Science teachers' transformative and continuous professional development: A journey towards capacity-building and reflexive practice

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Kenneth Mlungisi Ngcoza

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Declaration

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

Signature

27/03/08
Date

Abstract

This study was conducted in Grahamstown in the Eastern Cape, South Africa. Triggered by the demands of South African post-apartheid curriculum transformation, the study focused on establishing a sustainable science *teachers' transformative and continuous professional development* (TTCPD) network with the view to improving their practice. It is premised on the assumption that teachers are capable of taking responsibility for their *own* professional development. It is a case study carried over a period of four years with a group of eight teachers.

Rooted in the socially critical-emancipatory orientation in conjunction with the participatory action research approach, and located in the qualitative and interpretive research paradigms, it focuses on doing research in democratic and egalitarian ways through working *with* teachers rather than *on* them. Such a stance supposes a collaborative partnership and a dialogic relationship viewed as being both reciprocal and mutually enriching for the teachers who were seen as co-learners and co-researchers in this study.

Two main goals of the study may be identified. For the first goal, the actors in this study established a sustainable and participative approach to professional development. This was explored through the formation of a TTCPD network which was informed by the *actor-network theory* framework. Our focus was on co-construction of scientific knowledge utilising the development and adaptation of learning and teaching support materials (LTSMs) as a catalyst to drive the process. The second goal was to examine how the TTCPD network enhanced the teachers' subject-content knowledge, pedagogical-content knowledge as well as individual and collaborative reflections.

The research process evolved into three main phases: The initial phase involved adapting and modifying LTSMs which were initially used in conjunction with micro-scale science kits and pilot tested with a group of Grade 10 students. This led to the second phase of the research project, which was aimed at gaining insights into the science teachers' capabilities in developing teaching and learning units of work.

The second phase focused on the development of a collaborative orientation to the development of LTSMs and culminated in the formation of sub-networks responsible for certain tasks within the broader network. As common ground, we focused on developing teaching and learning units of work on the following science topics: *electrostatics, electricity,* and *electrochemistry,* to illuminate and foster integration within science.

The third phase was concerned with gaining insights into the science teachers' practice in their classrooms. This phase focused on putting theory into practice through the collaborative implementation of teaching and learning units of work. Feedback on the lessons was discussed during our workshops as an attempt to further enhance collaborative reflections.

Data was generated using *workshop discussions with reflective notes; active interviews; focus group discussions; co-teaching, participant observation* and *videotaped lessons with reflective notes;* and a *research journal.* A variety of data generation techniques were employed to enhance validity and quality of the research. Techniques for validation and trustworthiness of data included *triangulation*; *member checks* or *face validity*; *prolonged engagement*; *catalytic validity* and *peer validation.*

The study exposed the underlying historical, ideological and epistemological contradictions of the teachers' past educational backgrounds. It emerged that the ways in which they were taught were at times an inhibitor to innovativeness, perpetuating transmissive approaches to teaching and learning. Lack of professional development and support, and the tensions between policy formulation and implementation exacerbated this. Reflections from the teachers' experiences further revealed that, for teachers to be effective agents of change in the reform process, empowerment opportunities are vital. As a result, exposure to the TTCPD network was useful in capacitating the teachers with the development of LTSMs, which led to the enhancement of their pedagogical, and science content knowledge conceptual development as well as collaborative reflections.

The main findings of this study is that, science teachers' transformative and continuous professional development based on participative approaches and mutual collegial support are indispensable, and that teachers' socio-cultural contexts and experiences should be taken into consideration during this process. Teachers should be regarded as central in the process, and mutual respect and dialogical relationships are pivotal. A further recommendation of this study is that capacity-building is critical for quality teaching and learning, and there is a need to move beyond the rhetoric of complacency to pro-activism, supporting ongoing development of teachers in professional transformative networks.

Dedication

This thesis is dedicated to my beloved son Nkosiphendule, a name interpreted to mean 'God has answered' and to my dearest wife, who had miscarriages twice in two consecutive years prior to my son's birth. Indeed, God answered our prayers. Nkosiphendule is thus the name my son has earned because of this tragedy, as well as being my *carbon copy*. And his other name, which he has to live up to, is Mbasa, which means 'The medallist'.

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There were many minds, hearts and souls who made the completion of this thesis possible. I would like to express my sincere gratitude to all those contributors.

Firstly, I would like to thank my mother maRhadebe, who died at an age of 83 in 2004, for bringing me to this mother earth and for her nurturing and caring attitude throughout my life. I remember when I was at Samuel Ntsiko Primary School she used to sacrifice her bread for us so that we could have some energy to study. That will remain indelible in my mind, and I thank her for that.

I live close to my ancestors, and most particularly to my late father Gxarha, a humble, hard worker. I thank him every day for the blessings he continually bestows on me. My responsibility to him is indeed what this thesis is all about.

I am grateful to my dearest wife who, throughout this period, fulfilled her role as wife and mother without complaining. A very creative and industrious designer, in my absence she kept on changing and making informed alterations in our sweet home. I cannot forget to thank my son Mbasa, whose first language is ironically English even though his mother and father speak *isiXhosa* (that is awesome, and reflects the realities of our beloved country, South Africa), and his sense of humour and openness has been very therapeutic during the stressful times in this journey.

To my entire family and relatives: you are special in my life and I thank you all for your wonderful and tireless support in various ways throughout this journey. God bless you!

I thank all the science teachers I have been working with in our participatory action research network for their dedication and commitment. Without their support my dream would not have been realised. Many thanks too to their learners, who sacrificed their free time to involve themselves in this initiative.

My gratitude also goes to Jaap Kuiper, my former supervisor, whose shoes I had to fill when he left the Education Department at Rhodes University. Many thanks go to Gill Boltt and Pat Irwin, my later supervisors, who showed faith in me and were always available when I needed help. I will never forget their assistance, guidance and caring attitude throughout this voyage, and I now feel empowered as a change agent. Thank you, once again.

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I thank the Dean of Research office for financial support and for affording me the opportunity to attend conferences. My interaction with fellow students and academics from other institutions throughout my engagement in this study helped me to view science education and science teachers' professional development through a new set of lenses. I hope that the experience I gained through my study will be reflected in the years to come. For that, I am thankful.

To all these people, I owe my thanks for their time and generosity.

Contents

ABBREVIATIONS

AANT	Actor/Actant-Network Theory
ACE	Advanced Certificate in Education
ANC	African National Congress
ANT	Actor-Network Theory
CASS	Continuous Assessment
C2005	Curriculum 2005
CK	Content Knowledge
CTA	Common Tasks for Assessment
BEd	Bachelor of Education
DET	Department of Education and Training
DoE	Department of Education
EESU	Environmental Education and Sustainability Unit
FET	Further Education and Training
GADRA	Grahamstown Area Distress Relief Association
HoD	Head of Department
HoR	House of Representatives
INSET	In-Service Training
JSTC	Junior Secondary Teacher's Certificate
LoLT	Language of Learning and Leaching
LPUs	Learning Programme Units
LTSMs	Learning and Teaching Support Materials
MBL	Mobile Biology Laboratory
MEd	Masters in Education
NGO	Non-Governmental Organisation
NMMU	Nelson Mandela Metropolitan University
OBE	Outcomes-Based Education
PAR	Participatory Action Research
PCK	Pedagogical Content Knowledge
PEEOE	Predict-Explain-Explore-Observe-Explain
PGCE	Post Graduate Certificate in Education

POE	Predict-Observe-Explain
PRESET	Pre-Service Training
RADMASTE	Research and Development in Mathematics, Science and Technology Education
RU	Rhodes University
RUMEP	Rhodes University Mathematics Education Project
SAARMSTE	South African Association for Research in Mathematics, Science and Technology Education
SAASTE	South African Association for Science and Technology Education
SEP	Science Education Project
SMT	School Management Team
STD	Senior Teacher's Diploma
TTCPD	Teachers' Transformative and Continuous Professional Development
UNISA	University of South Africa
UFH	University of Fort Hare
UPE	University of Port Elizabeth
WSDP	Whole School Development Programme
ZAD	Zone of Actual Development
ZPD	Zone of Proximal Development

Chapter 1

An introduction to the study

> In undertaking a journey, a traveller bespeaks a purpose. She leaves her home and ventures forth not merely because of the pleasures of the trip but because of a desire to understand or experience those marvels of which she has heard rumours. What she knows is that something may exist which can enrich her present situation; what she does not know is how or where, or indeed whether, she will discover its presence. The teacher development with which we are concerned involves a search for an unknown quality.
>
> (Oberg & Underwood, 1992:162)

1.1 Introduction

In this thesis I hope to share some of the decisions, plans and strategies I made in this research journey, which focuses on science teachers' transformative and continuous professional development network. In line with actor-network theory, I refer to the participants in this study as actors (see Section 4.2.2). Professional development in this thesis is regarded as being transformative and continuous since ongoing capacity-building with a view to bring about change in the actors' practice is central to it. Kreber (2005) considers transformative learning to be a co-construction of knowledge. Furthermore, teachers' professional growth is seen as a continuous process of learning, and through the process of reflection (see Section 3.5.1), underlying assumptions and beliefs are questioned and transformed.

Fullan (1991) contends that professional development encompasses what educators bring to their work and what happens to them throughout their career. He adds that "the educator as life-long learner is the key to future reform" (Fullan, 1991:289). It is recognised, however, that teacher professional development is a complex phenomenon as it entails a search for an unknown quality as Oberg and Underwood (1992) state in the epigraph.

This thesis documents a research journey during which I have learnt about engaging in a transformative and continuous professional development network, about collaborative development and implementation of learning and teaching support materials, about engagement in individual and collaborative reflections, and finally about how to conduct research with science teachers. Like Clandinin and Connelly (1998:247), as I thought about my own life and the lives of the science teachers I was engaged with in this study, I definitely saw opportunities and possibilities for growth and change in our professional development.

In essence, professional development is viewed as an ongoing process in this thesis. My main contention is that the TTCPD network is central in education (see Chapter 6). It is also my belief that a TTCPD network should be collaborative in nature. It is for these reasons that a participatory action research approach (see Section 5.3.2) was adopted as a catalyst or vehicle for the promotion of participative approaches.

The underlying assumption here was that all the network actors in the research project were seen as human resources, who were capable of taking responsibility for their *own* professional development. Central in this thesis also was the notion of how to conduct research *with* rather than *on* teachers.

1.2 Rationale and motivation for the study

The focus of this study is on the promotion of the TTCPD network. It was first conceptualised and piloted in 2000, at the time when I was a science subject adviser in the Grahamstown district, responsible for supporting science teachers in the schools. The support was on both the subject-content knowledge and pedagogical-content knowledge of science teachers in order to improve teaching and learning of science. However such support, albeit needed in most schools, was minimal due to a variety of problems such as transport and lack of physical resources in some schools, in particular, historically disadvantaged schools.

What enabled me to keep in contact with science teachers and be engaged in science workshops, though, was the *micro-scale science kit project*, initiated and facilitated by the Chemistry Department at Rhodes University in collaboration with the science subject adviser from the Provincial Department of Education (DoE). Science teachers from the various schools who attended the workshops commented that such workshops were an empowering experience since they were afforded opportunities to interact and share knowledge with other teachers from the other schools. Since they were also supplied with the micro-scale science kits, they were able to do practical activities with their learners at their schools. They further reported that doing practical activities with their learners helped to improve their learners' conceptual development and understanding as well as their attitude towards science.

