you briefly describe er your own theory of how teaching occurs (How teaching occurs or learning occurs?) It could be both (Could be both?).

F: Er, {pause} well you know it's-there's a lot of like content and-and factual knowledge and stuff that we have to transfer, I mean pupils, kids form their own knowledge the way they interact they-they-society and stuff like that from their own backgrounds and er we provide and if left to their own devices I mean they'd be acting spontaneously and form ..?.. their own. But what we as teachers are doing is directing them, erm we are giving them knowledge about maths and science and things like that and which probably otherwise wouldn't have taken interest in (Mh). So we are providing them with this here. And err what we should be providing them with is in fact skills, skills such as the ability to-doing, I don,t know how you assess those but the ability to interpret to understand, skills such as that-that would bear on dealing with the scientific problem, to conceptualise it to interpret the scientific problem (Mh). Since skills like to know that they are more important than teaching them the factual knowledge because if they have those basics, the ability to think to think abstractly, and stuff like that, with that as a life skill (Mh) they can go ahead and erm deal with problems as they come along. As they go along they will be learning more, and they do a lot of problems. So we deal-we as teachers are more facilitators I would say. We are there to guide along. I think skills are more important than ...?...

I: When did you develop this attitude? That skills are more important than just transferring factual knowledge to the students? Was it before you started your HDE course or it has enlightened you on that.

F: I-I will I'll tell you like in my final year of Bsc (Mh) ..... I became ..I became aware of teaching and what was lacking in my schooling and stuff like that. I became aware of it because like skills that I, in other words I-I hadn't developed the art of writing or thinking critically or writing down arguments and doing thi-analysing things like and had become a bit of a problem for me and I-and I de-decided that had I been taught those skills I mean I excelled in science and maths but I knew all of it, but I wasn't I couldn't deal with problems beyond that. I realised that (Mh) and became a little bit more err when-while doing my HDipEd now I realised that this is what I've been thinking and it became a bit more concretely for me. (Mh) So those lacking skills that I have been experiencing ..?... (Ok they became consolidated) Mhh. (Well you are being aware of that now.)

I: Ok. Now we go into interviews about instances and non-instances in science teaching. Ok. What I'll do is I'll read out and in your view do-would you think that science teaching was happening in the instances that I would provide or I will read out to you, and err if you feel that you cannot tell er what would you need I would like you to state what would be needed to help you to tell whether science teaching is taking place or not. And then if you think that science teaching is taking place I would like you to give your reasons why you think so. (In this interview?) Yes. Ok. Err. We have a teacher handing out crystals. Ok. That is the instance. And er to explain more about it, the teacher is in a std 6 class at the start of a topic on crystals he asks the class "What can you tell me about the crystals I've just passed around the class?"

F: Ok science teaching happening there "What can you tell me about the crystals that have been passed round the class?" (Mh). It's quite an open ended question, some students may not know what crystals are ok the object that is passed around is called just crystals but what are they may be bit of a problem but erm and er students may then go ahead and define it by saying oh it's blue it's got this shape, it feels like this. Ok. And then if left at that er kids will then think that things that feel like that or looks like that or has this form is then a crystal it may cause misconceptions. I-but I think it's a fair way of starting by you know um or maybe you could have started the question by 'what do you think this is?' And people will give their idea. (Mh) ideas of what it is. (So would you think that teaching is taking place or not or some?) From the level where people are thinking about what he's given them, (Mh) yes maybe science teaching is taking place,. (Do you think the kids are learning?) Learning as such err, well if this-this is just a sentence, maybe a bit later as he develops (Mh) the lesson maybe they will be learning something, but for the-just that sentence erm they're learning just to think about of something about what is given to them to make a-to make a decision on what it is. (Ya. Ok).

I: Now we've got a student watching TV. (Mh) Ok a student at home watching a TV programme on chemical plants which produce new plastics from coal. Do you think that there is some teaching happening there?

F: Well what is happens well I w-watch most-I can't just put-watch these programmes about how they make plastics or bread and er yes er to an extent where you see the process happening {some disturbing noise} Ya we are learning about the process it's like er ya oh now I know how they make that plastic. You-you kind of learn something, ya. (Mh) ... I know now where my-my can of coke comes from, how it was made. Now that's something. (Ya. But would you consider teaching-science teaching to be happening) Science teaching? (At that time when the student is watching the TV programme?) Well I've learned something and I think that's-that's good. (Ya you have learned) Ya. (Do you think teaching has taken place?) {Pause} Teaching? (Mh) {Pause} Well is learning teaching? Can it stand from teaching alone. (What do you think?) Maybe we learn from everyday interactions (Ya)

I: OK you could have learned. So you could have learned or this particular student could have learned without being taught. Is that what you are saying?

F: ... could be taught in a sense where he has a teacher up in front and he is taking notes or something (Isn't the TV doing that?) Well he's just seeing something err he doesn't err he's not actively engaged he can't say hey stop now what's happening here, (Mh) Er he may think about these things but he doesn't have the opportunity to interact and ask questions. And if that happens that's that that's not teaching, because then you are developing skills as well as much as introducing facts and process of how er a bottle was made. So er the extent that he's learned something, yes to the extent that he's been er {Pause} I don't know. I don't know. {Smiles}

I: Ok. Le-lets go to the next one. The-there are students in a library doing some problems. You've got two std 8 students who are working on a set of vapour pressure problems from a chemistry textbook given for homework. (Ok they are working with problems) Ya they're working on problems. (Ok is teaching /learning occurring?)

F: Ok the-the, what's Ok sh-er with what they have learned in the classroom ok they-they now they are coming to the library to do problems. Yes they are applying what they have learnt and from-ok probably taking information from the textbook then applying err that knowledge that they have gained to work out the problem. (Mh) So they are using their ability ...?.... so they are developing something and er what they are now doing is err something that they'll internalise how to do this problem. (Mh) So they are learning. (Ya. But are they being taught?) Are they being taught? (at that instant when they are working on these problems) No they are not being taught.

I: The next one is on a university lecturer who is lecturing on molecular orbitals to a small group of grade ones. Let's say you take professor Gerrans ({F laughs} to a group of grade ones?)

F: Lecturing on what he would lecture (Lecturing on molecular orbitals to those grade ones) Well I don't think they have the foundation or erm, it may be too far fetched for them they don't have the-the structures (Mh) to be taught molecular orbitals at that age or you know from what they've already learnt. I don't think that a grade one kid knows anything about molecular orbitals unless it's 1994 and I'm still behind. And err so I don't think he's teaching them anything or that they are learning anything either because they don't have the foundation of structures, they have'nt internalised anything about you know a s-a foundation where they can learn about molecular orbitals. ({pause} Ok.)

I: Erm {Clears throat} So you've got a teacher questioning a student's statement. So during that instance, what happens? You've got a teacher who reads a std 8 chemistry student's statement that "ideal gas have no volume" and then asks the student "Were *you* referring to the gas particles or the gas as a whole?" { Door bangs in a nearby office./ We change the venue} Ya the question is on a teacher who reads a std 8 chemistry student's statement that "Ideal gases have no volume and asks were you referring to the gas particles or the gas as a whole?" Do you thing science teaching is happening here?

F: {Clears throat} If I were the student-if I were the student if I made a statement like that it would stem from being told about the gas as a whole. Ok. Er I would probably be thinking about the gas as a whole, and now that I'm being told about thinking of gas particles, or I'm not thinking of it as a whole er I would be a bit confused but none the less thinking about what is it actually to the gas particles or the gas as a whole, have I not made the statement or have I not seen the whole picture so err surely the er student is being prompted to think about something more than the statement that he's made. So er yes the-teach-, yes the student may be learning something from that and is he being taught, ya he's being taught to err to think about actually the statement that is being made. Ya.

I: Ok. Now the other one you've got a teacher who asks students to label a diagram. Ok. A teacher at the end of a demonstration on the electrolysis of water, distributes a drawing and asks students to label the apparatus used in the experiment from memory. (Label the apparatus used in the experiment from memory) Yes.

F: Err is teaching happening from there? Err (Ya) Ye what has happened is just a demonstration? (Mh). Ok. And err I don't think, sorry. (It was at the end of the demonstration.) demonstration. Ok. ...? . 'emonstrated to but I don't think there's enough in that demonstration for me to err concretise about the apparatus that they've been I mean basically there may have been a mention of the apparatus being used. (Mhh) Ok. And er its a demonstration I have actively engaged with those apparatus and they don't know what they are. So from memory maybe I'd remember the names er but not knowing what they are used for or how actually they work I don't think that would be long term memory I just would be able to label them immediately after the, thing maybe weren't listening I'd skip out the ..?.. apparatus. But erm I don't think there's adequate teaching happening there as far as-as trying to label apparatus or what the apparatus are used for. (Mh) I don't think that the pupils have learnt anything much either from just recall from memory because its too short a time to learn. To know exactly what these apparatus are (Ok) I don't think so. (Ok.)

I: This time it will be student asking a question (about time {laughs}) So you've got a junior secondary student in a class, who is watching an experiment on the electrolysis of water which has been going on for sometime, then asks the teacher "Do you think you've all the oxygen out there already?" (OK) So there is a student who is watching this experiment which has been set up for sometime and then wondering ...?... and asks the teacher if he has all the oxygen in there. Do you think there's any teach-

F: ..... surely the teac-er the student is engaged in some kind of thought he's thinking about this. Er probably the teacher has left it I mean the experiment has been running for some time so er he's probably just left it at there and er left the kids to think about it. I don't know if he has ...?... the environment where he is, er awaiting something, some kind of question like that. Surely the kid's learning something I mean he's thinking about something and if he finds the answer to that he'd remember it. I would. (Mh) I mean asked this question and I want the answer to it. So he would internalise it he's got to learn something from that. So yes the pupil is learning something I don't know what or how far teaching has been done. (Ok.) Surely the student is thinking. (But you're not sure whether there is any teaching taking place?) Mm mm. (Do you feel that you need more information to know if) Ya, ya w-what environment, did the-did the teacher just come and set the experiment and leave or was it explained, did he leave it for sometime so that he'd created the environment where he knew and anticipated questions from students,(MH) He set up a few questions on the board, things like that. Or did he do statements for them to react on.

I: Ok. The next one is on a student baking. You have a student at home is following a recipe for baking a fruit cake.

F: Has he learnt anything? Er (Is teaching taking) Is teaching taking place. Well if he can follow instructions then its fine we can all do that, but I mean we all can cook but none of us-I don't think everybody is chef. I mean we probably all can follow recipes but say for instance if something goes wrong we don't have enough sugar we've got to improvise. Then if he's able to do that then he's learnt. He's er-he's been taught, you know the skills of-of improvising. So if he's been able to do that then he's been taught. But merely following a recipe and er I mean anybody can do that to follow a recipe, ok to the extent that he's taught to think from step to step, and that-that's good. (Mh) But as far as er further levels of being able to improvise and to think that now what do I do I don't have enough sugar or something (Mh) Er then I think that might be lacking, but if you can follow a recipe you are taught to think in a systematic orderly way. (Would the person be taught at the time of following the recipe? Is there any teaching taking place?) No, he's just merely following the recipe I don't think teaching is happening, I don't know why I'm using sugar, or what sugar does in baking I don't know what the yeast does (Mh) I don't think I'm learning anything just following instructions.

I: Ok. Now we are we're looking at questions about teaching tasks. Do you have any experience in teaching?

F: Experience in teaching? Er except for er the two week experience that we had before and a bit of maths tutoring not much.

I: Ok. Err I have here a list of tasks related to teaching and er I would like you to rate each-each aspect in terms of how important it is sorry how important do you think it is to know it to do it well. Ok. Whether it is crucial that that you know it, or it is just important or it is desirable but not important. Or any other rate that you want to give it. And er I would also like you to state your present competence in the task. (Ok) Ok. The first task that I have here is controlling the class?

F: Is it important? (Ya) I think it's ya. To an extent it is very important you've got to control the class so that everybody has the opportunity to learn. I mean you don't have a bunch of guys at the back of the classroom making rowdy noise disturbing the rest from learning or-or thinking about stuff. So yes I think it is important to control the class erm-erm-Are you talking about noise there and stuff like that? Er (It could be any kind of control) control er, showing you an authority that you you're the one who is controlling of the class, and pupils should pay attention to you ya I think that's important. Ya it er and I mean there should be a bit of er row-er-noise in the classroom that allows for interaction with peers but-but er constructive noise you know {pause} to an extent there should be control otherwise you could be side tracked completely from-from-if you if you want something done and ...?... (Ok)

I: Er, monitoring students progress? {Pause} Is that crucial?

F: I think its important I think its important because er I mean ...?.... stems from there how do you monitor their progress I mean how actually do you do that, how do you know that someone is actually understanding if someone has the ability to interpret to what extent are you going-But I think its important in that to a certain level yes you assess if someone knows so much and if they are lacking in some kind of er skill or something you can then and-and address that. Yes there should be some monitoring where a child headed ...?...

I: And selecting material to be learnt

F: I think that is vita-er (crucial) crucial ya I mean er you should -bearing in mind that its the pupil that's learning not your choice you know coming from the background of the pupil and wh-what would be appropriate for the pupil, yes the material that has been given to the kid should be wisely chosen in developing you know er should to ensure that they develop well so to speak. I mean you can't tell how someone is going to develop thought processes are, yo can't guide that you can't say this is how you must think about something. But surely you can help that along to a ceratin extent ya

(Mh)

I: Er serving the students as a source of knowledge and skill

F: Well erm {pause} Like I said before you know you should there as their full guide and as a facilitator. (Mh) I mean we learn as well in that processes. And er, so we are there, yes, as someone who they can come to for I mean they have their processes sorted out then they have internalised something. But if they have a problem dealing with science processes and they come back to you (mh) they can you know er re-address and stuff like that. So (So you ..?..) I don't think its er like er solitarian I know all that I know all the skill so you come to come to me and I'll tell how all-this is how you should do it. Ya sure enough you develop skills and stuff like practical skills and use things but you there you know as a facilitator.

I: So you wouldn't think that it is important to-to serve the students as a source?

F: Not as the only source. Sh-ok I know more but "more" right and you can come to me This is what I'm telling you, you can go and find out from other books from other research and stuff like that and ye ya you do help them.

I: So you don't like the way it has been phrased? (the ..?..) Ya I mean that the teacher will serve the students you don't want, I mean not that you don't want in your opinion you don't see a teacher as the only source of knowledge (No.) The other task is adapting material chosen to the level of the students.

F: Well with the curriculum and the syllabus that we were given I mean we may be dealing with a mixed ability classroom and stuff like that. And yes the material has to be adapted I think. But I think it's important that you adapt it you provide with to suit the needs of the classroom and more so now that you're dealing with ...... {END OF TAPE} (You were referring to the South African situation) Ya, we'll be dealing more with pupils from varying backgrounds varying abilities, langauge problems, and comprehension and things like that. So yes the material has to be adapted but not to the level where quality is er you know eroded, I mean we got to have to cut down on the quantity but and quality should be there should remain but adapted. Adapt the material but don't forget that it should be sound (Mh)

I: Ok. The next one is instructing students on the demands and procedures of learning, do you think that is important?

F: Instructing students on the demands and procedures (of learning) of learning. I don't really understand that.

I: Would you think that err a teacher (MH) should be-should know how to instruct students on the demands and procedures of learning to be able to do that, I mean is it important to do that teachers know that, Know how to instruct students on the demands and procedures of learning.

F: Err {pause} well I think there is certain amount of er a certain amount of knowledge that needs to be transferred to students and stuff like that. Erm {Pause} Yes the-I mean we've got to keep up to date with work and things that have to be done on time and stuff like that. I think it-it's not the fact hat we give up a set of work by the end of the day or bring back their homework and stuff like that. I think surely it is important to keep a record of where you are or where they are (Mh) But err-err it's what they gain from it which is more important. Yes to an extent it is important to make known that you know this is where we be headed to, this is the procedure. (Mh) the pupils should be aware of where they're headed ......

I: Mm Constructing experience for the students to interact with the content.

F: Constructing experience (for the students to interact with the content) Telling them how they should er I mean und-undertake the practicals. Erm. Yes there should some extent of some guidance, I think, but experience is something and individual is or engages in for themselves. So erm er yes it should be guided but the experience that they derive form it would be individual (mh) for every pupil So you can't construct it or make it convergent. Yes they should be guided. They would then learn from it. (Ya) That's where we have a problem with outcome based teaching, you know objectives, terminal behaviour (Mh). This is what I wanted kids to be able to do at the end of it. How sure are you that kids would be able to that, what if he doesn't what then. I think we should facilitate the fact that you know we are dealing with individuals. I have a bit of a problem with class based experience.

I: Ok. So far we-we've looked at the importance of or crucialness of these tasks I mean knowing how to do these tasks to be able to do them. Er what is your present competence on these tasks?

F: Well I have'nt had the opportunity to control a class I mean its ??progressive stuff like that (Mh) but er there is-well the fact that I have the theory about it I mean I'm thinking about it-it would have a bearing if faced with these situations when I go into the classroom (Mh). How well I do it I wouldn't know I mean I can think about it but actually doing it like controlling a class I may have ideas this is how I would do it or how it should be done. But as far as actually doing this stuff (MH) um I have'nt had any experience. And I guess it's something I will learn when-when I do teaching-prac teaching. But surely err having an idea about it would structure the way I would be doing it. (Mh)

I: Err, my next few questions relate to the work that you have done so far. {Pause} Can you tell me about the courses that you are doing this year or topics that are doing for your HDE.

F: My HDE I'm doing the science methodology physics ah mnca physics methodology, additional physics as well, (Mh) that's more of general science at std 6 and 8 and then biology up to matric, ok and we are doing theory of education, then computers and a language endorsement, I think that's it which I failed hopelessly {Giggles}.

I: So in your opinio-your physics additional studies (Mh) is that right (Mh) What are you actually doing there?

F: We deal a little bit about the history and how you know like Aristotle, and Carponecus and stuff like that, about the history of where physics and new science developed and stuff like that or a bit more about the historical background. (Mh)

I: So you are not actually looking at the syllabus?

F: Er there are aspects like the misconceptions and things like that I think we dealt with a bit in science physics. I think er M3 er mentioned theories about circuits and stuff like that ..?..

I: That-Wasn't that in the methodology?

F: Mmm No there was a bit of that in the additional studies, a slight bit ya know like er deal with misconceptio... of er ideas, so we dealt a bit with it but otherwise it was just more theory and history which is a bit ....?... down the history to see what went wrong. (Do you think it's helpful, the additional studies?) Helpful?, Err {pause} (Would you) to an extent having a bit of history is ok. I would-I would have thought that the additional studies would equip me more as a science teacher, like you know dealing with say misconceptions, what these are generally in science, err how to deal with them, how to be more competent in the science classroom as far as setting up experiments, more practical, something applicable, I mean I can take back when I'm leaving. History is ok to a certain extent, err I can read about it. I could have read all about that if he had said to us. But I thought additional studies would be where I would be given a little more of science coaching (more of the content) Ya (that you need in the schools) schools Ya, ya. I mean I'm not, I fear it a bit but I'm doing science up to std 7 and stuff, but I'm in a bit of {parse} fear of it because what if I don't know enough or something that's not in the science., I always have that horror but err I-I would have thought that it would be more constructive in a sense.

I: If-if you were given an opportunity to-to make some suggestions (Mh) In this particular case, you may suggest something but it may not be taken up (Mh). Ok. Wh-what kind of suggestions

F: As far as the additional studies are concerned? Yes they should be, ok we are dealing with a bit of history, we need that to deal with science and answer questions properly ... history of science I think it's important but as far as the rest of the course is concerned It should have been a bit more coaching in science dealing with our misconceptions, misconceptions that may arise in classrooms erm you know dealing with actual classroom situations, {pause} ya more relevant applicable stuff (Ok).

I: Err my last question I hope none crop up later. How do you feel about the way the course topics have been handled so far? That is in the research methodology (Yes I-I {frowning} research methods?) I'm sorry, physical science methodology?

F: Physical science methodology? As far as the whole entire HDE course is concerned we are dealing with a lot of repetition. I mean asa far as this textbook analysis or text analysis was concerned, we did it in core science, we did it in biology and we did it in science all within a week and it is frustrating and it has happened before with other topics as well (Mh) Er {pause} It's informative in that we have we are made aware of ideas and things that may come-come about, but err, I don't know, it's like err {Pause} I know we have to analyse curriculum make you know, be aware of what we are dealing with and stuff like that but I just don't feel that we are actively engaged in teaching , maybe I'm just too err I just want to get into teaching as such without having the background knowledge ()Mh). But er the are times when I felt why am I doing this and things like that. I'll keep note of it as we go along (Ya. So have kept a note of last week's er) Last week's ya I mean we did so much text analysis like in the core and stuff like that it became a bit frustrating.

I: What was it-why was it frustrating could it because you did it (Three times) three times (Mh) So was it he same-same book?

F: Err We have a basis, The-I mean we have a basic idea about it but doing it over three times is a bit too much. If you have an idea, I mean we you have an idea about something you can apply it all across-across the board. (Mh) And doing it three times is really a waste. Er that's more, that's another thing, I came in I think we should be given more erm of these things like how do you look at textbook at one-one you know at one workshop and erm not being asked oh why do you need to do it or something. I know I just-I've been having a bit of a problem as well because I find myself cutting pictures and making posters more of the time as far as biology is concerned. I mean I could be doing something more constructive, more helpful you know. This is what you look out for this is what you should be dealing with and things like that. I think I'm being treated more like erm as children, a child {Both laugh} a pupil. Well then hey I'm gonna be a teacher soon, (Mh) an adult you know what I mean (ya). I thinks that's what ..?.. as well. Like I said I was made more aware of er more of the idea of about teaching and learning process itself and stuff like that, that's good. Erm but as far as, like for biology, putting up charts, er running a lab and things like that, {pause}, maybe I'm a bit lazy in that I don't actually want to run a lab you have to collect animals and things like that. (Mh) Erm I don't know it's er it's becoming a bit frustrating after the first few weeks I want to quit the HDipEd. That this is just too much for me (Mh. W-w-where were you getting too much work?) The work was too much. (Mh) There was just so much going on. I mean like it was repetition I mean I'm to do analysis for biology I had to do analysis for science in the same textbook style (mh) I mean we one for that and then we do another one for that and then we do it all the time. It er it becomes its frustrating me because you spend so much time little assignments and typing up stuff, and things like that. Er I don't know it just becomes a bit frustrating.

I: So what would you prefer things, how do you (how would I prefer it?) things to be done?

F: Of course er as Mik-I meen I do realise that it is important that we get some kind of feel about-about things you know be aware things that happen in classrooms and stuff like that and er things that we can't do in classrooms and stuff like that. I think it should be a bit more constructive. Erm, actually like we don't even go out to classes, I mean schools and see different schools and things like that, engaging in that I mean we don't do that. (Mh) We only go to specific schools when we want to prac-teach. But you know actually sitting in on classrooms err seeing what happens, giving lessons. Oh! for biology we got quite a bit of practice with it giving lessons and critique and stuff like that. I think those were-those were good. (Didn't you get the same in) We had one in physical science (in biology you had several) We had three ok. (Ya) .... (That-that you found useful?) Ya ya. That was profitable because everybody did different lesson, and the giving specific things ended in like teaching skills, prac and things like that. And then from there we could discuss you know what the loop holes are, what you need to be aware of those were more concrete stuff which we could deal with.

I: Wouldn't you feel that if the same was done for the physical science methodology (You - e again) it would be repetition?

F: Ya again it would be repetition you know, I don't know how they could structure this. You know. (Ya) I thought that when I was doing the physical science methodology that I'll be taught how to do science as well, I mean doing experiments, and actually learning how to run a prac, practically doing it. (Mh. But you don't see it happening ?) {makes sound from back of mouth meaning no no.} Nothing happening, and I just get frustrated with all these assignments and write ups and things like that. Oh yes it's part of the game. (Ya you have to play it), you learn from it. (What's this saying I think if you can't do something, if you can't be on the opposite side you have to be on the same side som-something to that effect) Mh mh If you can't beat it joint it or something. (It's ya ya ya) {Both laugh} , (If you can't beat it join it) But then it's only for this year, right?) Ya. I've spoken to others who have taught already, and coming only now then to do their HDip.Ed. , and they find it very informative. (Mh) So surely, I mean I find it frustrating now in the end I'd err

I: So w-would you would you have preferred to be in a school situation (mh) before coming back and do your HDE?

F: I suppose that was the two weeks experience aiming to do hey, erm I think a bit of both, I think you know going to cla-er going to school with my methodology teachers and stuff like that you know different types of schools and picking out what the problems are, may-being aware of these in real life situations and then coming and then readdressing them (Mh) and the we run in classrooms and then consolidating and then going back to teach and see how these things work. I think that would have been a lot more constructive. (Mh) But surely a bit of theory has to be the way of .... is important.

I: Ya thank you. {The discussion went on and part of it was not recorded, then I decided to continue recording}

F: ...... misconceptions. And then those were not adequately addressed and related to school, how do I deal with that (Ya). My own misconceptions (We all have) Ya we all have misconceptions {Both laugh}

Ferrial's second interview. At School P. Date: 16/09/94
Venue: Residential place, P. School.

I: So maybe you could start by just saying what you experienced, ho you felt how things went on in your classes and the problems you had. and how you went around solving those.