My tenure as a science subject adviser also coincided with the introduction of the new Curriculum 2005 (C2005) and outcomes-based education (OBE) in 1997. I was required to be involved with the co-ordination of the OBE workshops, which were intended to sensitise teachers to the new curriculum. This further enhanced my experience of working with science teachers.

In this research study, my motivation to focus on participatory action research approaches as a catalyst or vehicle to promote the TTCPD network, resulted from several factors, namely:

- my experience of and passion for working with science teachers;
- the need to understand teachers' historical, contextual and socio-economic backgrounds;
- the need for the TTCPD network in order for teachers to be effective agents of change;
- the need to enhance science teachers' subject-content and pedagogical-content knowledge;

- the need for science teachers to be able to collaboratively develop their own teaching and learning support materials and learning programme units in order to enhance teaching and learning of science;
- the need for teachers to reflect individually and collaboratively on their practice and to see themselves as co-learners and co-researchers (see Chapter 6); and finally
- the need to address the tensions between curriculum development and implementation in South Africa.

These factors resonate with the state of science education and curricular issues in South Africa. In essence, all these overlapping factors were instrumental in triggering my interest to engage in this PhD study.

1.3 Conceptualisation of the research project

Although I am presently a science teacher educator based at university, I started my professional career as a senior secondary school mathematics and science teacher. Later, I became the coordinator of the Science Education Project (SEP), a museum educator and a science subject adviser. As a result of my work and passion in supporting professional development initiatives for science teachers, I decided to pursue and embark on a doctoral study in science education. Thus, one of my strong research interests has been and continues to be teacher development, specifically in the context of science education.

I first visited and approached individual senior secondary school science teachers, negotiating with them to be part of this project, and I received positive responses. Initially, I had envisaged working with science teachers from the former model C schools, a former House of Representatives (HoR) school and former Department of Education and Training (DET) schools. I had hoped that working with teachers from such diverse schools would afford us in the network opportunities to share knowledge, expertise and resources irrespective of the schools' geographical location.

In our initial meeting held in 2000, in which we negotiated about this project, I noticed among other things that some teachers, especially from historically disadvantaged schools, were reserved and did not contribute much to the discussions. One possible reason for this could be language barriers as our meeting was conducted in English. I immediately saw that as a potential problem.

It was later proposed that it would be better if we could have at least two science teachers per school so that teachers could collaborate together at work. Since it was difficult to recruit two teachers per school from the former model C schools and from the former HoR school because there was only one teacher in the grade we proposed to focus on, we finally decided to work with teachers from four former DET schools.

1.4 Goals of the study

The main aim of this research study was to investigate the benefits of engaging science teachers in the teachers' transformative and continuous professional development network utilising the PAR approach as an enabling strategy to enhance teaching and learning of science.

The research study thus sought to address the following two research goals:

- to examine how participatory approaches could help facilitate and enhance a TTCPD network with the view to improving teaching and learning of science; and
- to examine how a TTCPD network through collaboratively developing and implementing learning and teaching support materials could enhance teachers'
  - subject-content knowledge and pedagogical-content knowledge;
  - individual and collaborative reflections; and ultimately
  - practice of teaching.

1.5 Research questions

The primary question in this research study was:

Does engaging science teachers in a TTCPD network (see Chapter 9)

- influence their subject-content knowledge, pedagogical-content knowledge, perspectives, assumptions and beliefs about their practice?
- enhance collaboration and collegial support amongst them?
- enhance individual and collaborative reflections on their practice?

Furthermore, to achieve the research goals, the following two secondary questions were asked:

Do science teachers' educational backgrounds (see Chapter 7)

- influence their subject-content knowledge, pedagogical-content knowledge, perspectives, assumptions and beliefs about teaching and learning? and
- influence their teaching of science?

Does the way science was taught at the teachers' colleges have an influence on the science teachers' (see Chapter 8)

- perspectives, assumptions and beliefs?
- practice of teaching?

Does professional development and support influence the science teachers' (see Chapter 8)

- practice of teaching?
- school-based and collegial support?

1.6 Research methodology

> Like all other people, educational researchers have conceptual frameworks that affect what they find interesting or important, how they choose what to study, and the sense they make of the results of their study. Using more technical wording, a researcher's conceptual framework influences the choice of research topic or problem, the selection of methods and techniques he or she uses to investigate the topic or address the problem, and his or her interpretation of the data...
>
> (Anderson, 1998:255)

This research study is located within the qualitative research and interpretive paradigms (see Section 5.3.1). Within these paradigms, I chose to situate this study within the socially critical-emancipatory orientation (see Section 4.2.1) in conjunction with the participatory action research approach (see Section 5.3.2).

According to Carr and Kemmis (1986), a socially critical-emancipatory orientation has empowerment and emancipation of actors at its heart; while PAR helps to transform actors' lives by having them play an integral role in their own research. Kemmis and Wilkinson (1998:21) argue, "PAR attempts to help people investigate and change their social and educational realities by changing some of their practices which constitute their lived realities". In this respect, blending of the socially critical-emancipatory orientation and the PAR approach was realistic since they both have an emancipatory and empowering focus embedded in their principles.

As an additional lens to analyse and understand data, I also explored the actor-network theory (ANT) (see Section 4.2.2) as an enabling methodological and epistemological framework. I also explored the reflexive approach (see Section 5.3.2) to enhance reflexivity in this study: an understanding of the notions of empowerment and emancipation in this study was further achieved through reflectivity (theory) and reflexivity (theory and practice) (see Sections 3.5.1 and 3.5.2 respectively). I contend that reflexivity is an appropriate approach in this study since central to it is co-engagement and action.

1.7 Thesis outline: Metamorphosis-An overview of the chapters

> Travellers normally prepare for the adventures they hope to have, but itineraries, maps and plans in themselves do not create their journeys. A journey is an experience, lived just as it turns out to be: moment-by-moment, day-by-day, month-by-month, and event-by-event. Preparing for each part of the journey involves making decisions, designing plans, and outlining key strategies to help set directions for the coming adventures.
>
> (Lotz, 1996:2)

This *metamorphosis* section presents the layout of this thesis. This metaphor highlights the life of this research project as well as the various stages of development and possibilities for continuity of the research process. Such transformative learning and development happened over a long a time. However, although this thesis is composed of a specified number of chapters, in my view, it is an *incomplete metamorphosis* in the sense that the research journey is an ongoing process. This thesis documents part of that journey.

The *journey* metaphor reflects the need for plans and informed decisions that actors need to take into consideration when engaging in a journey, a view echoed by Lotz (1996) in the epigraph. Central to this study was capacity-building of all involved with the aim to improve practice.

The content of this thesis has been conceptualised into three parts composed of ten chapters, namely:

PART 1: Research landscape

The *research landscape*, backgrounds the planning involved in any research process, introduces the reader to the research study and orientates him or her contextually, conceptually and methodologically into the orientation and framework of the study. It is constituted of five chapters:

Chapter 1: Introduction

This chapter presents an outline of the research, whose focus is on science teachers' transformative and continuous professional development. It also highlights the rationale and motivation for the study, specific goals, and research questions as well as the research methodology adopted.

Chapter 2: Context

This chapter locates the research study in its South African context. Since the South African schooling system is faced with many challenges, consideration of both the macro-context of South Africa and micro-context of the schools involved in the research study was essential. The South African contextual, historical and social factors such as the current educational and socio-political conditions indeed substantially influenced the direction of this research study. A discussion of the past South African school education system, the nature of science education in historically disadvantaged schools, and the transformation in curriculum are examined. This chapter also describes the schools where the teachers involved in this study teach.

Chapter 3: Conceptual orientation

This chapter discusses the literature relating to teachers' professional development. My contention is that teachers' professional development should be viewed as an ongoing process throughout the teachers' careers. Although this topic is pursued in general terms; a particular issue is whether learning opportunities created for the teachers enabled them to take more responsibility for their actions in order to improve teaching and learning of science. I propose that co-engagement and collaboration of teachers in such actions requires enabling environments. Enabling environments allow teachers to co-engage and interact in socio-cultural negotiation of meanings in constructive and reciprocal ways. This dynamic role requires teachers to develop professional attributes so that they can see themselves as invaluable human resources capable of negotiating meaning in the process of the construction of knowledge.

Chapter 4: Research orientation

This chapter discusses the philosophical underpinnings of the research orientation and framework of this study. First, the socially critical-emancipatory orientation as a guide to the study is explored. This is essential since inquiry in this study is located within the process and context of human experiences. Secondly, actor-network theory as an enabling lens or framework to analyse epistemological and methodological underpinnings of this study is discussed. Blending this orientation and framework was useful since central to the study was the empowerment of all actors involved.

Chapter 5: Research methodology

This chapter explains the research design of this study – its methodological theoretical framework; how research design decisions were taken; what factors influenced and affected such decisions. First, to give the context of the study, its overview is provided. A discussion of the methodological framework in terms of its qualitative research and the interpretive paradigms follows. An exploration of the participatory action-research and reflexive approaches is provided. Lastly, the research-design process and methodological issues pertaining to data generating techniques, data analysis, validity, and ethical issues as well as our roles as reflexive co-researchers are highlighted.

PART 2: Changing gears

The *changing gear* metaphor highlights the ebb and flow of the action o f doing research (Loughran & Gunstone, 1997:175). It is associated with energy and commitment in the research journey as change entails changing decisions and directions. To foster transformative and continuous professional development different strategies, time and space are required: bear in mind that change is not a linear process and gears have to be changed all the time. This section consists of three chapters:

Chapter 6: Research process

This chapter reviews the process and development of this research project. It explores how the science teachers involved in this study were mobilised to form a network. Paying attention to the contradictions and tensions that surfaced, this chapter also provides an account of the teachers' different stages of development and growth. Foundational to the network, capacity-building activities were the ideals of fostering improvement in science teaching and learning in secondary schools, in particular, historically disadvantaged schools in Grahamstown. Summaries of findings are thus presented on activities and relations within the network as it is proposed in the actor-network theory. I also focus on the evolution of the network's goals, development and implementation of mediating artefacts which are in the form of learning and teaching support materials. I conclude by highlighting the key issues that emerged during part of this research process.

Chapter 7: Teachers' perceptions of their educational background

In this chapter, the experiences of the six science teachers at school and at teacher's colleges are explored. The investigation of these science teachers' educational background was intended to provide insight into potential factors that could play a role in influencing their practice in teaching science. This was critical since teachers' professional knowledge is shaped by their own experience of schooling and how they have been socialised in the teaching profession: how teachers were taught at school and at teachers' colleges will invariably influence how they themselves teach.

Chapter 8: Practices of teaching and professional support

This chapter foregrounds the teachers' practice of teaching and professional development and support within their different school contexts. This was seen as fundamental in the context of this study since the culture of a school contributes to the learning of teachers. Without a supportive culture the professional learning of teachers might not survive. With this in mind, this study contends that there is a need for creation of learning communities of practice in schools. The notion of a community of practice helps to describe how teachers' learning occurs in collaborative school-based communities. In the light of this, an examination of the teachers' practice of teaching and professional development and support is essential.