F: Ok. Er Well, when I first begun here, well er it looks like well I never taught before. (Ok) This was my first experience. Er [pause] so er I was, before I begun here I wasn't quite sure what it is exactly I'm here for to teach, you know what is it I want as a teacher the goal that I have as yet described for myself and I guess it is understandably so, I haven't taught before. Er well after the first, well things were really nice I'm glad I came her I chose it because it was different from government schools and err something different I new the experience would be different not only for teaching but for myself as well because I'm staying here at the school so it was more than just a school that I was involved in it was getting involved in, it was the atmosphere in the community (Mh) as well. So er I'm really glad that I did that and that I'm really glad for the experience, looking back. Erm well after a week of teaching up to two weeks of teaching well it wasn't that I found myself lagging behind, lack of control er not sure you know didn't quite know the ?.... flow of the vibe of the classroom, er what is it that I was trying top get across to the classroom and etc etc and I was er helped by Stella and Ann when they got me to sit down and talked about things ... you know for me to get more structure and they gave me advice and things like that. Then after that I got a lot of support from them and encouragement and things went much better. I would I really worked hard you know. I spent hours planning, thinking about things, it doesn't come quite easy to me. (Mh) So preparing a lesson I become quite anxious and it takes quite a while for me to think about something when preparing a lesson, something new and something different something creative it takes quite a while. Er and how to teach etc etc. Er er well as far as that is concer-I'm slowly getting I found that the last few weeks I'm not doing much work it becomes a lot easier to do the lessons and things like that. You more or less access out what the class is able to do the time and things like that. (Mm) Er as far as the crits are gone I found the science, er, well as far as M1 is concerned she was very supportive and-and er gave lots of good advice er that kind of thing, er always asking what I thought how I would do it differently I like the idea to be warned that she's coming, which isn't the case in biology. (they just rock up) {some laughter} They just, they just rock up and hope to see something innovative when you may be in the middle of a section and just continuing with work. Then you get critted on that lesson which is not as exciting as when you began with it and that's supposed to give them a feeling of where you are (Mh) and you know I don't think that's fair. And er another thing it's like er (Don't you think its a way of getting you to be, .. up to date) up to date. Ya sure enough er you know I'm saying if you like. For instance today I got critted by Ann. I started yesterday with doing data response and skills. Today was me and what I did was the aim of that lesson yesterday was to get them to work in groups I assigned them to be in and then answering all the questions, give them the time to answer all the questions then gave specific questions to each group. And then they had to dec-consolidate that answer and then one person elected as leader had to come to address the rest of the class whi·· I thought was a good skill. (Mh) Which keyed on today, ok where I left yesterday because they didn't complete. And er (the biology group?) Yes that was the biology group, that keyed up today. And er well the crit that I got was that it was fair it was just average it wasn't good. (Mh) Well I begun that thing with the aim and I you know and er its just that its the lesson needed to continue it was no other way I could {pause} (ya) do it. I had to finish the work before, that kind of thing. So it is a bit er, I don't know {pause}. It is, well a lot of good ... es off being critted, you do find your own faults and things are highlighted to you. But you know judgement being made and surely a judgement does then leave er a feeling, you know kind of first impressions last that kind of thing. About the lesson somehow I feel it isn't totally fair. (If they had to pass a judgement or something like that) Well ya. Well I guess therefore we get critted more than once, because its the cumulative that comes at the end. Well it's been ok. Er I've learnt quite a lot that's what I was here, I guess if I knew everything I wouldn't be here. So I-I accept that their course? ... and er that I'm here to learn. But its been a good experience (Mh).

I: Erm, how do you rate your lesson? How successful were they? What happened that would make you conclude that they were successful? (If they were successful) I'm talking about those which were successful. (which were successful)

F: Well I find that a lot of group activity an activity where they were left to fully think for themselves, I'm talking about std six biology (Mh) now the kids enjoyed that and er I was also told today that I do a lot of fun activities instead of teaching which I disagree with as long as there is learning taking place (Ya). I'm quite happy. What I did today was er I introduced the lesson as a competition. 'Who would like to win this year' You need to follow these instructions these are the rules of the competition. And that's how I organised the class in ... and they had to work through a crossword. They were given the closing date of the competition etc etc that kind of thing (Mh). .. And er well the crossword although fun weren't or needed or required that they er use their books for the whole section of what we've done so as to find answers in order to fill it in. So surely revision was taking place there. They were using some words that language skill, in which English was being vocabulary was being t-propagated there and er working with someone else as a pair (mh) the thing about competition working within a set time ....(some deletion by mistake) by the pupils in a lesson like what {pause} an ... would do for this one then I'm really glad they have learned. I've taught something, they remember something. And I'm sure when they get the results of this crossword, the correct answers something they're going to remember.

I: So you feel that those lessons where students were having a bit of fun while they were learning were more successful?

F: Yes. Well I felt content. (Mh) Er and they seemed to be happy as well, they enjoyed as well. (Did you give them) They ... worksheets as well (worksheets?) .... (Ok. So did you conduct some kind of evaluation of that to see how much they learnt and so on, did you give them a test or something?) You mean the crossword? The crossword was run as a test (Oh, ok) One group got all the answers correct. Ok, so I'm glad about that, everything was done. I didn't expect them to write everything, to complete the crossword, I had to give them clues on the board which I did. (Ok) They got a few of it right which it seems some were almost there. So, yes they have learned the section. They know the section.

I: So you feel that those objectives you set for the lesson were-

F: (Yes, I think so. I would seem to thing so. And er ya er well the std 8 biology I've been doing things such as tissues. I've tried introducing things by using common day examples etc. er it worked ok but I felt that I needed to get across more conten. in this case here because in the exam they will need to know how to identify this tissue, there is no other way you could have learned that unless you have been taught or told how to do it. There were various skills that I tried to bring in like writing skills, making your own paragraphs, looking for topic sentences things like that, which I brought in as well which helped them with their notes in biology. With science er mostly worksheets, also a lot of-encouraged group work, assignments, well there was one assignment and for std 7 as well (Mh). And mostly worksheets where they have to, left to conduct their own experiments to find the answers. I didn't do much teaching yes I agree. I wanted them to come up with the answers. I don't know if it was that successful. Er you know and er I don't know maybe I guess you find that out after you have given a test or evaluated it.

I: So besides the worksheets which other teaching approaches did you use?

F: I used videos, ok I used videos what else did I do, er practical work, a little bit of fieldwork in std 6 biology they went outside and did some work; conducting their own experiments and setting it up and practical activities, video and overheads and board work, crossword puzzles and whorly words.

I: Were all of these done, were you made aware of these during your methodology or some were just methods you decided to use?, even though they were not discussed?

F: Well Ya well [pause] I never really reflected on my methodology, the teaching methods that I was taught. Maybe I did in a subconscious way, but not with the intention like er I would be doing this as specifically said in my methodology notes, (Mh) that kind of thing like for example like graphing skills a did as a mini-lesson in my methodology which I gave here as well. Bu I reworked? it from my evaluation from my methodology lesson and I used it quite effectively. So yes I did use staff from my methodology.

I: Lets look at lessons which you feel were unsuccessful. What happened during those lessons?

F: Well er I did have a bit of a problem of control at first, (Mh) structuring and timing. Well the rapport got better, the control cot better the timing also, the way I gave homework what I gave as homework. Er well I'd find myself, well as part of, well stemming from the personality that I am er, I'd usually remember things after or I'd try to rectify what I have done, seeing my mistake that kind of thing, I may not foresee it while planning (Ok) and then I'd usually end up giving an instruction that I hadn't thought about during the lesson or during the preparation a bit later. But I would know that even during the next time I did it I would include in my prep. So it was not useless because in the end I did learn. Er what else? You are being tape recorded {referring to her room mate. We all laugh}. Well er the incidence with the std 7's was er was very upsetting. I've tried very hard with the std 7's. They are known to be a notorious class in the school. so I thought let me do my own work, trying to make the effort with them in technology, as well as in science, preparing good worksheets, let them do the work, would help and let them get involved .... its a more attitude thing that kind of stems from them, you know you get stared down imagine, after giving them an instruction and they will look at you like what the hell are you speaking about (Ya) What happened in that lesson was er I just felt like I was in this primary school with kids screaming at me and er no one listening to an instructions that was taken, and me having to scream and I couldn't handle it (ya) that kind of thing. It was an experience. It was a lot of experience. It's only made me stronger, a little bit harder. I just hope that it doesn't mean I have to be laizaire about it. It doesn't matter. Sure enough different situation award different er {pause} you know approaches and responses (Mh). And if something like this happens again maybe I'll be able to handle them.

I: Was this the first time such an incidence happened?

F: Yes. This was the first time.

I: I'm wondering if they were not trying to show off in my presence. (Well you heard remarks that you were telling me about) Ya remarks I heard that you wouldn't make it (Ya). Ok. Now, Stella, was she sitting in some of those lessons or (Yes. She used to sit in most of the lessons, especially with std 7H). Was there each time when she wasn't around, when it was just you and the class besides the day when I in? (Yes, there were, there were times. And they behaved ok. Its was, well it was a Thursday afternoon lesson. At the end of the day they don't really give a damn. It's a tug-of-war kind of thing.) So the way they were behaving could have been (stemming from the last period, your presence maybe, and I don't know maybe its the attitude as well). Ok.

F: But there have been successful lessons with them. (And you were conducting your lessons along the same lines you were) Ya (in the same way that you did for the one on the Thursday afternoon.) Well er {pause} One where I thought I had total control was when they were taking down notes from an overhead transparency. (Ya) Just as long as they got the notes down we don't need to learn it, we don't have to do the work, they will learn it when the exams come, just as long as they have a note. But what I find when it comes to a practical activity they become rowdy and disruptive and they take their time because they've got to do the work now. (So in other words) they sound (there is some kind of laziness) Yes exactly, the lazy element give us the notes and we will study it for the exams. ..... (Ok)

I: It would be interesting to find out from Stella how they how they behave, how they conduct themselves in her class, if they have the same attitude that give us the notes and we will do them for the exams we will study them for the exams. (Ya) And when it comes to practical work then it seems to be problematic. (Yes it's always a ......)

F: Yes its always a ......

I: Erm let us look at the content. How confident were you in the chem-I mean with the science? ....

F: Confident? (Ya) Well I found myself really learning a lot of things. A lot of things became clearer for me now than they were at a school, that kind of thing. Well I-when I when I first heard that I was teaching acids and bases and reactions and combustion to std 7's I thought oh my god I know nothing about acids and bases. But I learnt as I taught. I'm glad that this has been more that just a teaching experience because I've learnt myself. (Ok) Er, and like I mentioned to you before I wish there were we were also given lessons on misconceptions and things like that. Er my misconceptions being exposed students' misconceptions and the answer the real answer I mean to the present misconceptions (Ok) and how it really happens that kind of thing. Well I guess the information that you are going to be teaching has to be learnt. I mean you can't be taught that in basically methodology, or you would be going through school again (Yes) So I guess it's something we have to learn as well. I have'nt been stunned by any questions that I didn't know how to answer er what you usually have to do with kids is that you can maybe I had to think about it or I did have an answer. But surely you do learn again, relearn the material you have forgotten in order to teach.

I: How helpful were those lesson you had with M1 on acids and bases.

F: Well I did, I must admit that I used er the lesson on indicators of acids and bases as one of my lessons (Mh) which was nice and I planned to use the neutralisation as one er you know one example after I have that neutralisation exercise with the 7K as a fun thing as a competition thing as well, but which didn't er materialise. Er the sad part about the teaching prac is that I had to share lessons because I couldn't take the full set of three lessons for week for 7K or 6A. You see I couldn't er usually my lesson had to be continued by Stella or completed by Stella. So like where I missed out periodically on a lesson and er you know the thing which is a bit sad. But er I used some methodology ideas, My resource file came in handy as well. But I guess that's just by mere luck because I had the appropriate things that I needed. But surely its some thing to help into having hint. Ya er {pause} there were bits and pieces that came in handy but er, from the methodology.

I: I've heard from M1 and you have also confirmed it that you were taking the students for some technology, (Yes) with ST whatever. (Technology, ya) How has that influenced your teaching.

F: My teaching? Well technology is basically a new subject at school P. they don't have any fixed syllabus (Ok). Er Lorana is not really a technology teacher, she's a science teacher and it's also her first time. The approach that she uses is design and then er you get your materials you make your thing then you implement it to see that it works, that kind of thing. The problem here was, that Lorana seems to find is that the design and in the design they want materials that are too expensive or can't be afforded too. I suggested and approach in which she is giving them the materials and designing from the materials that they have, in order to cut down on costs kind of thing. Er I don't know if it works and there are these students who are conscientious and who are that way orientated to make things, but then three quarters of the class seem uninterested in technology. They would be interested in baking cakes, that kind of thing you know foll-w-ing a recipe and doing it unthinking for themselves. It's funny when you think it would be more adventurous to design your own. There are a few that yes get excited about. The rest aren't and I was amazed. I would have thought that people would have been ya-hooing about technology. But they just seem to be agh, it's another free subject (Ya).

I: What did you say are your resources? (For technology?) Ya?

F: Well what I did with technology was I my curriculum package lesson. Instead of doing it for science I did it in technology and I used that class as my volunteer group. (Mh) What I did at first was to give them a bit of background information about physical methods that were used, that I used to clean up an oil spills and then tell me what the consequences are of oil spills. And then I told them a few of the methods that are used (Ya). Ok and then er what I did was to get them to the library with a worksheet set up and questions they needed to answer about oil about oil spill. And at the end of that double period they needed to have designed more or less something that would help them in a simulation 'clean up and oil spill in a pipepan', kind of thing, which did not go very well because I wanted them to design something give me a list of what they needed, more or like er technology where they do the design and then give Lorana the sheet and then she purchases the materials they constructed and then they do the whatever. So that's what I intended but it didn't work out because no body came with the list, they never completed the work. They went into detention after that and half of them pitched up for detention. Detention is not effective here. So what I decided was then to run the practical myself. To simulate I put them into groups I gave them different materials, set out in worksheet, simulated an oil spill in a pipepan and some water and some oil. They had to work through a worksheet by-work through with different material such as cotton wool and er string, cloth, see how well they clean, they had to time how long it took and effective and how clean it was. After they have done various materials they would then on their own try to use a combination and see the quickest time, that kind of thing. And then after that they consolidated it consolidated it together and er they do have the question that they did a week before in the library work plus the worksheet that they did at the lesson that I gave as a report which, I'm gonna wait till Tuesday. That's what I did basically. I did it basically because for the moment they are waiting for material to come for the projects that they planned four weeks ago. The costs are just too much.

I: Isn't there a fee charged that? (for technology?) mh (as a subject?) Ya. (if you choose technology and then you got to pay?)

F: I don't know maybe they should consider something like that. But it's a private school and they pay quite a bit of fees anyway. (Ya)

I: While we were talking about those misconceptions, you were saying that you wish that in your HDE you would have been in a position where you would expose your own misconceptions and become aware of other misconceptions. Didn't you do it in your additional studies in chemistry?

F: We were given basically in the additional studies the history of chemistry and the history of physics. A bit of misconceptions yes, but we were never really given the right answers in the end. (Ok). You know that this is a misconception, this is a misconception (what ..) but what is the right answer?. (We had a little discussion yesterday, you remember about the molecules) Ya I know I -I still look up the way I've been teaching it is the way I h-you know the kids are looking at it as they have been formed analogies with people, people as molecules and things like that (Mh) So I don't know when you say, when you told me about heat not being, the molecule is not heating up I can understand it as it being er as maybe between the molecules? probably I don't know.

I: Well the way I look at as we discuss I could have been wrong, it's just that when you heat water {pause} er what happens? The temperature rises (yes). What temperature, is it the temperature of the water or that of the particles?

F: Well water is made up of water molecules. So wha-are you talking about the spaces? (It is the whole thing that is being heated up) Ya. (But I'm not sure I think I'll ask this in one of our discussions) Is the temperature of a single molecule or the temperature of the entire thing? (Ya it is the temperature of the entire thing, it wouldn't be the temperature of an individual molecule) Yes (but it is the activity of the molecule in its vibration) That's making the heat (Ya) Ya sure. (The way it is presented there is that it is that it is the actual molecules) No, well ya, the way I tried to do it with conduction was to tell them that a molecule was carrying a package which was heat from one person to the next person as it vibrates or ran along (ya) as in the relay race and the baton, (Ok) that's how I tried to teach heat conduction. (I wish I had been there.) You can check through the lessons. (I still need your, i shouldn't record this I still need your lesson plan for today, and maybe if I could look at the one on conduction) Do you want my file on Thursday? (Ya I think I would like to borrow it) on Thursday? I'll give you everything on Thursday. (Ya. Mh what else is there ......) {A question was asked which was not recorded} I tried to spread it out but sometimes I get the response that I don't know and no matter how long I wait I know I'm not going to get an answer. (Ok) That has happened with std 6As, you just get a blank stare and it goes on and on. And if you for an answer and you try and prompt they seem to get upset. Erm I'm trying to think, er especially with some of the kids in 6A they are a slower class. And because of the pressures of the peers around as well, they seem to laugh at them (if they give an answer) or they don't give an answer or ya. If they don't give an answer they get upset the longer you wait because everybody else gets anxious as well (Mh) And to try and avoid that and to move the lesson up as well because you never finish (ya). Well the knowledge also sometimes of er you know er what the problem areas are and things like that as well.

I: So you are not sure whether you are going to be teaching next year or not?

F: Well I'm going to apply .... ya I guess I'll be teaching but I eventually want to get into environment education. I think I'm a bit hasty in wanting to get into it quickly I realise I have to taking step by step. There is no way I can get into it immediately I need the education and I need the confidence and so forth, but teaching is a step towards that. We can start environmental education in school where it is needed and things like that. So yes. (So you er) So er-I'll be teaching, I'll be going back home in the Northern Transvaal, I'll have to go back home and do my teaching there.

I: Going back to the place where you will be furthering your interest (Yes) in environmental studies (Yes most definitely.) Thank you very much.

Ferrial Interview 3:
Date: 25/10/1994.
Venue: 17th Floor University corner

We met in room 111A in the chemistry building and moved to the university corner because it's more peaceful there. On the way we talked about a number of things including the reasons for the number of interviews I have with each of the students. Initial tape recordings are continued below:

I: .... ya that's basically why we have these two interviews (mm) to see if there has been any change (change) ya that's why we have these two interviews. Ideally the first one should have been at the beginning of the year before you actually read the stuff (.....) before you dealt with the course but since we start at about the same time one gets focused the first quarter or third of the year (ya) I had to (ya). So once again thank you for coming (you're welcome) ya. Like I said I hope it doesn't take long but it all depends on how much we say you know as we-we proceed with the [pause] I want to call it a discussion (ya ya) mm (ok). So er I will not ask you questions about yourself because I don't think any of that will change (Ya I don't ...... the same) ya they'd it would still be the same . Just let me (Now you're more lost than you were before) Is that how you feel? (No I don't suppose ... the course is .... you know wha-wha-what do I do now finding a job) Well I thought you-you were settled for that one, you're going back home (mh) probably you'll start teaching there before you actually go into your (my environment education) environment education.

F: Er well there isn't a-a high school, an english medium school at Portgieteruis which is a bit of a problem. (ok, high school?) Ya there isn't any English medium high school and what h-what has happened recently is that there are English speaking white people in Portgieterruis, but who have had to travel to Pietersburg erm (That's what you have to do?) Ya that's what I ad to do because there is no English medium school. I mean even if there were even if there wasn't a white city girl.(Ok) Ok. Now what they want to do is make this school which is legitimately Afrikaans where there can exist. I mean if they have English speaking students in the school they cant make it strictly Afrikaans. So what they want to do is load off-dread off ... those English speaking people.

I: Ok are you saying that there were Afrikaans (There are Afrikaans) English I mean Afrikaans speaking schools

F: Yes there are only Afrikaans medium schools with English speaking pupils. So what they want to do is get rid of these English speaking pupils so that they can strictly become legitimately, legally Afrikaans medium school. (And you can't teach there either) And I can't teach there either.

I: What about the other so called black schools (ya) are there any there?

F: It's not in English as well (Ah well.) There's teacher's Training College but I don't know if I can get in there. I'm going to apply and see what happens. Well there's Pietersburg which I haven't applied as yet but I'll try. (Ok. I wish all the best) Thanks (At first it's quite difficult to get into it) Mh (I suppose some of us were lucky because we just knew that once I finish my degree the government will take care of me going to school to teach.) In Swaziland? (Ya)

I: Basically there are no formal applications though you do sign some forms that's all (mm. Ok) Ya Ok. So the first set of questions as you see there will be on science and teaching (and teaching) ya. So I would like to get your understanding on some of the things there. For instance the first one is what is your understanding of the word science? That is what does it mean to you? What does science mean to you?

F: Well science encompasses um a lot of things as would be-as a lay person before I would have thought of it as strictly dealing with science and chemistry and inventing things and theories you know and hypotheses and stuff like that. But it encompasses a whole lot of things um socially politically, economically as well. Talking strictly of science as we know it in-in-in teaching. I think it's a lot of things it involves a lot of skills a lot of thinking um a lot of you know all the cognitive affective and psychomotor skills, and er it's something that's ever changing it's always changing (mm) Um it's just something that helps to define the world and describe the world around us (ok) to make sense of what is going on. (mm Ok).

I: And then scientific knowledge? (scientific knowledge?) What do you think is meant BY scientific knowledge?

F: [Long pause] Scientific knowledge is someone who has a broad um knowledge about science science like science the topic, the subject science (ya) But again any kind of research any kind of knowledge whether it strictly science or say in this field say social anthropology I would think it's some kind of scientific knowledge (mh, Now how do you think er this) this knowledge has been produced? (has been produced?) Well its by our observations, by our theorising by our um er doing you know experiment and practical activities (mh) over the years accumulating these and going further progress and so forth. (ok).

I: I think we can skip the third question. Lets look at the fourth one. What teaching strategies would you consider to be more effective for teaching science to secondary students?

F: [She reads again] What teaching strategies er would you consider to be more effective for science teaching to secondary students? Er well I don't know. We are talking about a new South Africa and different schooling system. Um I may um talk of strategies that I may have read in books by they-I don't believe we can just take them out and plug into a South African situation. I think we are dealing with you know ideal classrooms and a new-whole new situation um where different and varied strategies and mixtures of these need to be considered. we need to consider um um social you know social backgrounds and stuff like that you know in order to implement some kind of er strategy but I don't think any one is er-can be proposed as to be - as the ideal way. I'm not so sure how to-on how to deal with this you know in the new South African setting. But I do believe that strategies that incorporate pupils doing their own thinking their own experimenting (mh) and bringing all domains to be effective um in dealing more with science and technology and stuff like that. You know from pupils you don't know what they are are exposed to from their background developing science on that socially constructed knowledge or something like that. (So bringing all these er) ya I mean there's a lot more to consider in the classroom. (Ya. Ok)

I: Now what do you think of the suggestion that er many students develop their own theories to explain nature and sometimes you find that these can be-are substantially different from the-the so called scientific theories?

F: Ya. I think-yes students do. I have-it come with-er to explain nature it can come from er cultural backgrounds (mm) um religion and stuff like that um can have a bearing on what pup-what how pupils explain certain things er and sometimes these can be subst-yes ... are different from so called scientific theories. (So you do agree that students do develop) yes (theories) yes for our upbringing background what we perceive on our own as well (mm Would you have any idea what causes them to be different from the scientific theories?) Well er when-when we begin-I mean when we're born-when we-we-we communicate with our parents with our environment with our society (mh) and we - it could stem from what we get in from that surroundings you know what we develop ourselves. (Any idea on how they differ from the scientific theories?) How they differ? (How they may differ?) How they may differ? (mh what differences could there be?) [Pause] I don't understand. (In what way)In what ways do they differ? do they differ ya?) Well sometimes something can be imposed on you, you see for example your culture may say you know concept say heat may be explained by your culture and this is completely different from what scientific theory has about the concept of heat (Ok).

I: Um. Let's-How would you consider students own theories when teaching? Maybe you could start from how you did if you did consider them during your teaching practice. Did you take them into account?

F: I think we need to know considering that we are dealing with the cult-with classroom that is multicultural (Mm) We need to consider what pupils own conceptions are of certain things are (mm) erm from their social - from their statements that stem from their social background. We have to construct knowledge from there (mh) so we do need to take them into consideration. (Were you able to do that at P.?) Bring erm Well I must admit that I didn't pay much attention to that. When I taught things such as radiation, such as convection and currents and stuff like that, I taught it to them but I never stopped, I think I failed greatly in not um you know addressing that and asking what they actually thought it was.

I: What do you think the problem was for you to do that (Why) To be able to address or to look into what kind of misconceptions the students had? (Why I didn't?) Ya.