PART 3: A journey of hope

This last section with its metaphor of a *journey of hope* reflects the benefits of a TTCPD network: what we have learnt, the challenges, and what we perceive as possibilities for the future. The journey of hope metaphor is associated with actors seeing the need to form networks in which they are afforded opportunities to learn together. The ideal network of hope involving a wide range of actors such as university researchers, subject advisers and teachers in professional networks is necessary for change to take place. This section consists of two chapters:

Chapter 9: The TTCPD network

This chapter examines the benefits of the teachers' transformative and continuous professional development network on their conceptualisation of science, and the curriculum, and subsequently the transformation on their practice. One function of this collaborative network was to develop and implement learning and teaching support materials with a view to improve teaching and learning of science. The idea of networking is at the heart of this thesis as the provision of learning spaces for teachers is an essential element in the quality of teaching and learning.

Chapter 10: Research reflections, strengths, limitations and recommendations

In this chapter, my reflections are in the form of my experiences of the research design process, and the research strengths, limitations and difficulties encountered in the study. I also critically reflect on the methodology, content of the study as well as the extent to which the research goals and questions have been satisfied. It is recognised, however, that this study also raised many other questions that were not answered because they lay beyond the brief of this study. Lessons learnt and their implications have also been explored. Finally, some tentative recommendations are provided.

1.8 Concluding remarks

This chapter provides an overview of this study on science teachers' transformative and continuous professional development. Professional development is viewed as a transformative and ongoing process, with the teachers themselves taking responsibility for their own development and growth. The rationale and motivation for the study is also explored. Furthermore, how the study was contextualised is discussed. The goals, research questions and research methodology adopted in this study are examined. The conclusion ends with an overview of the chapters.

In the next chapter, an in-depth discussion on the context of the study will be foregrounded. Locating the study in its South African context, an examination of the past school education system, the nature of science education in historically disadvantaged schools, and the transformation in curriculum is provided.

Chapter 2

The context

> Education is the great engine of personal development. It is through education that the daughter of a peasant can become a doctor, that the son of a mineworker can become the head of the mine, that a child of farm workers can become the president of a great nation. It is what we make out of what we have, not what we are given, that separates one person from another.
>
> (Mandela, 1994:155)

2.1 Introduction

The main mission of this study was to explore ways and means of contributing towards sustaining science teachers' transformative and continuous professional development network and support (see Chapter 6). The focus was on secondary school science teachers. All the schools involved in this research study are situated in the so-called 'townships'[1] of Grahamstown, a large semi-rural town in the Eastern Cape, South Africa. In line with the transformation in South Africa, the 'township' is now referred to as Grahamstown East.

This chapter seeks to locate the research study within the South African context. Since the South African schooling system has been (and is still) fraught with problems, it is recognised that both the macro-context of South Africa and micro-context of the schools involved in the study are important. Improvement in practice is critical, since according to Spanneberg and Brown (2003:154), in the new curriculum in South Africa, the emphasis has shifted from being mainly on the transmission of knowledge to building skills, knowledge, attitude and values. This would affect the way teachers should teach. The challenge, however, is that most teachers have been 'trained' in a teacher-centred approach at the teachers' colleges;

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[1] The apartheid government, to designate a geographical area set aside for blacks only, used the term 'township'. With the exception of the 'townships' in Grahamstown, most 'townships' (such as Soweto), were a result of the forced removals due to the Group Areas Act.

and they have been practising these methods and been guided by the old goals for many years (see Chapter 8). The South African contextual, historical and social factors such as the current educational and socio-political conditions thus substantially influenced the direction of this research study.

For the schools involved in this study, I have used the following pseudonyms; Matyana, Pioneer, Phandulwazi and Mfundweni. The pseudonyms for the six science teachers involved are Zapholo, Ngwenya, Neon, Khwezi, Leo and Nomfundo.

2.2 The South African school education system

The education system issues raised in this thesis are not unique to South Africa (see Sections 2.2.1 and 2.2.2). For example, in the context of the Namibian education system, Pomuti, LeCzel, Liman, Swarts and Van Graan (2003:12) argue that, the concept of learner-centredness relates to attaining the "educational goals of access, equity, quality and democracy". This is true for South Africa as well.

2.2.1 The past school education system

Mandela (1994:155) explains that the foreign churches and missions funded education for Africans[2] in South Africa. He further highlights the fact that the then ruling United Party essentially provided the same syllabus for both African and white secondary schools. The mission schools provided them with Western-style English-language quality education.

Personally, what I miss in Mandela's (1994:155) account of the good-quality education he and others received from the mission schools is the question of teachers' professional development, which is a focus of this study. What strategies did the

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[2] Unlike Walker (1996) who uses a lower-case for 'african' as an indicator of an apartheid construction of a social or 'racial' group, the former president of South Africa, Nelson Mandela, uses a capital letter to emphasise nationality; otherwise the terms black and white are widely used in South Africa.

mission schools use to ensure ongoing teachers' professional development and support? This is a question worth pondering: in my view if we are sincere in taking the past and present into account when focusing on the future, we ought to learn from the success stories of the past that Mandela highlighted.

It is suggested, therefore, that the work presented in this thesis should be viewed against the historical, political, cultural and socio-economic background of our country, South Africa. This is deemed necessary in the context of a country riddled by the tragic and abominable legacies of the apartheid education system[3].

For instance, the basis for separate and unequal education for blacks and whites was firmly formulated in South Africa by the Bantu Education Act of 1953. Thus, black education was relegated to the present level of inferiority. Indeed, Mandela (1994:155) reminds us that the Nationalist government passed the notorious Act as an apartheid[4] stamp on the education system of every African child; and the education system has been one of the principal instruments through which the apartheid system has been sustained and perpetuated (Graham-Brown, 1991:155).

The responsibility for this lay with the prime minister, Dr Hendrik Verwoerd, who was regarded as the architect of the apartheid which attempted to segregate black and white system at all levels: social, educational and political (Walker, 1996:45). To Walker, Bantu Education deliberately sought to stifle intellectual capacity. Hartshorne (1992:60), too, points out that secondary education in South Africa was

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[3] Authors such as Behr (1988), Christie (1991), Graham-Brown (1991), Hartshorne (1992), Mandela (1994), Kallaway, Kruss, Fataar and Donn (1998) have contributed to the documentation of the history of education in South Africa. In this text, I have briefly explored this history just to whet the reader's appetite.

[4] Mandela (1994:104 - 55) explains that apartheid means "'apartness' and the premise of apartheid was that whites were superior to Africans, Coloureds and Indians, and the function of it was to entrench white supremacy." However, Mandela himself points out that even before the Nationalist government led by Dr Malan came into power, the disparities in funding were alarming in that the government spent about six times as much per white student as per African student. This was exacerbated by the fact that education was not compulsory for Africans and was only free in primary grades.

"authoritarian, teacher-dominated, content-orientated and knowledge-based". This suggests that skills and application of knowledge were neglected.

In this vein, Mandela (1994:156) himself echoes that Bantu Education was a "poison one could not drink even at the point of death from thirst". He further reports that Verwoerd said "there is no place for the Bantu in the European community above the level of certain forms of labour" (*ibid*). As a result, most blacks from historically disadvantaged schools, including all of us in our research network, have unfortunately drunk and tasted such a poison (see Chapter 7).

The consequences of Bantu Education, however, haunted the Nationalist government in many ways as Mandela (1994:158) reminds us:

> For it was Bantu Education that produced in the 1970s the angriest, most rebellious generation of black youth the country had ever seen. When these children of Bantu Education entered their late teens and early twenties, they rose with vehemence.

Bantu Education was thus at the centre of the revival of resistance to apartheid in the 1970s (Graham-Brown, 1991:156), and the 1976 Soweto riots ignited the flames of resistance, spreading out to the entire South African country. That proved to be a turning point in the apartheid education system in South Africa.

Similarly, however, the struggle against apartheid equally prohibited quality education. As Bateson (1995:5) points out, for decades the black schools of South Africa had to be used as battlefields in the struggle against the apartheid. Unfortunately, much of the resistance degenerated into withdrawal of teachers from effective teaching and withdrawal of students from learning. To compound the problem, the community saw schools as government schools rather than schools that belonged to their communities. This was exacerbated by the dearth of qualified, competent and experienced professional personnel that were the key to quality education. This is not surprising, however, considering the fact that Blacks were denied free access to quality education, particularly tertiary education (Mandela, 1994:155).

Furthermore, there were very few highly qualified and experienced black educators and educational researchers (Walker, 1996:46). Pertaining to research endeavours, Walker (*ibid*) further adds:

> Our educational research traditions in South Africa are fragile, distorted by the past in which conservative, white Afrikaner intellectuals supported the social engineering of apartheid by constructing educational philosophies which justified segregation and the domination of white over black, all dressed up in the pseudo-scientific language of 'fundamental pedagogics'[5].

Also, from my own experience as a teacher educator, the abhorrent culture of teaching and learning that exists, particularly in historically disadvantaged schools, is alarming and detrimental to quality education. And it would be naïve to divorce this from the ills of the Bantu Education system. Southwood (2000:5), too, attributes the breakdown of the culture of teaching and learning to the traumatic history of South Africa and argues that "the political oppression has led to a demoralised and demotivated profession."

This was further exacerbated by the fact that, during the struggle against apartheid, teachers were seen as collaborators with the oppressors. For example, when Afrikaans was mandated to be the medium of instruction in some subjects and forced down the throats of students in all historically disadvantaged schools, some teachers, unlike students who fought against the dictate, meekly submitted (Bateson, 1995:7). As a result, teachers became soft targets for politicians.

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[5] Walker (1996:59) explains that "fundamental pedagogics is an educational philosophy propagated by Afrikaner Nationalist academics to uphold 'Christian, national' principles, central to which is the assertion of segregation and white superiority disguised under a cloak of 'scientific objectivity'. Given Afrikaner control, in particular of teachers' colleges, fundamental pedagogics has been highly influential in the construction of teachers and teaching as an authoritarian process to mould children and lead them from ignorance, irresponsibility and incompetence to maturity."

From my own experience as a teacher, even armchair politicians had the audacity to attack, and pathologise or demonise the toothless teachers. Regrettably, teachers also lost the respect of the communities in which they taught.

In 1994, however, the first democratic elections took place in South Africa and political power was peacefully passed from the Nationalist government to the African National Congress (ANC)-led government (Robinson, 1999; Aldous, 2004). The democratic government introduced the new curriculum, which it claimed was intended to revolutionise[6] education and 'training' in order to redress the imbalances of the past (Walker, 1996:45). Curriculum 2005 with its outcomes-based education philosophy was thus the result of this government-driven change (see Section 2.2.2).

> The bold initiative, which will for the first time shift the emphasis from academic learning to encouraging skills, is expected to help radically transform education. Curriculum 2005 was a complete overhaul of this country's education system and was being hailed as the most 'important milestone' in South African schools this century. (*Sunday Times*, March 23, 1997, an article critiqued in my Master's portfolio 1997/998)

> Curriculum 2005 would introduce a lifelong people-centred education system. The new 'outcomes based' curriculum, in line with similar systems in Australia and Netherlands, aimed to create active learners who would be equipped to become critical thinkers, capable of reasoning, reflection and action. I'm confident that it will be a giant step forward in ensuring quality education for all people of South Africa and that it will be embraced by all those who have a part in the learning process. (*Daily Dispatch*, March, 25, 1997, an article critiqued in my Master's portfolio 1997/1998)

These quotes bear testimony to the need for change in South Africa. Despite these ambitions, however, the post-apartheid era of transformation has been a period of turbulent political change replete with many challenges (Scholtz, Watson & Amosun, 2004:41). For example, the curriculum innovation concerned with the transformation of teachers' pedagogical practices proved to be a challenge to the

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[6] The parallels between political revolutions and scientific revolutions has been observed by Thomas Kuhn (1977), who explained that in science the scientific community has to abandon once time-honoured ways regarding the world and pursuing science in favour of some other. He further referred to such drastic changes as the 'paradigm shift' (*ibid*:92). However, Kuhn warns that, in any change, people should see or be made to see the need for change.

teaching fraternity. Such challenges have been exacerbated by serious tensions between policy formulation and policy implementation.