F: Er I just wanted to get through the work erm that was basically it. But I know now I should have er sat down and seen maybe by way of probing, you know speaking to them or even questioning and seeing what their own concepts are. Well it's not strictly for er multicultural background or-or for a new setting, but also for any class I think it would be good to get pupil's own conceptions before you begin the lesson and then try and construct from there. (ok)

I: You've had some experience of teaching. So in question question 7 I would like you to briefly describe you theory of how teaching occurs. (Of how learning occurs?) of how teaching occurs

F: ... we going to get a new Vygotsky here and Piaget Erm well in a lot of group work and a lot of teaching, a lot of learning happens in group work (mm) I noticed that a lot of kids communicate with each other disc-discuss with each other and er a lot of learning happens there um it needs to be more pupil centred and where pupils do much of their own thinking more of their own work, (mm)and I'm sur-I believe that is when learning really happens (ok) and er pupils are actively involved. (Mh). As far as teaching is concerned um with science I believe there are certain facts and stuff that needs to get through, But I think we should be taking more er-er facilitator role (ok) Um ok we can give students some facts, ok, but dealing with problems and stuff like that in order top see how these things actually work (mh) they should indeed do it themselves, or discover it for themselves I think that's the best learning. And the best learning is when they do it together in a group. And the whole setting of the classroom er we should like you know the content should be what should be learned for the year should be decided by the teacher and the pupil. And we should er I was thinking erm like in modules, do certain modules and then I give them the facts that they need to know for two weeks together should discuss the problems that I handed out to them come up with solutions, that kind of thing. Dealing with theories or the concepts that will we've given them. I think that's effective because they're applying them, learning about them and solving problems with them. I think that's effective learning. Where they actually do-they actually mimic what is actually done out of school. (Do you have any theory of how teaching occurs?) How teaching occurs? (Mh. You have focused on) learning (learning) I tend to do that because I believe-I don't really like the word teacher or teaching. I believe it is learning that happens. I learn and they learn at the same time (mh). Um it's just that I'm facilitator role their learning so it's more of facilitating than teacher. (So you see your role as that of a facilitator?) Ya. I hope to but I don't know if I've been effective in that. Erm (what's your problem with teaching or teacher?) With teacher? (mh) Is that you always need to erm-well looking back on how I experienced as far as teacher was concerned. It was very stifling. We had to get word-wo you know --- through the syllabus through the year. There wasn't much-I've forgotten everything. There wasn't much I had learnt. Even if it was science-even if it was basically about filling in a form outside of school those things weren't learned you know. Things that were m..... things outside of school (Would you consider those teachers to have been teaching?) Teaching? (Ya. To have been teaching you even though you didn't learn? Or you have forgotten what you _) well now you're looking- I'm looking at it from a different angle now. If they were teaching erm I don't think I've learned anything. Er then their teaching wasn't effective (Aha) [Pause] Maybe I have to define clearly what teaching is-it can be put in many differen ways (Is it). Um when you thinks of teaching you think of it as the usual ... the teacher comes up gives you certain things and you've got to do it in the way that you are taught to do certain things. Er that's looking at it in one way. And then you look at it from the learning-learner perspective you think of some answers as teaching has-hasn't been effective (Mh) When you think of it if I haven't learned anything then teaching hasn't been effective. Teaching may be also being pure facilitator (mh) That may be teaching. (So there could be teaching without learning?) There could be teaching without learning? (mm) Ya like - .. sound like I'm a bit confused now [both laugh] (Maybe now that you are confused you'll start thinking about it.) Ya. (and figuring out which is which) Ya. [pause] (Ok we could go on we can go on fortunately there are no right answers or right-wrong answers here. I'm just trying to find out what ideas you have about these things.) Well there seems to be stigma attached with teacher teaching taught, ya those kinds of terms. Like you wanna be a teacher and er that kind of thing. I-I er and look at it and therefore you have an image of-or a definition that teaching that well isn't good or teacher isn't good [laughing] or teaching (ok) isn't good. But if you define as-as parting with knowledge and giving someone else knowledge (mh) or the ability to do something for himself then teaching is good if it's done in that way (ya) you know. Ya.

I: I think that is fine I think we can look at the next one the next of questions here [turning over the page of the schedule]. So these are actually instances and non-instances of science teaching. So you have to decide which (is teaching) illustrates ya, which is science teaching, that's why I think I've underline science teaching (ya) there because I'm interested in that one (....) Ya science teaching. And then whatever answer you give as yes or no, I would like you to give reasons why you say teaching is taking place or not ok. Um [clears throat] We have a teacher handing out (crystals) ok in a std 6 class and then asks the class what they can tell him about the crystals passed around the-the (class) yes.

F: Ok I would have done this maybe differently. What I would have begun before handing out the crystal asked students what are crystals ok and then got what they think bout it (aha) and then possibly get hand out these and ask "are these crystals?" (ok) ok and then see what er what they can tell me about their structure, what they look like the form etc. (Now in this particular instance would you consider science teaching to be taking place or not?) [pause] Well basically what is happening is that they're told it's-it's crystals (mh) and all they are doing is basically describing form and structure which can be done in any way I can describe anything see. I (Mh) Maybe not not as effectively but you have a sense of it. Er maybe it's increasing their descriptive skills [pause] Yes and no I don't know [laughter] now I don't know (You can't really decide which is which) mm mm. Well if it's on the topic of crystals at least you could have started - big you know the lesson differently (Mh) So in that case I don't think she was every effective. But er can you tell me about passed around the class I think it's a good way of getting people to to talk and describe (mh) [pause] so yes and no (it's somewhere in between) ya. (ok).

I: Now let's look at the next one. A student watching TV at home (mh) on a programme of chemical plants produces from coal-plast-chemical plants producing plastics from coal [F clears throat] Do you think science teaching is taking place here?

F: Well the pupil is learning something hopefully. He's watching something, he's hearing it and he's visually seeing it. I'm sure if he's interested he's sitting at home watching a program on chemical plants erm that he's learning something. If not in the true scientific form of things maybe just er well in these programms you're watching TV on how bottles are made or something (mm) but yes he's learned something about a process (ya) So I think ya some tea-learning has happened. As far as science teaching erm [laughs] again Victoria you've got me. Science teaching is happening erm [pause] no I don't think it's effective teaching alone as a programme. It needs to be backed up before and after the programme. (So what you are saying is that science teaching is taking place but it is insufficient?) Ya (it's inadequate) Ya-ya (ok) ... he's probably learning something, he's being told things ..'s learning something. But as far as science is concerned I think it needs to be backed up. (Ok).

I: Then we've got those students in the library working on problems. [Reading] Two std 8 students in a library working on a set of vapour pressure problems from the chemistry textbook given for homework.

F: Ya I think learning is taking place here. They are working in a pair er they're doing problems and I think it's only with problems you know that you get to learn better. Erm and if the problems are of a type-well if they are from the textbook erm well I hope they are of a type which is linked to everyday then I think it's more forceful (mm) But I do believe learning is taking place here and it seems effective, ya .. (Teaching? Any science teaching taking place?) [pause] Ya pupils are t-being taught to work together as a pair (in this particular situation, they are in the library) ya (they're working is science teaching taking place?) [pause] Science teaching? (Ya, while they are working on those problems) Well they're teaching themselves. (Ok. So science teaching is taking place?) Yes. (Right).

I: Erm we have a university lecturer [F laughs, both laugh] you remember this one? lecturing (on molecular orbital theory to a small group of grade ones) Do you think science teaching is taking place there?

F: No I don't think so. Er I don't understand it and I'm not in grade one. Erm [pause] on molecular orbital theory, it depend at what level he's teaching molecular orbital theory. I don't know if he can take it down to grade one level but I do believe in the bit-in the when Piagetian themes that erm you know there are stages of development and I don't think grade ones are gonna take any of this in (Mh). I don't believe any science teaching is taking place if he is - he or she is lecturing on molecular orbital theory at the level we know-we are supposed to know it, to a small group of grade ones. No, he's just probably confusing them. No teaching is ta-nothing is done here and nothing effective is done here and I don't think the kids are learning anything. And I don't think any effective teaching is happening here. (Ok. This is a classical one) [both laugh].

I: Ok lets look at the fifth one now. Teacher questioning an student's statement. A teacher reads a std 8 chemistry student's statement that "ideal gases have no volume" and asks "were you referring to the gas particles or the gas as a whole"? Do you think science teaching is taking place here?

F: [Pause] Yes mm it's making the pupil aware of the statement he's-he's-he's put down "ideal gases have no volume". He has to define now whether it was the specific particles that he was talking about to or the gas as the whole. (ya) Ya so yes the pupil is-is um is learning something and he's got to think further than what he's just put down and look at various-you know he's got to make definite what he's talking about and the teacher is probing further. Um so yes erm there is um [pause] teaching in the sense that learning is happening yes. (Ok so you are assuming that learning is taking place?) Ya. (in this situation) Yes.

I: Now we've got a teacher asking students to label a diagram at the end of a demonstration on electrolysis of water ok. [pause]

F: .... Um Well erm I don't see the use of this but er -erm yes if indeed if the teacher believes that erm these apparatus whatever that are used in electrolysis are important to know then you know then yes it may be effective (Science teaching?) Er Science teaching [pause] ya you got to know the things (mh) and you got to know what the stuff are and there's no two ways about that (ya). So I believe yes in the method labelling the apparatus used in the experiment from memory (mh). Maybe she could have used the things and specifically shown them what the things are and asked them what it was (Ya it is at the end of a demonstration) OK (It says teacher at the end of a demonstration) So she needn't have er-if she was going to get it from every pupil then yes but there was demonstration to refer to I think ya-ya (science teaching) so they-so they have learn what the things are (and science teaching is taking place? [pause] ya ok ya. (Ok).

I: Can we go on to the next one. (Ok) Um we have a student asking a question. A junior secondary student in class watching an experiment on the electrolysis of water which has been going for some time asks the teacher " do you think you've got all the oxygen out there already. Do you think science teaching is taking place here? (Um) Student watching .... a demonstration which has been going on for some time and then asks the question.

F: Well um they're watching an experiment (ya) that's purely a demonstration. They could have done it themselves and then tested for oxygen themselves (mh) that would have been more effective (ok) Ok. I mean Do you think you've got all the oxygen out of there already I would have thrown the question back to the pupil. What do you think er (mm) and possibly the teacher could have said anything and-and the pupil could have taken that for plump (some interruption from MSc students who should be having a discussion here)

I: Ya we've done number 7. Ok. (Mmm) Student baking. Student at home following a recipe for baking a fruit cake. Do you think science teaching is taking place there.

F: No. He's just basically following a recipe. That is basically carrying out instruction. He doesn't know why he's using or she uses a certain ingredient or what one does to each other or how the whole thing becomes a cake in the end. I don't think any teaching has happened here, he hasn't learned anything so it's following instructions and the end with a lovely fruitcake. (So neither teaching nor learning is taking place her?) mh-mh No. (Did you want to say something about those?) No I'm just thinking about teaching and learning. We-we it's only in when we're doing it practically that we realise what works for us and what doesn't work. (Eh) And what I think my concepts of teaching may be different to what others believe and may not even go according to the books but if [another interruption by an MSc student.] (Sorry about that interruption.) It's alright. It's just that you know-you're you find your own niche when you speak about what works and what doesn't work (YA) about teaching and learning. (I suppose that's true).

I: Ok. Let us look at the teaching tasks. Er I remember last time you hadn't had any experience (mh-mh) whatsoever with these (ya) I'm sure your views have changed (they have) .. other time and maybe some have and others have not. Ok. (I .... sometimes relate it to teaching ... each aspect ... think how important it is to know how to do it well important Mm. So would you-what do you think about controlling the class? Do you think it's very important or

F: Yes controlling the classroom in important. Erm I'm not talking about strict disciplineering you know (ya) But having some kind of control over the class where erm ther-there may be noise. Um maybe control as well (ya) you know er in-in a way that things get done where-where teaching and learning are able to um happen. So you need to have some control over the classroom Yes. So I think it is important. So in this scale of crucial, important and desirable, I think it is important. (Ok). I think it is important. (And your present competence?) In controlling the classroom? (Yes). Well erm there were days when I felt that my control was good and there were others as well where it was not no good. (Mh) But er if differs from day to day. I think I'm getting there and in organising myself also in the classroom so ya I think I'm getting to a point where-where I feel I'm more or less in control. But I can't describe exactly where-when it will be, what it is, but if you know there was a point where I felt I was more in control of the classroom, the classroom is more in control of themselves and yes it is conducive to the teaching (Mh. So you do think it is the role of the teacher to maintain control in the class). Um I would say that I would have said it before that it's half and half, you meet halfway. I believe that kids now don't really care about controlling themselves er (mh) so it becomes a duty of the teacher, and I she should do it she should do it in a way that um well is acceptable to both, conducive. It's more the role of the teacher. Yes.

I: Now the task of monitoring students' progress.

F: I think that's crucial. (Ya). I think it's- it's vital because then you know that something is learnt or not. How it is done or when it is done to what extent it is done etc, that I'm not so sure about ... if a test is adequate in monitoring er students' progress. Um I believe more-more problems and modules of problems are more an assessment of students' progress in-to having them write tests. A variety of these can act as monitors. () I think it's important it's crucial (ok) that um-um students are monitored. (Mh) In various ways. (And your competence?) In monitoring students' progress? All I really did more of the time was where they'd re-what they had to say things to me I had done before to see if they had really learned something. You see we had test. We even had little crosswords in-in biology where they had to recall you know. So I could see to an extent-I even had a chat with the pupils, not all of them but a few in ...... (So in other words during your teaching practice you did try to make attempts) to see how much they've learned, how far they are progressing (ok)

I: And then selecting materials to be learned

F: Well I think it's import-ya I think it's important to select the materials for the students although some of the things are not necessary (mh) are totally over the top. I don't think they should be um learnt. So I think selection should be made on the basis of what the students know and on the background where they're coming from what is important to them. Sort of a survey of what they thing is important. Also ... what you-you-you regard as important for them. That er ya selection of materials to be learned should be, ya that's important too to select material. (Ok. how-how competent are you in that with the little bit of teaching practice that you had?) Er well er you need to get through the syllabus and see the things that need to be taught because I mean they're going to write an exam and they're gonna be tested on it (yes) Um but there are -um you know there are certain things that are emphasised with-with as far as biology was concerned I did more you know they could-the ecology aspect, the environment aspect it was emphasised the affective domain was emphasised. Um I still don't know-I mean I don't-I'm not knowledgeable with the material an-and what's out there (mh) what pupils know what kind of (... in the task of selecting materials)mh (to be learned, you may not know the material now, but you may feel that put in the situation again you would be in a position to select appropriate materials to be learned in the class). I can say that well I f-what I think is more or less important (ya) you know. But I don't know if they are indeed materials but then again I think it depend on the student and what their needs are as well and their outside needs to (ya) to make a selection. (ok).