From my own experience as a teacher educator, what has been seen as a 'paradigm shift' (using the Kuhnian (1962, 1977) term) by policy-makers turned out to be a 'paradigm leap' for some teachers, especially in historically disadvantaged schools. This could be attributed to, amongst other things, the drastic shortage of both human and physical resources in these schools.

Certainly this is not surprising since, according to Walker (1996), teachers under the conditions of apartheid education did not see themselves as agents in curriculum development. In this vein, Walker (*ibid*:47) notes:

> Teachers in South Africa mostly do not start from positions of innovative and reflective practice, given the history and effects of authoritarian surveillance of teachers' working lives, of political oppression, and a truncated view of their professionalism which has turned on teachers as mere installments of state ideology.

Since as Walker (1991) reminds us, teachers in the past were regarded as the products of the curriculum content and processes, there is a need to prepare them for the demands of any new curriculum. This further suggests that the necessity for effective professional development is paramount and should not be underestimated. Yet, as Kuiper and Van Harmeulen (1996) point out, the practice of supporting teachers by the department in South Africa has been once-off workshops that are insufficient to engender the professional development and growth needed.

Based on my experience as a science subject adviser and as one of the facilitators of the OBE workshops in the Eastern Cape, I concur with Kuiper and Van Harmelen's claim. However, it should be noted that these challenges are not only unique to South African. For example, Loughran and Gunstone (1997:160) state that professional development for teachers in Australia "fails to have cumulative effect and often comprises once-off courses designed to support particular innovations but lacks coherent integration into teachers' work."

In such circumstances, the focus is usually on catch-up and quick fix solutions, something which teachers have been victims of in South Africa.

In this study, the claim that teacher support is limited has been illustrated by the quotes extracted from the active interviews (see Section 5.4.1) conducted with the teachers involved. In a research study conducted in Finland, Kosunen and Mikkola (2002:140) too point out that the fact that a programme is recorded in a study guide does not guarantee that it will be realised in the way intended.

In essence, the contention of this study is double-barrelled. It is, on one hand, concerned with the development of professional support among science teachers from four historically disadvantaged schools, that is, inter-school professional support[7]. On the other hand, it is interested in the development of professional support of the science teachers within their schools, that is, intra-school's professional development[8] opportunities. The development of such models is dependent on the engagement of teachers, acknowledging that they are human resources themselves. This point assumes that teachers are capable of taking responsibility for their own professional development provided there are opportunities and learning spaces for growth in collaboration with others. This was the contention of this study.

The reality, however, is that teachers are not used to working collaboratively with their colleagues. This they might have inherited from the ways they themselves were taught at school and at teachers' colleges (see Chapter 7). Since teachers were not taught to work with colleagues, Southwood (2000:6) says, there seems to be reticence on their part to 'open up' their classroom doors; teachers tend to limit themselves to 'solitary confinement' in their classrooms, which seem to be their comfort zones.

[7] Spanneberg and Brown (2003) refer to inter-school professional development and support as a cluster model.

[8] Loughran and Gunstone (1997) and Southwood (2000) refer to intra-school professional development and support as school-based support.

Zapholo, one of the experienced science teachers in the network uses a metaphor to highlight such isolation behind the private walls of the classroom (Walker, 1996:55):

> Before I was involved in our research network, I had what I call 'the classroom and me', which means that my science classroom belongs to me and nobody else can interfere when I'm teaching my learners. That is, I'm teaching my learners a certain way of doing things, and if I allow another person to come into my classroom, he or she will distract the teaching process. (Zapholo: Active interview 16/04/04)

Clearly, this shows that some teachers' classrooms are seen as private no-go areas. Yet, the irony is that the new curriculum in South Africa purports to require that teachers work together. This suggests that there is a need for the promotion of collaborative and participatory approaches to teachers' professional development.

2.2.2 Science education in some historically disadvantaged schools

Bodner (1986:873) contends that, traditionally, science has been perceived by many educationists as a body of knowledge to be transferred intact from the teachers and textbooks to the learners. Furthermore, rather than focusing on the extent to which learners understood scientific concepts; emphasis was placed on rote learning and regurgitation of facts (Tobin, Briscoe & Holman, 1990). Freire (1970:53) points out that, in such education, learners are perceived as the depositories and the teacher as the depositor, resulting in conceptual development and understanding being compromised.

The lack of understanding of scientific concepts was exacerbated by the fact that little or no practical work[9] was done in science in most schools (Van der Linde, 1994, cited in Vermaak, 1997), especially in the historically disadvantaged black schools. This is attributed to, among other things, unqualified or under-qualified science teachers

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[9] The term 'practical work' as opposed to 'laboratory work' has been used in this text to denote science experiments/activities either in the classroom or in the laboratory and/or even at home and outside environment.

and lack of resources (Foundation for Research Development, 1994b, cited in Vermaak, 1997; Tobin, Seiler & Smith, 1999).

As an attempt to improve science teaching and learning in South African black secondary schools in particular, micro-scale science kits[10] were designed and manufactured by Somerset Educational in collaboration with the RADMASTE Centre[11] at the University of the Witwatersrand (Vermaak, 1997). These science kits were intended to encourage interactive 'hands-on' and 'minds-on' activities. They were also used in conjunction with worksheets intended to help teachers and learners develop an appropriate conceptual understanding of science.

Ten senior secondary schools from the Grahamstown district were involved in the micro-scale science kit project. The main aim of the project was to help promote science and improve science teaching and learning in the local schools. It was also envisaged that the project would contribute to a mutually beneficial interaction between Rhodes University's Education Department, Science Faculty Departments, Provincial Department of Education, and the science teachers from the local schools.

The Zenex Foundation funded the schools involved in the project. These funds were in the form of micro-scale science kits, as well as chemicals. The science subject adviser (that is, myself, the main researcher in this study) and a key science teacher (Zapholo), one of the network actors in this study, attended workshops at RADMASTE Centre on the use of these kits. Before the kits were given to schools, the key science teacher and I collaboratively conducted teachers' workshops to ensure that teachers were familiar with how to use the kits and the worksheets. Thereafter, I conducted follow-up classroom visits to give individual support to science teachers in their school contexts.

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[10] Micro-scale science kits contain micro-electricity kits composed of batteries/cells, bulbs, bulb holders, springs, vials, paper clips, and so on, and the micro-chemistry kits have items such as vials, propettes, micro-spatulas, and chemicals.

[11] RADMASTE is the acronym of the Centre for Research and Development in Mathematics, Science and Technology Education.

While observing some science teachers using these science kits and worksheets in their classrooms, I found that these were being used as recipes, with a 'cookbook' approach. Some teachers seemed to be happy to have these resources without questioning how best they could be used. Questions such as, 'What do we do with the micro-scale science kits to enhance teaching and learning meaningfully and with increased understanding?' were rarely asked. Clearly, having the science kits does not guarantee concept development in science. In view of this, it is suggested that science teachers need to challenge their own practices and explore innovative ways of teaching and learning when using the kits. Rather than merely following recipes when using these kits, inquiry-based learning approaches should be promoted (McGonical, 1999). Inquiry-based learning actively co-engages learners in the co-construction of knowledge.

Certainly, this research study has its roots in the innovation of micro-scale science kits. The desire to work with science teachers and encourage them to explore interactive approaches in teaching and learning also prompted and influenced this research study. In essence, the factors highlighted in section 1.1 above informed the aim of this research study, which was to explore the potential that PAR approaches have in promoting a TTCPD network and support with the view to enhancing teaching and learning of science (see Chapter 6).

2.2.3 Transformation in curricula

The education system in South Africa is currently undergoing transformation. A new curriculum, referred to as Curriculum 2005, underpinned by an outcomes-based education philosophy (Sanders, 1999:382) has been introduced in schools. OBE is situated within a (social) constructivist theoretical framework (*ibid*). This approach may be seen as the merging of the Piagetian constructivist and the Vygotskian social interaction perspectives (Sprod, 1998; Tao, 1999).

Such development represents a major paradigm shift from the traditional practice in which the curriculum was content-based and teacher-centred to one in where the teacher is the facilitator and the learners are constructing understanding from information (Letts & Bailey, 1997; Malcolm & Smith, 1998; Smith, Malcolm & Ovens, 1999; Johnson *et al.*, 1999). Taking learners' beliefs and preconceptions into consideration during the teaching and learning processes is understood in the literature as learner-centredness (Duggan, 1996). Thus, Duggan (1996:68) contends that commitment to learner-centred education means

> putting learners first, recognising and building on the knowledge, skills, abilities and experience, responding to their needs, taking into account the different ways in which they learn and demonstrating respect for their language and culture.

Inevitably, learner-centredness means that learners are central in the curriculum and putting them first is critical (Duggan, 1996). Unlike teacher-centred approaches with their teacher dominance and focus on teaching that leads to rote learning (O'Sullivan, 2004), learner-centredness puts the emphasis on ensuring effective learning. Furthermore, learning is perceived to be dependent on the learner making links between existing knowledge and the content of instruction.

Such an approach, however, demands that teachers should revisit the 'dispenser of knowledge' role and recognise that the learners construct understanding of knowledge in their own ways (Prawat, 1996; Van Harmelen, 1997; Ritchie, 1998). Furthermore, learners possess their own understanding of science concepts and many commonsense beliefs about scientific phenomena (Liew, 1995; Meyer & Carlisle, 1996; Kuiper, 1998). Reflecting these conceptual shifts, Schön (1983, 1987), describes the type of teachers needed in today's schools as reflective practitioners (see Section 3.5.1) rather than 'technical experts'.

It seems this is easier said than done. For instance, all the six science teachers involved in this study felt that the principles of OBE were good on paper but were severely challenging when put into practice. As far as these science teachers are concerned, the problem lies by and large with the way in which the OBE principles have been introduced and implemented. Rogan, Grayson, Van der Akker, Ndlalane, Dlamini and Aldous (2002), too, note that the details on how to implement the curriculum at school level are often neglected. Instead, the emphasis is always on the development of the curriculum at the expense of implementation.

As a result, the implementation process is generally chaotic in most schools. From my own experience, this is exacerbated by the fact that teacher empowerment and support is lacking; yet, the development of capacity in schools (Czerniewicz, Murray & Probyn, 2000; Rogan *et al.*, 2002) is critical. Furthermore, for effective professional development to take place, it should be tailored to and cater for the diverse learning needs of teachers (Hargreaves & Fullan, 1998; Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003; Goodnough, 2003; Schoultz & Hultman, 2004). It is in this context that there needs to be ongoing support for teachers.