I: Now serving the students as a source of knowledge and skill.

F: Like I said I always like to play the facilitator (ya). Um so um [she rereads] Well I have a certain amount of knowledge over them and maybe-maybe practical skills that I've learned over them. Erm er I believe yes I maybe a source (mh) in-in-in some in them wanting further information of knowledge and skill (mh) But I see myself as a person for - to whom they'll come when they do encounter a problem or they can't get any further with what they are busy with. (Mm) So um yes a source of knowledge and skill but not the [stress] source. (oh ok. ... So how would you rate it?) Well it's-it's an important source as well. (It's important to be a source?) Yes. (But not "the" source?) No. Not the source. (Ok) The only source. (Ok). (Er have we answered the) competence in the task (competence) in the task (Mh) Of being a source? Well I-I find those times when I would answer and I would feel ye I know [laughing] and er but I think I need to develop that as well in my knowledge and skill and I think it will come over time. But I erm the problem arises when you see things more clearly and you try and transfer that source of knowledge when they try and extract it from you, when you give it to them from what you know from what your mind says believing that you understand it the say way that you see things the same way. (mm) And that serves a bit of a problem you know when you transfer that .. in the transference of that knowledge and skill, you know doing it in a way that students do understand. Ya um well my competence is not as well as ...be. Or .. I may have the knowledge and skill but my transference

I believe is more important. (Ok).

I: Now adapting material (chosen to the level of the students) Yes.

F: I think that is important as well. (mm) Important [pause] important not crucial important that-yes we can adapt things to the level of the students but I believe it's important, it's very important because they have to get some kind of understanding and some kind of hope they'll formulate their own pictures in understanding it. But erm not to the extent where we don't give them the truth or the real thing so (Mm) Is it you know knowledge as it stands but um I think it's important to-to adapt it to their level so that you know its a stage of understanding (mm). You know we can go further from there. It's the way I have learned using analogies and bringing things down. It's how we learn it's how we read a book or pictures (ok) and images. (But it shouldn't be at the expense of truth) of the-ya of (I mean the truth and both .....) Ya. (ya) .... They should be made aware of those things even though you're not teaching it or telling it to them (ya) they should be made aware of it. (Ok) Instructing students on the demands and procedures of learning. (Mm) [Pause] Are you prescribing the learning process? [Pause] Well-well you can't strictly you know demand that students or pupil learn in a certain way (mh. But anyway that demands and procedures I think it's what is demanded from them by their learning process.) Like what they are going o give me back like in a test for example

I: Ya what role-what is their role in the learning process? basically. I think that is what this question is all about, instructing students on the demands and procedures of learning in a way preparing them for the task that they are going to face during the course of the year.

F: [Pause] Ya er (What is expected of them) Ya well sure enough they should be told what is expected of them and I think that's crucial (mm) I think that's very import-crucial that they should be told what is expected of them. Yes but um [pause] then again this is er-it depends on the teacher (mm) what he or she sees as important to learning and which way he's going to conduct it the learning you know, guide the learning process (yes) Um [pause] well it like for example if-if I-I was a disciplinarian and said you've got to learn this and this and this and this is what you got to know at the end of this year. People you know this is now you're going to learn it and you do as I tell you. Well I'm not keen on that but I do believe that people should know that you know this is what we are aiming for (m) erm you know-er this is how it stands and er but in the interim they've got to construct all of that to come to the point ya ((So you feel that you have to meet them halfway-take them-) ya (halfway) mh (or a quarter way) ya (and then they have to make their own) Mh. (so you feel that is important Ok). Constructing experience for the student to interact with the content. Yes. I think that's-that's very important. It um I mean that pupils experiencing because it's only ... experiencing that the pupils learn and the interactions that they actually learn. So yes erm there should be construction of content with a lot of experience (mh) I think that's very important. (Ok. And your competence?) Competence? Well I tried a lot of practical work erm where and er group work where they had to come and tell me things and interact with the groups and consolidate some stuff, there was a lot of interaction um and er not all the way, I don't think I'm competent in the task of constructing experience I think I'm still learning about that (ok). I ya. (Mh)

I: Ok. Um a question that I would also like to ask you which is not there. What is your general opinion of the way things have happened? (The HDE over the year?) YA the HDE or

F: Well-well on practical teaching I found that there were things that were useful but on the overall I guess being there is a whole new com-is a whole new cup of tea compared to the HDE course (Mh). Um there were certain things that were useful like for example some mini lessons like in biology that were very useful. They had emphasis on group work and encouraging skills and practical work that was very useful. Er-er-but there seemed to be lack like I -like I can understand the right answe-of the right answers the way to to do things. You know I mean um if-for example the chemical bonding I feel I have been totally dismantled. I had a pictures of chemical bonding and what chemical bonds are, totally dismantled it's not all been put together. You know I think that's one really serious problem that needs to be addressed with the HDE. (mh) The rules and the one brought me back down again. Erm that's a serious problem. I um what else and then there is a statement that

I hope the HDE wasn't one of tips sometimes I believe it could have been it sh-it wasn't but it um it wasn't I hope it was-I hope it was um because sometimes I wish they could have told us a little more of how to do things or to go about and with stuff like that. So if it wasn't tips then what it is was [another interruption] (Sorry about that) I've gotten used to that. (It was the last one. So you were talking about the problems you experienced) in the HDE (and limitations) I think ya well the thing is as far as science is concerned we could have had a bit more of mini lesson on how to do certain lessons or how to do skills work , how to do like for example graphing skill, how to teach certain things, how to even teach chemical bonding could have had a constructive, you know demonstrations on how to do those things and get us involved in those things. I think those would have been more useful. For example take problem areas in schools and the syllabus, not all of it but problem areas and general consensus and then do lessons on these here bring out the misconceptions erm what the current things are about them and then doing a lesson on them (mm). I think it could have been totally constructive during the year. Addressing things like that, teaching and learning is important, evaluation is important doing these lessons is important. Um a-a lot more emphasis on the new science and what-the way science is going in the new South Africa, I think that was lacking. I mean we are dealing with dilemmas which which I think not Martha just bringing the issues which we mu.. know for the discussion or as such and no answers we.. I suppose there aren't real answers but you know certain view ..ts and things like that. Making us aware of these things and I think it's been totally isolated from what teaching is gonna be next year. We have been made aware that it's gonna be different, but-but how to what extent you know (mm). I think that should have been addressed more ya, those things. An-now we did core science today. And there were students who were brought in from Parktown Girls and other girls' schools. They talked about teaching and stuff like that, they brought out their documents they talked about you know abut their teaching experience their first year teaching experience basically. But I don't mean to be racist in any way but here I sat at the back, there was only two Indian there in the class and they talked about TED and everybody chatted and laughed about the TED and then they you know teacher's meetings and stuff like that which we were totally excluded from (Mh) as teach... I'm not a teacher but I know they weren't and I felt you know we could have had people from-from DET and different teaching organisations erm or departments to relate their stories as well their triumphs and tribulations as well. And I think -to make us more aware of where teaching has been the last few years and where it is going to as well. (Ok) All we've heard is the TED. (So you feel that it was biased in some way and some of you were left out) Ya (and I suppose if Dominic was there and Patrick was there they would have felt left out) Most d...itely (... ... Anything else?) There's something I thought of last week [laughing] but I have forgotten. Was it the mini-lessons ya (I'll tell you what if you do remember just jot it down) I'll do in my sleep (just jot it down .... Is that a limitation or a good point? It may have been just the mini lessons because I know that was one of those. It could have been just that (Ok) I think like-you know it should be broad as well but also specific you know to a large degree in the mini-lessons you know demonstration of mini-lessons and things like that ...

I: [With a sigh of relief] Thanks again. (That's it) Ya. That was the last. (You shouldn't .....) Thanks. (You're welcome Victoria.) I hope I haven't-I hope I haven't taken a lot of your time (No you haven't, Ya well I wasn't in the mood of studying, I'm not in the mood, I'm never in the mood of studying.) But one thing I'm grateful about is that you in the process you learned something I have) it wasn't a teaching learning thing but ... (I have .. most definitely I have sorted out a few things for myself. It made sure I kept things in mind which I don't really and you made me aware of things myself by having to write them down (ya) which was you know required of me. That was quite helpful.) And I'm grateful that you did take it upon yourself to-to keep a diary even though it wasn't something that you have done in the past. (I never kept a diary also er but er I'm glad I did thankful to you) Ya thank eh . I hope when you do your studies you will find people as co-operative as you have been (I hope so)[both laugh] (Thanks) Ya.

APPENDIX 4: Fieldnotes for lesson observation on chemical bonding

Fieldnotes for class discussion on chemical bonding.
Date: Wednesday 22/06/1994
Time 08.00

Notations: .... inaudible.

I came early today. I was around by 8 O'clock. M1 and 4 HDE students were present. M6 came in at about 08.05. M1 showed her the storeroom.
At the start of the lesson M1 introduced the lesson by referring to a handout she gave them yesterday. She went on to count the students. 13 were present. Ferrial and Mary were also present. Andrew was not yet present.
M6 was then introduced as Lecturer at College A (arbitrary), and that her MSc. project was on chemical bonding and designed worksheets around chemical bonding with particular reference to the TED syllabus. Students were also informed that the learning material in there tackles misconceptions and chemical bonding.
M1 informed that what was happening this year was different from last year. Before students were taken through with no thought of how to use the right ideas in the secondary science classroom.

M1: From teaching practice (TP) people ignored what happened in the lectures, used notes and school textbooks. Others ignored syllabus and textbook .... Others grapple to bring right ideas and text. ... want to get students ideas on how to cope in TP. In TP .... [the students are given an assignment. Mary seemed to think it's a small assignment, students complain that they have had 9 assignments to submit before they go on mid-year vacation].
M6: The aim is to make students well equipped for the topic.
M1: How many people are panicking about trying to do this assignment?
M6: I see a genuine anxiety. If you were-well all to think of every bridge you've ever seen, every bridge you've ever seen or pictures. If you were going to build a bridge what material would you use?
Ferrial: PVC [students laugh]
M6: PVC. Ok.
Charles: Concrete, and steel bars.
M6: What bridges have you seen?
[She continues soliciting ideas of the kinds of materials that are used to construct bridges. Students give their input. The following materials are mentioned: PVC, steel bars, stones, brick.
Charles: The bridges in Venice are made out of bricks, [M6: Stone] the arches....
M6: Bridges in Britain are old, even some ... that are made out of stone. So in other words they have been worked in this stone which is cut in an arch and is .... for over 2000 years. What else?
Kate: There is a rope with .....
M6: Ok. Can you build a bridge of plastic?
Charles: Maybe.
M6: ... Why do to think those materials have been chosen, why do we have some debate about plastic? Would you pack sand together to make a bridge? Why are there types of bridges which wouldn't ..... Why are they not able to-why don't they last? Why don't they .... etc. What is it....
Charles: They are not strong enough. They break easy.
M6: They are not strong enough. Why not?
Charles: They are made up of material; that break easily.
M6: What is different about them: steel concrete, stone, wood, rope, plastic ....
Brian: Strong bonding.
M6: The topic of this week is bonding, ok. Strong bonding between what?
Brian: Between the atoms.
M6: Alright. We are going to ... we set that entirely, but we going to explore materials and we are going to look at what is ... level that I believe in std 6 and 7. The present state of the syllabus ... std 8 and

9, we are going to move very shortly in 10 minutes to ..... current std 7 .... compulsory education and I have never ... chemical bonding to std 6. Because what is essential in our lives and the materia' we ... and the properties of those are very largely dependent on ie type bonding and so if you want to make sense at all about materials ... we've got ... and some of my whole ... that I developed a couple of years ago is .... our next year or so and hopefully you would have a hand in adding to evaluating work chemical bonding? What I would like to see is that as we enter the phase of education we've got to .... something on chemical bonding. ..... It doesn't deal with quantum mechanics because the std 6 and 7 child is not interested. So it deals with real practical aspect of chemical bonding that affects the kind of material that .... helps them to defend them why we ... those materials. But now M1 said something about the syllabus [that it was fine but our interpretation was wrong]. What I actually did was quite an interesting exercise ... I had a look at the things that are .... I'm hoping that by the end of the session we will be able to work within the syllabus. Don't worry that you haven't read .... Teachers have to stand now ... certainly I hope ... text. Ok. Now I just want us to think for moment about ... the kind of materials ...... What other properties would have an effect on the chemical bonding? Can you think of other properties that are determined by the kinds of bonding?

Charles: Possibly the flexibility (M6: Flexibility) of the material.
M6: In other words breaking.
Brian: Melting point (M6: Melting point)
Kim: Conductivity.
M6: Conductivity and heat conductivity. What's determined by the bonding structure?
Stud: Density.
M6: Density that's the packing determined by bonding. What else?
Kate: Appearance.
M6: Appearance. Ok. Then lustre, what else?
S2: Colour
Brian: Phase
M6: Phase. Yes. Solid liquid and gas will be determined by the chemical bonds. We have looked at a few properties of matter and they all link to chemical bonding. Think about aspects of everyday life ... choose substances on the basis of those properties: density, ... kinds of washing powders that you use, detergents, polar molecules is very important. So the forces between the molecules in a detergent and the dirt and the material are very very important facts ... So I could go into virtually every single area of life and you will find .... bonding.... So lets move straight to .... what we are going to do is on the pages-have you had-you need to see pages CB? up to CB4. So we are going to do these 4 exercises photocopied out of the package that I have prepared for teachers which looks like this completely unreduced. [Showing them photocopies which have been reduced ... worksheets with design used in the classroom and which have been used successfully by many teachers .... Right we set out there stations, I think we've got 5 groups 2, 4, 6, 8, 10. So lets have 2 or 3 people in each group. You will find a set of 7 test tubes.

[She briefly goes through the worksheet, precautions and what to do, and then gives the students time-20 minutes-to do the exercise in their groups. Meantime she moves to groups giving students pins to scratch with: wax, copper, quartz, sulphur, iodine and calcite. She continues giving hints.]

M6: You don't need to answer all the questions in writing. Ok. So you could just glance through what you need- #1 name of substance .... Then just look at #2 at forces between atoms ... at the beginning of test ..... Can just leave #3 and start with #4. 1, 2 and 3 are to help the children to be able to see that there is a difference between melting and burning. We want to focus the idea ...... So if you start with samples in a test tube and you fill in this table. Use the pins to break the substances. You can handle all the substances except the iodine. The iodine is on a separate piece of filter paper. So just take the iodine and pour into the test tube. [Students break into groups and start working. After about twenty minutes she calls the students for a discussion of their observation. She draws a table on the board to record observations] And altogether lets run through our table. Ok.

lets take what .... simple molecule. Ok. Now std 8 or 9 even 7 don't know anything about what simple molecules could mean .... so they deduced what is in this column from the investigation but this column written down as per instruction because they haven't been exposed to those terms. ok. Copper [pause] yes. (...) network. Quartz, which are little stones picked up from outside, strong, network. What do we have for sulphur? Alright simple molecules. For simple molecules ... Iodine?

Ray: Weak (she writes in table on the board as shown in Table 1 below.)

M6: Calcite. I chose calcite because it is available in most laboratories. It seems to be on the list of things that were supplied certainly in the majority of schools that I think .... But many out in rural areas in Lebowa and Gazankulu too. ok. What here-

Ss: Strong and network.

M6: Was the.e another one? Is this all that you did?

Ss: Ya.

M6: Ok. I had iron as well. The iron would obviously be strong and network. Ok.

Substance	Breaks apart	Melts or sublimes	Weak or strong forces	Simple molecules or network
Wax			weak	simple molecule
Copper			strong	network
Quartz			strong	network
Sulphur			weak	simple molecule
Iodine			weak	simple molecule
Calcite			strong	network

Now what we need to do then is to say what do we mean by simple molecules, what do we mean by network molecules. So at this point in teaching std 9s I would then go on to explain what I mean by that. Now a simple and in fact in this hand out there is a definition of what is a simple molecule and what is a network structure. I don't think you've got the handout which defines them. I want to write it down ... I think the best way to explain this in std 8 is to actually draw the diagram, but I'll give you the definition first. It consists of unlimited very large numbers of atoms joined in 3 dimensions by strong forces which we call chemical bonds. [Allows students to copy down dictated definition then draws circles on the board] and the overlap of the circles represents a strong force and this would represent a force of attraction ... though a bond network ... So any of those substances we have written down here then ... could be represented by this structure strong forces between adjacent atoms in the piece of the substance. .... like this where each of these represents an atom ... represents the strong forces and goes into 3 dimensions. So if you took that little piece of copper between every single atom in that piece of copper ... there are strong forces of holding them together. Now what about a simple molecule .... that. A simple molecule consists of either [draws on the board] an explicit number of atoms joined by chemical bonds or an unlimited chain in one dimension of bonded atoms [labels network diagram]. What does a simple molecule look like? It might be diatomic, it might be like sulphur which we know to have 8 [draws and counts 8 overlapping circles atoms joined in a ring structure. It might be a chain such as you get with polythene. Ok. Any of the polymers are in one dimensional chain [draws] So those can also be simple molecular.

Ray: What about the differences between intramolecular and intermolecular-

M6: Wait you are in std 9. At most you have never heard of (R: I know) Ok. At the moment we haven't spoken of intramolecular and intermolecular yet. No. (R: but ....) We are coming to it. Ok. ... might explain why that one is a simple molecule and why that one is

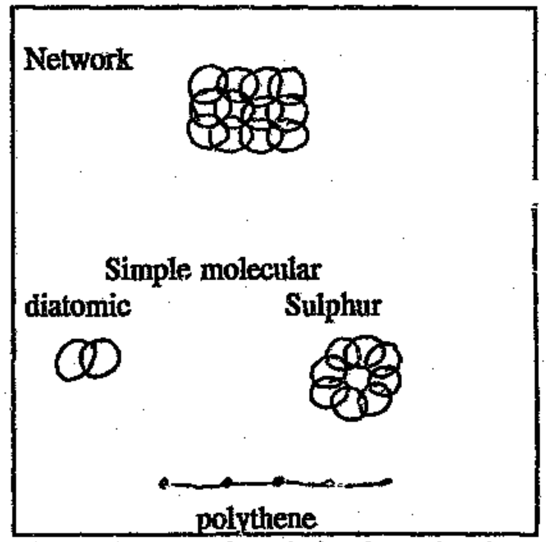
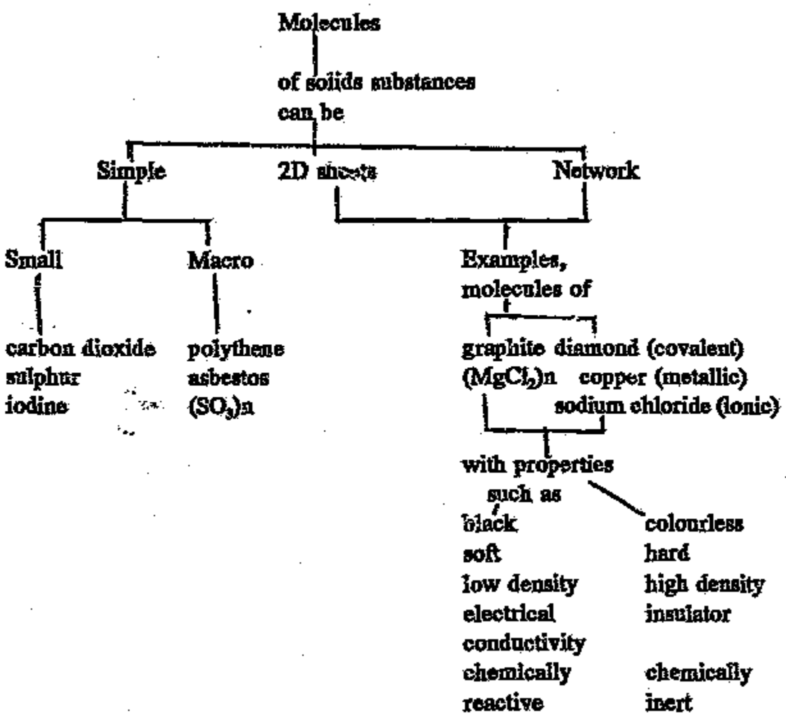


Figure 1 Network and simple molecules

a network molecule. Right ... let's say in your copper, quartz, calcite, your iron is joined to the atoms next to them by a chemical bond, whereas in your simple molecular structure you've got a fixed number and all of those have fixed numbers: sulphur, iodine, wax. Wax is a mixture of different-the candle wax-of different oils but each of them have fixed numbers. Ok. You could for instance break up a pen like this [orange fine pen] and take bits of that polythene ... as an example of a simple molecular structure. Right within this molecule .... chemical bonds ... but in one little piece of sulphur there are many many molecules. You are able to take ... where you are breaking chemical bonds ... where you are actually breaking up this ring of 8 ... What happens there's another molecule of sulphur atoms next to it and another and another and another [Draws clusters of sulphur molecules of 8 atoms] When you break the sulphur with a pin you are breaking the forces between the molecules. So you are not exerting a strong enough force ... that's the reason why you couldn't break any substances because you could not exert a force strong enough to overcome the chemical bonds whereas in simple molecular substances you not breaking chemical bonds .... I've got a concept map up here that gives you an idea about different molecules.



Ok. Now first of all the things that you dealt with were solids. ... and we will come back to that point in a moment. So we are only talking about molecules of substances that are in solid state. .. Simple molecules or 3 dimensional molecules .. that's an intermediate sheet ... when you're teaching it's better just to have your extreme cases .... so that's why I took just those two. So right your simple molecule is a group of molecules of definite number of atoms and can be what we sometimes call macromolecule and those are one dimensional chain ... If we were to take examples of those .... small molecules, remember we are talking amount solid state, ... so you could if you had access to it, use dry ice, you could use dry ice or something else that sublimes apart from ice ... the chains of polythene, asbestos, sulphur trioxide, are just some of these substances and the 3 dimension matrix, notice that I've specifically taken three examples here. Three examples of.... traditionally taught to represent what kind of bonding? ... I've specifically chosen those examples not because I would mention those three words ... just to demonstrate to you that all of those ... network molecules. Right look at those examples that you dealt with copper, calcite do also range ... Graphite is an example of two dimensional solid and so I've just put that in your information. I wouldn't show that to my class because it adds extra complexity .. to show ... The two dimensional sheets are of graphite ... planar. Network structure .. planar ... so it's got ... it's in a plane and it's got reinforces in between them. I've just written down that some of the differences between graphite and diamond .. you probably know, for instance particularly the soft part of the pencil, that graphite is used as a lubricant. Diamond is the highest in the scale as the hardest that we know of in a substance ... That ... makes a difference in bonding, would cause that property. .... density, conductivity, natural conductivity ... result of the fact that graphite is just carbon. So the only difference is the way those carbon atoms are joined together. [Pause] Ok. Now in my definition here, what would you say have I called a molecule? ... (Ss: ...) What is a molecule? Is this a molecule [pointing at network structure drawn on the board] ...

Kate: Part of a network.

M6: Ok. Lets have a look at (Ss: ....) Yes it's a network molecule ... Right we are going to get a definition of a form of a molecule. We are going to call that a molecule and we are also going to call that a molecule [labelling the drawings].

S1: Anything with more than one atom.

M6: Anything with more than one atom. If there is something distinctive that would say that this is a molecule rather than the whole thing [circling group of 8 atoms of sulphur ring].

S2: Bond.

Ray: Atoms must be bonded together.

M6: Ok. So it's a group of clusters lets say of more than one atom (Ray: joined by chemical bonds) joined by chemical bond. Remember we just call that strong force called a chemical bond. Ok. So a molecule then is a cluster. Here's a really controversial one. What would you say a chemical reaction is? [some silence]

Kim: Chemical reactions break and make chemical bonds.

M6: Remember it is a chemical bond, so lets just call it a bond. You break a bond right. Kim said that a chemical reaction is a process in which you break or presumably make chemical bonds. Do you agree? ... I can see a few nods, wake up. Lets hear the rest.... If I take sodium chloride salt and dissolve it in water. is that a chemical reaction? (....) Pardon?

Jim: You break bonds in sodium chloride molecule.

M6: Yes. You are saying that sodium chloride bonds will be broken up so you say that you break bonds. Ok. You are right. Dissolving sodium chloride is a chemical reaction. I would say yes. Some people would say no. ..... M1 is ... clear because this has been an area of some contention. Ok. So you are not making a new substance ... On that basis some people would say "No that's not a chemical reaction" and particularly when you're teaching ... chemistry. If you don't know what a chemical reaction is no wonder many many people in school say "Well chemistry is a lot of incomprehensible rules" ... they can't see the ... Right. We would say then that's a good definition .... If a bond is broken that means that if you dissolve a network solid, a chemical reaction takes place. In dissolving a molecular substance no chemical reaction takes place. What about when you melt it? ... Now remember we said we are dealing with substances in the solid state. ... concept map what will happen? Lets take these first of all, what will happen when we melt a molecule of sulphur? Is it a chemical reaction? Do I break a bond?

Kim: Breaking bonds between the molecules.

M6: In simple molecules we do not have bonds between the molecules. A bond is the strong force that holds the atoms together to make a molecule. Ok. So you know we are not breaking chemical bonds when you melt your sulphur. And when you melt the iodine you are not breaking chemical bonds nor when you melt the wax. In other words that's why it could ... about temperature in test tube over your bunsen burner flame holding it there ... You are able to melt that substance because you did not need a whole lot of energy to melt it ... because you did not need to break chemical bonds. Right. What happens when you melt a network solid or substance? I'm sure you've all seen gold being poured. By the way that's a good example in the classroom because children have actually seen quite a lot of adverts of gold being poured. So they know that you can melt gold. When you melt gold do you break chemical bonds? Well you need lots of energy to melt gold ... So you do. You break up a network structure to make this into a liquid. Right the ... out of their position, normally they've been in a solid held into their position by strong forces into-in 3 dimensions. ... So yes when you melt a network structure you are breaking chemical bonds. You need lots of energy .... Right now as rule of thumb. Over 800°C high melting point, generally indicates a network structure. And up to 800°C for the melting point ... there is a little overlap but generally represents some form of molecular structure.