The six science teachers felt that before this new curriculum was introduced it should have been thoroughly researched, and the department should have established whether teachers were ready for change or not, as the underlying assumption is that teachers are supposed to be convinced agents of change (see Section 3.4.2). Rogan *et al.* (2002) elaborate that "changing teaching and learning practices should be viewed as a change of culture rather than merely a technical one." And, sadly, it seems that some teachers are not ready for change in South Africa. To this end, Zapholo commented:

> Everybody in the country speaks of change, but are we ready for change? If we are ready, then, what do you need to do to effect that change? And I think, personally I believe, that the change must begin within an individual. (Follow-up active interviews 10/10/04)

There is some value in Zapholo's suggestion that change begins with the individual and teachers should be prepared to take responsibility for their own learning in order to cope with change. Similarly, however, I would propose that there is a need for the creation of environments that are conducive to change taking place and this could be done through the creation of learning opportunities for teachers. Zapholo further reminds us:

> Remember, we have been through the old type of syllabus for so many years, and suddenly the very same teachers must change the whole thing and speak of learner-centredness. In the first place, I don't think some of us even understand whether the old curriculum was teacher-centred. To some of us, it was not teacher-centred because with the teaching of learners, you know you must simply give information to a child. So, to speak of learner-centredness in a very, very short space of time and carry out two-weekly programmes to show teachers how they should prepare lessons, how they should assess was very quick. (Active interview 16/03/04)

This suggests that the ways in which teachers were 'trained' cannot be downplayed during any transformation process. Ngwenya also supports this view and commented:

> The problem is that we were trained for a certain period of years at the teacher's college, and we were taught to teach in certain ways. In this new system, however, we were not given this opportunity, but we were just trained for two days and shown how to do OBE. (Active interview 04/05/04)

The time spent on workshops thus proved to be insufficient, as the science teachers experienced when they went back to their schools after attending the once-off OBE workshops: they found the approaches they had learnt challenging to implement. They recognised that learning about OBE approaches and implementing them were two different things. This suggests that putting theory into practice is a complex process. To this end, Neon recommended:

> If teachers could be given, say, three months to study OBE, that is, how it is done, how it is assessed, and then they go and teach in the OBE approaches; maybe they can have a better understanding of it. Because when we were taught OBE, it was only for five days, doing everything, assessment, how to teach OBE and everything else in OBE. Or you have a one-day workshop after two weeks or after a month. (Active interview 06/04/04)

It can be deduced from these teachers' comments that, while they personally welcome the transformation in curriculum, they feel that there should be efficient and sufficient time and space given to teacher development and growth. The six science teachers further highlighted the point that the lack of understanding of OBE approaches was exacerbated by the fact that some of the OBE facilitators themselves were not sure about the OBE principles. In their study conducted in Mpumalanga schools, Rogan *et al.* (2002) also say this.

Instead of acting as catalysts and providing a positive influence on the teaching and learning of science in new ways, many of the OBE facilitators add more confusion. All they seem to know and talk about is group work. As a result, most teachers perceive OBE as putting learners into groups. From my own experience also, there is a tendency to equate activity with learning during such group activities. Yet, engaging learners in group activities does not necessarily guarantee that learning will take place. In fact, I would argue that it should be borne in mind that learners have different learning preferences and teachers should not lose sight of that. Furthermore, equating activity with learning can be problematic.

The six science teachers also felt that there was a need for school principals and heads of department (HoDs) to undergo 'training' so that they could be able to support the implementation process of OBE effectively. Clearly, teacher support is essential, yet when I asked Neon if they had support after the OBE workshops, he responded:

> We get checked after three months to find out if things are working well or not, yet you will find that one's focus is on teaching and you leave out the assessment, and you say that you will do assessment later. But now after three months you panic that you are behind schedule and you end up changing your OBE teaching style so that when the officials come to your school to check you they mustn't find that you are behind. So, to make for the lost time, you end up teaching the syllabus. (Active interview 06/04/04)

Neon's comment is telling and it seems teachers are caught between the hard rock and the soft place. Striking the balance between teaching in interactive methods and completing the syllabus is evidently a challenge. This is compounded by the lack of support teachers are getting from the district office. Agreeing, Zapholo added:

> The National Office or District Office does not monitor this process. They do not worry about the actual implementation of OBE, but what they want is the end product, that is, how assessment is done. Exactly the same notion of the old curriculum, that the end result is most important. (Active interview 16/03/04)

This suggests that, without a proper support system in place, teachers will continue being overwhelmed by the demands of the new curriculum. For example, Khwezi indicated that he had attended only one workshop run for science teachers in the Further Education and Training (FET) band in 2004, and there has been no follow-up since then. Furthermore, with limited knowledge teachers find it difficult to support one another. In this vein, he said:

> I think some teachers lack confidence, they are not confident enough to discuss issues related to their subject areas. Also, the OBE workshops that are run for teachers even the facilitators themselves who run these workshops are unable to answer some of the questions asked by the teachers. So, teachers end up doing what they feel is right for them when they go back to their schools. (Active interview 20/04/04)

I agree with Khwezi that if a teacher is not knowledgeable in the subject area, that teacher will not have self-confidence. Yet, the idea of sharing expertise within the school is strongly supported by professional development literature (Fullan, 1993; Loucks-Horsley *et al.*, 2003) and a prerequisite for such sharing of expertise is self-confidence. Thus, teachers need opportunities to discuss curriculum in an ongoing manner with their colleagues (DiGisi, Nix, Daniels, Kramer & Cyr, 1999). Leo thus suggested that there should be ongoing workshops, specifically on assessment, and she commented:

> Up to now, most teachers are struggling with assessment; even some school principals know nothing about OBE and assessment. So, I would say through being involved in our research network I'm fortunate because I'm being exposed to development opportunities. At my school, however, I find that they are still behind and some of the teachers know nothing, for instance, about the new revised curriculum statement. (Active interview 07/04/04)

The six science teachers felt that the problems of OBE were also compounded by, for example, the Grade 9 common tasks for assessment (CTAs), which contain very little content knowledge to prepare the learners to cope with Grade 10 work. When I asked

Khwezi why some teachers neglected content knowledge at his school, he volunteered:

> In my school some of the teachers who teach in Grade 8 and 9 are teachers who have specialised in agricultural sciences and have limited science background. Their understanding of the science concepts is at the same level as that of their learners since they have done science up to Grade 9. Thus they tend to concentrate on the topics they are comfortable with, only neglecting other sections of the work. As a result of this, learners struggle to grasp science concepts in Grade 10. If you teach Grade 10, you find that you have to start from scratch. (Follow-up active interview 01/02/05)

This strongly suggests that teachers' ongoing professional development is essential. Similarly, the six science teachers felt that inquiry and investigative approaches need to be encouraged, rather than following predetermined ways of teaching science as is currently happening in some schools. Furthermore, there was a need for teachers to be equipped with skills on how to elicit, mobilise and incorporate learners' prior knowledge during teaching and learning repertoires. They further explained that eliciting learners' prior knowledge could give learners an opportunity to be actively engaged in discussions.

Also, it emerged from the interviews that learners seemed to be struggling with language, reading and writing as well as doing simple mathematical calculations. Yet these skills are critical. When I asked Ngwenya about his experiences of the learners coming from primary schools he said:

> Those learners coming from primary schools, there is a problem when they come to the secondary school. First, they are struggling with mathematics. Secondly, when it comes to science it is still difficult because they take science to be something that is in the textbook. Although they have been exposed to the OBE approaches, they don't link science to their everyday life experiences at all. So, you find that you have to start with the work they should have done at primary school level. (Active interview 04/05/04)

Clearly, Ngwenya recognises the need to make science relevant to the learners' everyday lives (Malcolm & Smith, 1998; Smit, 1998; Stears, Malcolm & Knowlas, 2003); learners' everyday knowledge could be used as a starting point for learning science. This is, indeed, in line with the recognition of learners' prior knowledge and hence the (social) constructivist approaches to teaching and learning (McRobbie & Tobin, 1997; Taylor, 1998; Moll, 2002). The social constructivist perspective recognises the importance of social and personal aspects of learning (McRobbie & Tobin, 1997).

It is also evident that there is a need for teachers themselves to be equipped with language skills (Burkett, Clegg, Landon, Reilly & Verster, 2001; Hendricks, 2003) so that they can improve teaching and learning of science. Burkett *et al.* (2001) note that it is difficult to teach and learn through a second language when neither the teacher nor learner speak it well enough. Quite interestingly and revealingly, Zapholo too commented that when you ask teachers why learners were lacking these basic skills they say, *"It is the way OBE is doing things" (Active interview 16/03/04).* From Zapholo's comment it is evident that some teachers are using OBE as a scapegoat.

On a positive note, however, when I asked the six science teachers how they thought their understanding of OBE had impacted on their teaching and learning beliefs, they responded that when OBE was introduced they saw a different way of doing things. However, they warned that teachers should be careful not to throw out the baby with the bathwater as they feel that teachers should draw upon the good things from the past. Richardson and Anders (1994) support this view and suggest that there is a need for teachers to question both old and new practices. However, they all realised that a teacher's knowledge base is critical. It is for these reasons that teachers' professional development and support is emphasised in this thesis.
Similarly, Zapholo commented:

> Subject-content knowledge played a pivotal role here. It is still my belief that if as educators we are not clear about the subject content knowledge, we will struggle to put it across to our learners. In my case, ever since I improved my subject-content knowledge many things began to dawn to me. I could see things with a new set of lenses. (Active interview 16/03/05)

I agree with Zapholo that teachers should strive to be masters and authorities in their subject areas. Ngwenya added:

> Although in this new curriculum learners should be actively involved and take responsibility for their learning, you as a teacher should be in a position to explain things to them, that is, you should be knowledgeable in your subject-content knowledge. You should also do research on the topic to be dealt with so that you can be clear, broadminded and open-minded during your lesson. (Active interview 12/05/05)

It is inspiring that Ngwenya recognises the vital role that should be played by a teacher during teaching and learning. He also highlighted his view that a possible reason why learners do not like science could be due to the thinking that science is only in the textbook- yet science is what they experience in their everyday lives (Smit, 1998; Stears *et al.*, 2003).

Through being involved in our research network, the six science teachers felt that they now understand the OBE approaches much better than before. To this end, Khwezi commented:

> I can say that OBE as was discussed in our network has impacted positively on my beliefs about teaching and learning. When I prepare my teaching and learning units of work now, I prepare them in such a way that my learners are actively involved. That is, I would say most of my lessons within the unit of work are learner-centred. During practical activities, I assist my learners with clearing of misconceptions. So, most of the time I plan my teaching and learning units of work in such a way that my learners are encouraged to take responsibility for their own learning. (Active interview 20/04/04)

This suggests that Khwezi attempts to focus on conceptual development and understanding during his lessons. On the clearing of learners' misconceptions or alternative conceptions, Kallery and Psillos (2001) note that a teacher's conceptual understanding is important: teachers themselves ought to be knowledgeable in their subject-content knowledge. Both Leo and Neon provide some possible solutions for some of these dilemmas.

> In order to encourage teachers to accept and see the need for change, workshops need to be organised and during such workshops the facilitators should not bombard teachers with lots of information. Also, there should be continuous workshops and teachers should be accredited for attending them. (Leo: Active interview 07/04/04)

> I would suggest that teachers should strive to improve their qualifications so that they can be able to cope with the demands of OBE and the two-day or weekly training we've been given by the Department of Education in which they expect us to know everything is not enough. (Neon: Active interview 06/04/04)

Essentially, all the six science teachers expressed the need for ongoing teacher support in the form of workshops. This suggests that teachers given the opportunities to learn can be willing to contribute towards their own professional development and change in education. In this vein, Walker (1991:116) notes that, "Teachers should be participants in change, rather than receivers and implementers." Furthermore, Walker (*ibid*:46 - 55) is optimistic that through action research teachers can be removed from the marginalised positions and from working in isolation behind the private walls of their classrooms. However, the science teachers involved in this study also recognise the need for teachers to be proactive in improving their own qualifications in order to cope with change.