Charles: Sorry, if there is no bond between molecules then what holds the molecules together?

M6: Remember how we defined the bond to be. It's a strong force.

Ray: So a hydrogen bond isn't a bond?

M6: No. So now a strong force is greater than about 100kJmol^{-1}. Ok. And we find intermolecular forces are the hydrogen bonds [tape ends]. It's not a bond. It's an intermolecular force. It's approximately 40kJmol^{-1}. (S: ...)No. There is big gap. $<$ 40kJmol^{-1} is intermolecular, $>$100kJmol^{-1} is a bond. Ok. ..... (Ss:...) The hydrogen bonds are the strongest o f the intermolecular forces.

Kim: Are you saying that melting gold is a chemical reaction?

M6: Yes. [Students laugh showing some uncertainty about the idea] By my definition. Ok. [Laughter continues] But notice that I'm being quite frank with you. Not everybody would agree with me. Although there are more eminent scientists than myself who would .... Ok.

Ivy: This is your definition. Where did you get it from? If you can change definitions we can also call a bond anything.

M6: Ok. Now the definition on the bonds is well accepted. I looked at ... presented in a paper on the definitions of ... drawn from the literature worldwide and the journals and textbook and came up with something 40 different definitions. ... and then he traced through the decades about the middle of the last century on how scientist had focused on one aspect of definition and then focused on another and so on. At the end of it ... definitely a consensus of the fact that chemists needed to tighten up on what they call a chemical bond and the one that I suggested to you ... well accepted that definition. Could I also say that John Bradley is a member of one of the ISI system international ... that determines standards not only for units but also determine definition and so on for the SR system and has been working for a s number of years on this. ... definitions of concepts. This is certainly the one that he would suggest. He was my supervisor for my MSc. So a lot of what I'm suggesting comes from this. So it's not just my opinion, but it's consensus, it's consistent ...

Winnie: When you're teaching hydrogen bonding (M6: I've always taught in inverted commas) needs to be redefined. It is difficult because textbooks refer to it as hydrogen bond.

M6: But the textbooks make it clear that it is an intermolecular force.

Winnie: But it calls it a bond and that causes confusion

M6: It can and you need to focus your pupils attention that it is actually not a bond and suggest that they always write it in inverted commas. It's probably the easiest way of getting out of it. There isn't ... actually confusion in what's written in textbooks because they quite clarify hydrogen bonds being an intermolecular force. (Ss:...) Yes. Well I've read one journal that calls it ... but I haven't seen it being adopted .... Ok. Right. Now I want to focus on the origin.... Where-what kind of forces have .... chemical bonds? We have said that chemical bonds are strong forces of attraction between atoms.Think about the kinds of forces that we know of ... If you were in physics classifying forces, think about what kind of fields you are in ....

S1: Gravitational sphere; (M6: Gravitational sphere.) magnetic, electrostatic.

M6: Right. Those are basically the 3 kinds of forces and nuclear. Ok. What kind of forces are we talking about when we are dealing with chemical bonds? Are they gravitational, are they magnetic forces or are they electric forces? (Ss: ...) They are due to charges. Electrical charges. I think it's quite important to bring those ideas together in our minds. So at this point, just to focus I ... your attention quickly and do a little bit of improvising. Ok. I suggest that they do at this point ... those of you who have got plastic pens like this one [demonstrates an example of such a pen] Take them out. How many have got one? Over there, there and over here [pointing at three stations where a plastic pen has been suspended on a cotton thread] is a peg and a piece of cotton, a stick or a pencil with a bit of prestik holding it. I want you to rub one of them and put it in ...... Try it out before TP. You should try it out before you start. Ok. Rub your one pen .... rub another pen and bring it near ... [She tries it and the students do the same]. If it works ok. What was it doing attracting or repelling? ... It repels. If we're lucky ... with one of these you can get ... what I really need is something-rule. ... if you find in school socks .... use them. We still got a pen ... What I want you to actually do is spend a couple of minute here's some pens, here's some plastic rulers. Rub on to various item of clothing and see if you can get hem to repel and attract. [students given about two minutes to try this out, so they go to the three stations and try it out. Other are available to get attraction and repulsion forces.] Right folks I'm rushing you, putting two weeks work into 2 hours. ... Can see that's easy enough to do quite quickly. Certain .... on electrostatic forces .... can I just say that this package is available form RADMASTE at the university corner on the 18th floor. It's available if you actually want to buy one. You are welcome to borrow one and photocopy at your own expense. So if you're interested you can use it, you can adapt it ... In fact I would be delighted if you ... you should not feel that you need to write anything down .... Well these are electrostatic forces .... These electrostatic forces are forces between positive and negative charges. You know where the charges originate. You need to focus ideas. The fact that they will have done something on structure of the atom. So that they know that there are protons in the nucleus which is positively charged surrounded by an electron cloud. That's sufficient. Either you can think of your electrons as particles or as a negatively charged cloud. I think that you need to perhaps tell them to think of these electrons in both ways. So you have noticed that we have not introduced the molecular model and we have not done the quantum mechanics model and I think it is inappropriate to do at school level. I don't think it is inappropriate to go through the history of the development of the model ... essential .... dual nature of light and have all you need to do the history of the atom and you should at that point be linking it with the dual nature of the electron. Unfortunately that would have .... So that another aspect that's not fundamental to the teaching of chemical bonding. It is at a much more advanced level. What I say to kids is think of your atom like a light in a dark room. You got a light ... a candle shinning in a dark room. Take the flame from the candle to represent the nucleus and the light shines out from that candle with your book if you come close to the candle you'll be able to read. As you move a little further and further away from the candle .... and eventually you get to a [point where you can't read anymore. If you were to draw a sphere around your candle you would say that's the sphere in which the light is ok. Now I don't mean to say that there is no light out there but for all practical purposes that might be ... Now an atom is just ..... a nucleus surrounded by a sphere of electrons. Let's say that at a certain distance .... sphere we call that a ..... In a sense that's arbitrary ...... electron charges with ..... It also helps the children to realise that the atom is not a solid particle. ..... to something else that we are going to give a term to-interpretation .... atoms.

M1: I'm sorry. (M6: Have to hang on) [She changes the chalk board because one is full, by pulling down a clean one].

M6: Ok. Now we need to look at how does a bond come about. [Writes on the board] this molecule consists of two protons. I will use these symbols to represent my proton [figure 2] and one electron ok. So it's not the hydrogen molecule, it is the hydrogen molecule ion. It has one electron. I have chosen that because that's the simplest situation .... molecule. It has the fewest particles. ..... teaching at std 9 level they have already done vectors ... So they easily deal with this simple exercise. What forces are on those proton .... close to the system on this proton.

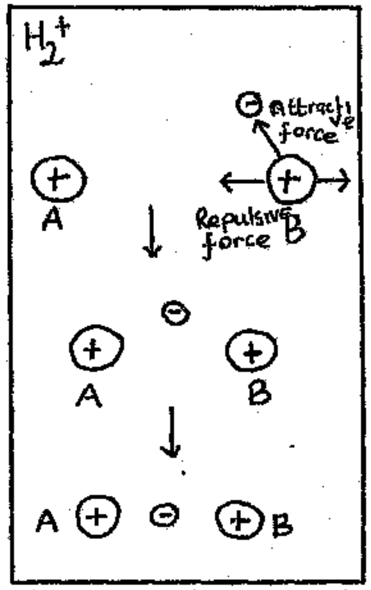


Figure 2 Bond formation in H_2^+

S: Repulsion.

M6: Repulsion due to what?

S: ...

M6: Right. In which direction will that .... represents the repulsive forces of this proton. ...... attraction to the next one. .... So when you do the exercise you need to explain that some of ... some of those particles have negative charges on ... has got positive charges. ... would repel other negatively charged objects but attract positively charged particles. ...

Negative repel negative, the positive .... So here we've got an attractive force and a repulsive force. .... a component of this attractive force in that direction ...... Right. Now if this force is bigger than that one it's gonna be ... and so this proton ..... along this axis until it's balanced by that force. ..... Similarly there's going to be a component .... and in our system there isn't anything to balance that. Actually it's not the proton but the electron which has it's inertia low ... move down but you could also think of this .... system that you would need up with something like that, where your .... forces on your proton are balanced on either side ... forces causes that to move in a line like that. And when you get to that situation you have a bond. Those three particles together because now all the forces are balanced and so there's no reason for them to move apart. Now with that very very simple exercise you can then come to the next point. What happens to our system if we bring another electron into the system there. Now the only way that I get round to saying this is to say to the pupils that electrons spin on their axis. We don't actually know that they spin on the axis but we have observed effects that are the same as if they were spinning on their axis. Right. Let us say now if a charged object spins on it's axis it develops a magnetic field. So if these were spinning they would develop a magnetic field with a N pole here and S pole there. And now if one comes along-another electron and spins the other way round, then it will develop a north pole here and a south pole here. Then those two magnetic fields will cause an attractive force between two negatively charged particles. Now we observe those effects in a magnetic field. We don't actually know they exist. Right. So if another electron comes along to our system up here, alright, it's going to position itself there because again the forces will balance and there will be a certain amount of attraction due top the opposite spin we are talking about, which will enable the forces ..... Now we can only have two different magnetic fields ok, can only have spin in two directions that's why you have only a pair of electrons together to form a bond. We can't have three electrons.

Brian: Why are they spinning in opposite directions?

M6: Well we don't know that they are spinning but if they have the same magnetic orientation in a magnetic field then they won't pair to form a bond. We actually know that. So it's only when you get a pair of electrons with opposite magnetic orientation that will bond. So every bond then consists of a pair of electrons that are simultaneously near nuclei. A bond is a pair of electrons, a strong force caused when a pair of electrons are simultaneously near two nuclei.

Rob: A pair of electrons are always the same distance all the time?

M6: Ok. You are thinking of the particle model for a start, aren't you?

Rob: Ya.

M6: Ok. Remember that is explicitly what I said think of the light analogy because a particle model of an electron is .... So honestly I don't think now where this electron is. I just know that there is a high electron density there, in this region [between the two hydrogen nuclei in the figure 2] I'm not sure how much you all done ... electron pairs of bonding. Anyway, Ok. So this is-here will be your high electron density region. If you want to change ....

Rob: at school the particle model ... and now I've been trying to incorporate all these other things of hybridisation and everything with the particle model and I find it very difficult.

M6: Yes. Ok I don't think you need hybridisation quite honestly but I think that you do need to give children some idea of interpenetration of orbitals ..... If you've got say ...... atoms bonding together to make a diatomic molecule ..... If your only picture of the atom is that of particle... the nucleus is the middle and you've got some particles that are flying .... Now don't think of your nucleus ....

S: ...

M6: Ya it's got huge problems conceptually at a very elementary level. ... to me if I thought of two candles shining, bring my candles together so that the light overlaps, so that I get a bright light there in between the candles. In other words high electron density, that to me makes much more sense ... of what a molecule is. You may like to argue with me. Ok, let's move on. Theoretically ... I just want to move on fairly quickly because I just want to focus on intermolecular forces. In the package what I've done is I've brought together bonding and intermolecular forces into one unit. .... School syllabus at std 9 you teach bonding and then you teach gas laws. .... It took me years of teaching std 9 to ... why the gas laws come in the middle .... there's a very good reason for this ....

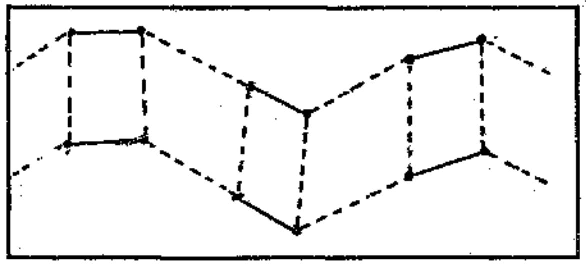


Figure 3 Iodine molecules in a crystal

Brian: Because gases have weaker intermolecular forces, liquids have strong intermolecular forces and solids have bonds.

M6: You're on the right track. In fact the idea .... In the handout given there is a pattern of dots [puts OHT of diagram with dots as shown in figure 3. Then she asks students to measure the distance between adjacent dots, to use solid lines to join dots that are near each other and dotted lines for those further apart, and to find halfway marks on the dotted lines. She went on informing students of the following: The short distance represents strong forces ie. chemical bonds: 10mm. The bond length will have the same distance. The dotted lines represent weak forces, ie. intermolecular forces between molecules. Focus on the distance which is linked to the forces, big distance - high potential energy, short distance low potential energy. The bond occurs at minimum potential energy. Also link the distance to strength of force and the energy; smaller distance stronger force- low potential energy]

Rob: Why don't they collide? Because of repulsive forces?

M6: Forces come to equilibrium position, though they are vibrating.

Charles: .....

M6: .... We stop here. We need to talk about the assignment.

M1: I would just like to wrap on the assignment. She draws the students' attention to the sequencing and possible selection of questions from the several questions given.