2.3 Research sites and participants involved in this study

In my original conceptualisation of this research project, I had planned to work with a wide range of schools in Grahamstown - with some historically disadvantaged schools (former DET), former House of Representatives (HoR) and former model C schools - so that these schools could learn from one another irrespective of their geographic location. My contention was that, working with teachers from different schools could be helpful to obtain diverse perspectives on teaching and learning. Hargreaves (1992:216), too, posits that teachers are likely to learn a great deal from contact with other teachers who have experience and are knowledgeable about teaching and learning. I agree with him, however, this has its logistical challenges.

Yet, I eventually purposively (Adams & Schvaneveldt, 1985; Nachmias & Nachmias, 1990) restricted the research to 8 science teachers from 4 historically disadvantaged secondary schools in Grahamstown East. Also, I had hoped that by choosing teachers from local schools it would be relatively easy to meet as a research network, and facilitate the sustainability and continuity of the research project; this, unfortunately, proved to be a wrong assumption. What inspired me, though, was that one of the experienced science teachers recommended that we should have at least two teachers from each school to ensure sustained collaboration within these schools. This too had its own challenges.

In this section of the thesis, the four secondary schools involved in this study are examined individually; the sequence is based on their ages. They are also compared or contrasted according to the school, teachers and learners, and their socio-economic community background. In addition, the culture of teaching and learning at these schools is explored.

2.3.1 Matyana Senior Secondary School

The school

Matyana Senior Secondary School is situated at Gqunu Village in the Grahamstown East, about three kilometres from Grahamstown in the Eastern Cape. It is the oldest senior secondary school in the 'township' and has recently been rebuilt and renovated. The new school buildings are made of face brick. The administration block consists of the principal's and the deputy principal's office, HoDs' offices, the secretary's office and the staff room. There are many teaching classrooms and some are even empty due to the migration and mobility of learners to the other schools. The school has a library with a few old books and there is no librarian so that the library is not functional. Matyana also has a computer laboratory with just a few computers.

The school has five laboratories: one physical science laboratory, one biology laboratory and three natural sciences laboratories. Zapholo explained that these laboratories are used for a range of purposes and he keeps all the equipment in the storeroom, which is a safe place. Hence, other science teachers have to get the equipment from him whenever they want it. However, Ngwenya stressed that the fact that Zapholo uses one of the fully equipped science laboratories as a classroom, means that other teachers teaching in the lower grades find it difficult to use it. He felt that it would have been useful if they could also have easy access to this laboratory. This suggests that the administrative challenges and the subtle tensions that the staff are faced with at their school could in the long run impact negatively on their collaborative and collegial support (see Chapter 3).

Similarly, next to the biology laboratory there is a storeroom where all the biology equipment is kept. Zapholo reckons, too, that with their equipment, all the experiments that are prescribed in the Grade 12 syllabuses for both biology and physical science could be performed at his school. Nonetheless, the biology teacher was obtaining assistance from the Mobile Biology Laboratory (MBL) project. Zapholo commented:

> Although the biology teacher benefits from the MBL project, I would like to see him have hands-on experience. He mustn't just stand there and watch experiments being done. Some of these apparatuses are available in our school, and he therefore needs to learn to do experiments himself. (Follow-up active interview 10/10/04)

From Zapholo's comment it is evident that even where science equipment is available at school, if teachers lack the skills to handle such apparatus it will not be used. In fact, he explained that he was aware that the biology teacher at their school is not very skilled and confident enough to handle the biology apparatus. More generally, he emphasised that there is a need for professional development for teachers so that they can be effective in their teaching and learning repertoires.

The teachers and learners

Matyana is a mixed-gender school. All its learners are black and their mother tongue is isiXhosa. All teachers are also black and most of them speak isiXhosa except for two who speak seSotho and one who is Ugandan. The medium of instruction at this school is English. In 2004, Matyana had a staff complement of 22 teachers (including the principal and the deputy principal) and an enrolment of only 613 learners, resulting in the teacher - learner ratio being 1:30. Off course, this ratio could be mis-leading especially in the lower classes, where it is possible to get a class of about 40 learners. In the natural sciences department there were 318 learners and 4 science teachers. The total number of learners in Grade 8 and 9 was 212 and in Grade 10, 11 and 12 there was a total of 76 learners.

This suggests that Matyana was faced with a drastic decrease in the number of learners due to the expansion of the 'township' as a result of the influx of people from the nearby farm areas, resulting in new schools being built. Also, the fact that learners are now able to study at former model C schools and former HoR schools in town it has also contributed significantly to the decrease in numbers. Those parents who can afford prefer to send their children where they will get quality education. The decrease in the number of students has resulted in many teachers being redeployed to other schools, which has impacted negatively on their school since they have lost some good science staff. As a result, some science teachers were overloaded. That being so, Zapholo and Ngwenya feel that they and other teachers could not identify their school's needs adequately because they simply lacked time to do so.

The community and its socio-economic background

Matyana is situated in a community with a poor socio-economic background. Most families are dependent on pensions and government grants. As a result, the school fee is set at a modest R80.00 per annum, yet most parents are unable to pay even this small amount.

2.3.2 Phandulwazi Senior Secondary School

The school

Phandulwazi Junior Secondary School was established in 1977 because Matyana Senior Secondary School, the only senior secondary school in the 'township' in those days, could not accommodate all the learners from the four feeder primary schools in Grahamstown East. It was later up-graded into a senior secondary school and was relocated to a semi-formal settlement towards the far end of Mgwenye 'township'. It started off with an enrolment of 2474 learners.

The new school buildings are made of face brick. The administration block consists of the principal's and deputy principal's office, the HoDs' offices, the secretary's office and the staff room. The school has four laboratories: two science and two biology laboratories with a few pieces of equipment and old chemicals. Khwezi stated that the Department of Education last gave them equipment a long time ago, yet they are required to produce good results. This, as far as he is concerned, makes teaching of science very difficult. Another challenge they are faced with is the problem of burglary: the science laboratory and the storeroom have been broken into. He said that all the science equipment donated by the Grahamstown Rotary Club and the tools were stolen. Khwezi thus feels that the local community is not looking after the school.

The school has a library with a wide range of old books. However, it is not functioning properly since there is no librarian in the school. As a result, learners are unable to use the school library optimally. There are many teaching classrooms and some are empty due to the migration and mobility of learners to the other schools in town.

The teachers and learners

In 2004 the school had a staff complement of 24 teachers and there were 776 learners, with a teacher - learner ratio of about 1:30. The decrease in the number of learners has resulted in some teachers being redeployed to other schools. In the natural sciences department there were 338 learners and 5 science teachers. The total number of learners in Grades 8 and 9 was 205 and in Grades 10, 11 and 12 there were 133 learners. However, the trend is that the number of learners doing science decreases in the senior classes.

Of the five science teachers, two teachers have specialised in agricultural sciences and Afrikaans. With the phasing out of Afrikaans, these teachers were assigned to teach the natural sciences in Grade 8 and 9. Since these teachers' science subject-content knowledge is limited, they end up selecting the sections with which they are comfortable. Kallery and Psillos (2001) point out that teachers' knowledge on the content they teach influences the way they represent that content to the learners. Here, Khwezi commented:

> In my school, some of the teachers who teach the natural sciences in Grade 8 and 9 have no science background. Their level of understanding of science concepts is at the same level as that of their learners since they themselves have done science only up to Grade 9. I think this is the reason why they neglect science content knowledge. (Follow-up active interview 01/02/05)

As a result, learners are struggling conceptually when they are in Grade 10. This in turn makes extra work for Grade 10 teachers since they have to start from scratch rather than building on what the learners have already done. Given some of these realities in school contexts, especially in historically disadvantaged schools, Khwezi emphasised that teachers' professional development (Southwood, 2000; Spanneberg & Brown, 2003) is vital if teachers are to be effective agents of change. However, Southwood (2000) is in favour of collaborative approaches to teachers' professional development whereby teachers take responsibility for their professional development and growth.

The community and its socio-economic background

Phandulwazi is situated in a semi-formal settlement at Mgwenye 'township'. Most people living in this community are from the rural outskirts of Grahamstown, and most of them are illiterate. Although they are very keen for their children to receive quality education, they do not make an effort to look after the school. Consequently, the school has been vandalised and burglary is common. Also, most people in this community are unemployed and some are pensioners. The school fee is R100 per year and most parents are unable to pay this amount. Some learners even go to school without having eaten anything at home; yet they are expected to learn effectively. Some learners come from the nearby farms and they have to walk long distances to school. By the time they start their schoolwork you find that they are already tired.

2.3.3 Pioneer Senior Secondary school

The school

In the 1980s, the only senior secondary school in Grahamstown East was Matyana Senior Secondary School, and Matyana could not accommodate all the secondary school learners from Phandulwazi. Pioneer Senior Secondary School was therefore started in 1983. It started with Standard 7 (Grade 9) and Standard 9 (Grade 11) learners, and most of its learners came from Phandulwazi Junior Secondary School. Pioneer Secondary School was also the first black school in Grahamstown to have both black and white teachers. When it started, the ratio of white to black teachers was 3:1 and now it has shifted to about 1:10.

The school buildings are made of face brick. The administration block consists of the principal's and the deputy principal's office, the secretary's office, HoDs' offices and the staff room. The school has four laboratories - two science laboratories and two biology laboratories - but these are not fully equipped. The school has a library as well as a few books and some old textbooks. At Pioneer there is a teacher who has specialised in library work and she oversees the school library. Pioneer also has a computer laboratory with a reasonable number of computers.

The teachers and learners

Pioneer is mixed-gender and multiracial school, with black learners whose mother tongue is isiXhosa, as well as few Afrikaans-speaking coloured learners. The medium of instruction at this school is English. In 2004, there were 32 black teachers (whose mother tongue was isiXhosa), 3 white teachers, 2 coloured teachers and 2 Indian teachers. Thus, Pioneer had a staff complement of 39 (including the principal and the deputy principal) and an enrolment of 1133 learners, resulting in a teacher - learner ratio of 1:30.

In the natural sciences department there were 545 learners and 5 science teachers. The total number of learners in Grades 8 and 9 was 375, and in Grades 10, 11 and 12 there were 170 learners. Neon reported that almost all teachers who teach science at his school were qualified and he regarded that as one of his school's strengths. Some teachers have also tried to improve their qualifications through studying at various institutions such as Rhodes University and the University of Port Elizabeth (UPE) (now called Nelson Mandela Metropolitan University).

He also indicated that the biology teacher has been afforded an empowerment opportunity by being involved in the Mobile Biology Laboratory (MBL) project. Basically, all the prescribed biology experiments are done with the Grade 11 and 12 learners. Neon commented that a similar initiative was needed in science as well. However, he added that being involved in the participatory action research network has been beneficial to him in that his subject-content knowledge and pedagogical-content knowledge (Kallery & Psillos, 2001; Sherin, 2002) have improved.

The community and its socio-economic background

Pioneer is situated in a community with a middle-class socio-economic background. Most families in the school community are teachers, nurses and police officers, and in the past their school used to attract learners from both rich and poor families. With the migration of most learners to the former model C schools and former HoR schools, the majority of learners are now from poor families. The school fee is R120 per annum, and some parents are unable to pay this amount. For the use of the computer laboratory, however, learners are required to pay an additional amount.

2.3.4 Mfundweni Senior Secondary School

The school

Mfundweni Senior Secondary School was started in 1991 in response to the back-to-school campaign in Grahamstown East. When it started it had no buildings of its own and it operated from three different primary schools, something which made administration of the school very challenging.

Presently, located at the far end of Mgwenye 'township', Mfundweni now has new buildings made of face brick. The administration block consists of the principal's and deputy principal's office, the HoDs' offices, the secretary's office and the staff room. The school has four laboratories: two science and two biology laboratories. However, the laboratories are not fully equipped. For example, in the science laboratory they only have the micro-scale science kits that they received during the time when their school was involved in the micro-chem kit project, a project that was the brainchild of the Chemistry Department, Rhodes University.

Apart from this, they have little other science apparatus at their school, which makes the teaching of science very difficult. They indicated that they had to borrow science equipment from other teachers to give their learners first-hand experience of science in practical work. Here, Hodson (1990) warns that during practical work learners may fail to relate laboratory work to other aspects of learning. In view of this, there is a need for a deep theoretical understanding to be explored when practical work is done.

There are many teaching classrooms and some are even empty due to the migration and mobility of learners to the other schools. The school has a library with a few old books. As a result, learners are finding it difficult to use the library optimally.

The teachers and learners

Mfundweni is a mixed-gender school. All its learners are black and their mother tongue is isiXhosa. Most teachers are also black and speak isiXhosa, and there is also one Afrikaans-speaking coloured teacher. The medium of instruction at this school is English. Mfundweni had a staff complement of 13 teachers (including the principal and the deputy principal) and an enrolment of only 400 students in 2004 giving a teacher-learner ratio of about 1:30.

This school is faced with a drastic decrease in the number of learners. This has been caused by the migration of learners to two nearby senior secondary schools, plus the fact that learners are now able to study at former model C schools in town and former HoR. Leo and Nomfundo further added that the poor results produced by their school have also contributed to the decline in the number of learners. Nomfundo commented:

> At our school I feel we are failing as well since our results are not so good. I feel the management should be doing something about our results and encourage other teachers to teach at matric level. At the moment, teachers who constantly do not produce good results are retained despite their poor performance in terms of their results. And these teachers let our school down. I feel there is a need to do some reshuffles. I believe that a school markets itself through excellent results. (Follow-up active interview 14/02/05)

The dwindling number of learners has resulted in many teachers being redeployed to other schools. For example, they indicated that the senior physical science teacher, who was also an HoD, had been redeployed to another school. As a result, they are now without an HoD. In the natural sciences department there were 198 learners and 3 science teachers in 2004. The total number of learners in Grades 8 and 9 was 120 and in Grades 10, 11 and 12 there were 78 learners.

Nomfundo and Leo pointed out that in the past the other teachers who were asked to teach science at their school were not adequately qualified to do so. They felt that this had had a negative impact on the learners' subject-content knowledge and attitude towards science as a result, particularly in the lower grades. Presently, however, they indicated that the physical science and biology teachers at their school are relatively well qualified. Furthermore, all of them in their natural sciences department have done some science courses to improve their qualifications.

Leo highlighted the fact that the biology teacher at their school is involved in the Mobile Biology Laboratory (MBL) project, so that all the prescribed biology experiments are performed for her Grade 12 learners. Consequently, the biology teacher's learners are doing very well. She further said that this form of school-based professional support has contributed a great deal towards teachers' professional development and could make them better agents of change (see Section 3.3.2). Leo and Nomfundo wished that there could be a similar project for science so that learners could experience science first hand. At present they have to work with scant resources and at times they have to improvise.

The community and its socio-economic background

Mfundweni is situated in a community with a poor socio-economic background in Mgwenye 'township'. Most people in this community are unemployed and are thus dependent on pensions and grants from the government. The school fee is R100 per annum and most parents are struggling to pay this amount, which makes the school very difficult to run.

2.4 Culture of teaching and learning at the four schools

Zapholo, Ngwenya, Leo and Nomfundo all said that the culture of teaching and learning at their schools was poor, both on the part of teachers and learners. As Zapholo puts it:

> Now, the culture of teaching and learning is gone, although on paper it's always there. But actually it is not there, and the school principal has little or no say in this regard. I think the fact that the District Office can take decisions, or government, without the knowledge of the principal is one factor that makes principals not to know anything. (Follow-up active interview 10/10/04)

From Zapholo's comment it seems their school principal and HoDs have no powers at their school and he feels that this impacts negatively on their school's governance. Ngwenya gave these details:

> Regarding the culture of teaching and learning, the tendency is that, let me start with teachers first, there is a tendency that in the mornings there is about 15 minutes taken by teachers having tea in the staff room; yet the school has started, you see. The same thing applies when it's break time: you will find that some teachers don't go to their classes immediately. Teachers don't listen to our school principal. Sometimes some teachers do not even honour their teaching periods, but simply stay in the staff room and send some work to their classes. So we are faced with such problems. Some teachers don't go to school regularly and there is a tendency that some teachers simply submit doctors' certificates. (Active interview 12/05/05)

These teachers' comments are very telling. When I asked Zapholo why he thought some teachers were delaying going to class, he said that the duration of their teaching periods was now 50 minutes, and most probably teachers were finding it difficult to teach for the entire period. In my view, this might be linked to the fact that some teachers might not be confident enough in their subject-content knowledge or that teachers do not prepare properly. This suggests that there is a need for teachers to be empowered and supported in to developing teaching and learning units of work and learning programme units whereby they plan for the entire year rather than for snapshots of lessons.

Ngwenya further reiterated that he felt that poor governance at his school had a negative impact on the culture of teaching and learning in general. Also, he pointed out that there seemed to be no co-operation among the management team members at his school. He attributed some of these challenges to the influence of teachers' unions too.

> We are currently experiencing many challenges because of the teachers' organisations, especially when there were strikes; then the learners are left alone in their classes. Some teachers take an opportunity of this and go to do their own things. Some teachers do not attend school regularly due to their own problems. For instance, right now there is a teacher who has been absent from school for six months due to ill health, but there was no substitute teacher appointed in his place and his learners have not been taught. (Follow-up active interview 7/10/04)

Such behaviour, he said, impacts negatively on the learners' attitude since they easily get used to not going to classes. He further noted that some learners do not want to do their work especially if they are given homework. They simply copy each other's work. He said that it is not surprising to find that about 60 per cent of the learners have written the same thing. Ngwenya added that at their school there was a high rate of absenteeism by learners especially on pension days. Also, the learners have a tendency of going to their homes especially during break time and not come back. When I asked him what they are trying to do to maintain discipline at their school, he reported that since corporal punishment was abolished they are experiencing serious discipline problems. As far as using detention is concerned, they are experiencing problems with this form of punishment as teachers have to stay at school in the afternoon too.

Leo and Nomfundo agreed that there were few teachers who are committed at their school. Some teachers, they said, do not even prepare and did not care. As a result, even though they have qualified teachers, their school results do not reflect that. Another contextual problem they mentioned was that in the natural sciences department they seldom have departmental meetings and there is no teamwork: they are thus pulling in different directions, and as far as they are concerned this ends up affecting the whole school. They also mentioned that there seemed to be consistent absenteeism by certain members of staff. Their learners' parents were also not committed; and if teachers and parents were not committed, learners would also not be serious about learning and as result; the culture of learning at their school was very poor.

They also said that some of their learners are involved in drugs and some do not come to school regularly. They also mentioned that their school is affected by poverty and by the HIV/AIDS pandemic; consequently there is a high rate of absenteeism by both teachers and learners. When a teacher is absent from school, the learners are discouraged and thus get used to staying outside their classroom and this ultimately affects the culture of learning among learners.

In contrast to Zapholo, Ngwenya, Nomfundo and Leo, Khwezi and Neon felt that most teachers were committed and were trying their level best at their schools. This was shown by regular attendance by most teachers, extra classes for Grade 12 learners by some teachers, and subsequently the improvement in the end of year matric results. Khwezi did say, however, that there were a few teachers who are still not committed at his school and this worried him.

Regarding the learners' culture of learning, they felt that there were still very few learners who were serious about their education. This was evident, they said, in learners' late arrival and high rate of absenteeism. They further said that it was difficult to organise extra classes to catch up with the syllabus. Neon said that poor attendance by learners was common especially after school holidays. Furthermore, some learners have a tendency to stay outdoors, especially when their teachers are not at school and felt that certain teachers were not strict enough and did not take teaching seriously.

2.5 Concluding remarks

The reality of the research presented in this thesis has to be understood in the context of the school scenarios described in this chapter. The four schools have been compared and contrasted and it emerged that there were many commonalities as well as contradictions.

The following chapter focuses on the conceptual orientation of this study, whose central and key theme is teachers' transformative and continuous professional development. This chapter discusses the literature relating to teachers' professional development. My contention is that teachers' professional development should be viewed as an ongoing process throughout the teachers' careers. This topic is pursued in general terms; but a particular issue is whether learning opportunities created for the teachers enabled them to take more responsibility for their actions in order to improve the teaching and learning of science. I propose that co-engagement and collaboration of teachers in such actions requires an enabling environment. Enabling environments allow teachers to co-engage and interact in socio-cultural negotiation of meanings in constructive and reciprocal ways. This dynamic role requires teachers to develop professional attributes so that they can see themselves as invaluable human resources capable of negotiating meaning in the process of co-construction of knowledge.

Chapter 3

Conceptual orientation

> Professional development, rather than being seen as a package to be delivered to teachers, might be better viewed as a process in which the ebb and flow of action, perceptions and change constantly changing with the demands, needs and requirements of the teaching and learning school settings. In the way we design, implement and evaluate professional development our understanding should no doubt similarly be influenced.
>
> (Loughran & Gunstone, 1997:175)

3.1 Introduction

This study has offered me an opportunity to gain practical experience in working collaboratively with senior secondary school science teachers through the development and implementation of inquiry-based learning and teaching support materials (see Chapter 6). To Edelson, Gordin and Pea (2007), inquiry-based learning is the pursuit of open-ended questions and can provide valuable opportunities for teachers to improve their understanding of subject-content knowledge and scientific practices. Furthermore, inquiry-based learning is interactive and can provide a valuable context for science learning.

This research is thus premised on principles of collaboration (see Section 3.2.2), which in my view is critical for teachers' professional development. I believe that through collaboration teachers can be afforded opportunities to share their expertise and in the process learn *with* and *from* one another in reciprocal ways.

In this study, I refer to such a learning environment as teachers' transformative and continuous professional development (TTCPD) network, in which teachers' needs and contexts were central as Loughran and Gunstone (1997) suggest in the epigraph. Professional development in this thesis is regarded as transformative and continuous since central to it is critical reflection and recognition of teachers' professional growth as a continuous process of learning (Southwood, 2000; Klentschy, 2005). Learning is regarded as transformative[12] and hence the central theme of this thesis is the promotion of the TTCPD network with a view to improving the teaching and learning of science. Through taking responsibility for their *own* professional development and growth, the six science teachers involved in this study embraced and saw the need for change. For transformation in curriculum in South Africa, it is recognised that the role of teachers cannot be underestimated.

This chapter discusses the literature relating to teachers' professional development. This topic is pursued in general terms; but a particular issue is whether learning opportunities created for the teachers enabled them to take more responsibility for their actions in order to improve the teaching and learning of science.

The concepts of reflective[13] and reflexive[14] practices (see Sections 3.5.1 and 3.5.2 respectively) are examined as useful referents for considering further understanding of the teachers' professional development. According to Spanneberg (2003:29), for professional development and growth to take place, "teachers need to continuously reflect, evaluate, plan and revise their own practice."

I propose that co-engagement and collaboration of teachers in such actions requires enabling environments (Sonn & Miller, 1995). Enabling environments allow teachers to co-engage and interact in socio-cultural negotiation of meanings in constructive and reciprocal ways. This dynamic role requires teachers to develop professional attributes so that they can see themselves as invaluable human resources capable of negotiating meaning in the process of co-construction of knowledge.

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[12] Timmons and Alur (2004), citing Mezirow (1991) point out that transformative learning can result in socio-cultural action. To Kappel and Daley (2004) and Taylor (2007), transformative learning is grounded in the nature of human communication and can be effective at capturing the meaning-making processes which precipitate deeper personal change (Cooper 2001).

[13] According to Bleakley (1999:320), the word 'reflection' stems from the Latin *reflectere*, meaning to 'bend'. This implies a mobile way of thinking, one that suits the task of thinking through problems clearly.

[14] Reflexivity entails taking informed decisions and actions.

3.2 Curriculum reform

Gayford (2001:316) points out that one of the challenges facing teachers is that in most cases they are required to adopt methodologies devised by policy-makers. Some of the policy-makers were even never exposed to classroom environments. I would argue that in South Africa it seems the introduction of C2005 and OBE is a good example. Teachers were made to believe that the 'old traditional' approaches were not conducive to effective learning, instead of acknowledging the good things they have been doing from the past.

As a possible way round this mental block, Rogan and Grayson (2003) propose that a new theory of implementation for the new curriculum in South Africa is needed, to make teachers active actors in the change process. They further suggest that the theory should take the diversity of schools into account, since the knowledge and skills of the teachers vary enormously. And it should be borne in mind that for each teacher, change is a highly personal experience.

This is critical since teachers are seen as central in the curriculum reform (Prawat, 1992). Thus, Czerniewicz *et al.* (2000) propose that an understanding of the curriculum as practice should pay attention to the ways in which the curriculum is shaped by context, in particular, by resources and capacity. However, they too feel that the conceptual split between policy formulation and implementation, not just at classroom level, obscures this connection.

In this vein, Rogan and Grayson (2003) warn that failure to take into account differences in schools in preparing teachers for the new curriculum would contribute to implementation problems, as is currently happening in South Africa. As such, the implementation of C2005 and OBE is fraught with many challenges. On implementation, Grimmett (1993:201) suggests that "teachers as adult learners need concrete exemplars or sensitising frameworks to guide them in their initial classroom experimentation essentially alien to their conventional way of teaching." These issues are, however, not unique to South Africa and reaffirm the need for teachers' professional development.

According to Loughran and Gunstone (1997:160), professional development for teachers in Australia also often comprises once-off courses designed to support particular innovations. In most cases the changes are not negotiated and integrated into teachers' work; the reform is top - down and as a result teachers are not regarded as central in the reform efforts. Similarly, in a study conducted in India, Dyer *et al.* (2002:337) highlighted that top - down and undemocratic approaches to teacher development were orchestrated, overlooking the possibilities of involving teachers as equals in programme development. Yet, teachers and what they actively do in the classrooms are important in change processes (Walker, 1991:118).

Gilbert (1994:514), too, posits that teachers should generate professional development as part of professional renewal. Spanneberg and Brown (2003:154) emphasise that "sustained support through resources and follow-up visits to schools" can also have positive results during teachers' professional development.

Unfortunately, from my own experience, teacher support is currently sadly missing in most schools in South Africa. Teachers in most schools have to fend for themselves with limited resources; and despite those constraints they are expected to produce quality teaching and learning. It should be borne in mind that transformation is not a spontaneous process, but has to be driven. Against this background, the present study was undertaken to inquire into the benefits of a TTCPD network for science teachers' practices.

3.3 Some features of transformative professional development

3.3.1 Subject-content and pedagogical-content knowledge

For Prawat (1992:355 - 6), teacher development is both political and epistemological for teacher growth and change. Seen politically, he argues, empowerment is about teachers' professional authority, the *de jure* power. Epistemologically, the emphasis is on knowledge acquisition, the *de facto* power. Catering for both the political and epistemological dimensions is essential to ensure that teachers are central in curriculum reform.

However, based on my own experience as a teacher, I would suggest that in the South African context the nature of pre-service education and training (see Chapter 7) that most teachers received from teachers' colleges deprived them of the political and epistemological powers that Prawat alludes to. In most cases, the course content was mainly on high school work and not beyond. This suggests that there is a need for professional development when teachers are in the field. Southwood (2000:19) defines teachers' professional development thus:

> An holistic view of learning and development that implies the active involvement of the teachers themselves in an ongoing process of professional development.

It seems Southwood's view of professional development, with the emphasis on an ongoing process of development, resonates with the notion of lifelong learning as expressed by Duggan (1996), Shäfer (1999) and Edwards (2002). Lifelong learning suggests that teachers need to learn throughout their professional life and recognise that learning has no horizons. Most importantly, teachers should learn to be lifelong learners themselves (Senge, 1990). Such lifelong learning opportunities however, are limited in most schools, especially, historically disadvantaged schools in South Africa.

Dillon, Osborne, Fairbrother and Kurina (2000:34) propose that professional development should be geared towards developing the necessary skills and competence that teachers require to become lifelong learners within the profession of teaching of their subject areas. This suggests that professional development initiatives should equip teachers with knowledge and skills so that they could be at the forefront and take responsibility for their own ongoing professional development.

It is recognised, however, that such an idealistic ambition requires capacity-building (Klentschy, 2005), self-motivation (Babikwa, 2004), pro-activity and enabling climates to be fostered in schools. Klentschy (*ibid*) proposes that capacity-building can be accomplished through a process that focuses on practitioner knowledge: practitioner knowledge is useful for practice that develops a response to specific problems of practice.

Their research study in Namibia led Pomuti *et al.* (2003) to observe that a strong professional support network as an enabling environment should be developed to give continuous support for practising teachers. They also believe that teachers can benefit from ongoing support within the school itself from peers and other professionals, a view echoed by Southwood (2000) and Spanneberg and Brown (2003). However, they see a need for a policy framework to define and guide parameters for the professional development.

Based on their experience in working with mathematics teachers, Spanneberg and Brown (2003) reiterate that the new curriculum requires many changes and innovations in teachers' practice. Thus, they agree that for teachers to cope with such reforms, professional development is essential. I concur with Spanneberg and Brown; and I believe that teacher change is a precursor of transformation in education. This study was thus triggered by the belief that for teachers to be effective agents of change (see Section 3.4.2), a TTCPD network and general support are vital ingredients.

From their Namibian research, Swarts and van Graan (2003:21) warn that if the education reform is predicated on teachers being both the agents and implementers of change, they have to be adequately prepared for that task. Likewise, from research undertaken with both primary and secondary school teachers in England, Dillon *et al.* (2000:iii) reported that the teachers involved in their study expressed a need for an organised system of continuous professional development.

Furthermore, those English teachers stated that they wanted a "user-friendly system through which they could develop and strengthen their professional practice, principally by learning from peers" (*ibid*). This is indeed inspiring to hear, since most teachers are not used to working together (see Chapter 8). Yet, since teachers have to do ongoing learning on the job (Hargreaves & Fullan, 1998:83), they need co-learning opportunities and hence access to other colleagues to share knowledge, experiences and expertise. Co-learning has been the contention of this study. Co-learning provides opportunities for practitioners to interact and co-construct knowledge as we did in this study (see Chapter 6).

Such co-learning has been conceived of as both facilitating subject-content knowledge (SCK) and pedagogical-content knowledge (PCK) (Schulman, 1986; Sherin, 2002), which are seen as inextricably intertwined. Sherin (2002) explains that pedagogical-content knowledge (PCK) is knowledge for teaching the subject matter. She observes that there is a strong relationship between SCK and PCK, and that SCK precedes PCK.

Competence in both SCK and PCK is regarded as vital in promoting meaningful learning among learners (Loucks-Horsley *et al.* 2003). Thus, Hargreaves and Fullan (1998) unequivocally recommend that teachers need to develop stronger and ongoing collaborative work cultures (see Section 3.2.2) with their colleagues in order to develop both their SCK and PCK.

3.3.2 Collaboration, collegiality and reciprocity

> Teacher collaboration and mutual support are essential components of teacher professional development throughout a teacher's career.
>
> (Southwood, 2000:30)

In this section I examine three interrelated concepts: collaboration, collegiality and reciprocity. These concepts are regarded as central in the teachers' professional development.

Collaboration

Gayford (2001:315) suggests that teachers should engage in their professional development networks in collaboration with their colleagues. Through such collaboration, teachers could be afforded opportunities to learn from one another. Southwood (2000:30) recommends that such collaboration should be based on "collegial respect and appreciation of individuals and their knowledge." I agree, through collegial respect actors can feel comfortable to be part of the network.

I also found that collegial respect was fostered through encouraging all network actors to participate actively in our activities and take turns in leading positions. Such division of labour (Hardman, 2005) proved invaluable in ensuring active participation of all the actors, even if the level and intensity of participation varied. Gayford (2001), too, believes that collaborative and enabling environments could encourage teachers to draw on their collective fund of knowledge and place value on their experience as practitioners.

Grimmett (1993:200) adds that collaboration should involve mutual negotiation and purposes by parties committed to the common goal. Mutual negotiation is a process that respects individual and collective autonomy of the actors. In our study, mutual negotiation, co-engagement and collaboration were enhanced through our workshops in which we co-constructed knowledge (see Chapter 6). This suggests that collaboration cannot take place in a vacuum but needs some form of a catalyst, and our mediating artefacts were the inquiry-based learning and teaching support materials.

To Vygotsky (1978) and Loucks-Horsley *et al.* (2003), collaboration capitalises on the social nature of learning and might precipitate a socio-cultural activity and collegial sharing. In socio-cultural contexts, learning is contextualised or situated (Lave and Wenger 1991), with learning and joint-problem-solving focusing on issues encountered in actors' experiences. Chiseri-Strater (1996) and Goodnough (2003) note that a collaborative inquiry in socio-cultural contexts can be supportive and empowering and is an integral part of learning.

In essence, collaboration should be a goal of professional learning, and collaborative work structures might provide the mechanisms for convening groups of professionals around common learning goals (Loucks-Horsley *et al.*, 2003:138). Similarly, Pollard and Tann (1993:17) explain:

> Collaboration produces discussions and action together. Aims are thus clarified, experiences are shared, language and concepts for analysing practice are refined, the personal insecurities of innovation reduced, evaluation becomes reciprocal and commitments are affirmed.

I would add that collaboration allows meaning to be jointly constructed by actors through the process of dialogue. However, for individuals to be able to co-engage effectively in such collaboration the prerequisite in my view is that they need to be knowledgeable in their subject areas. It is for this reason that teacher learning and teacher knowledge in this study was fostered through a series of workshops (see Chapter 6).

Here, Hargreaves and Dawe (1990:227) emphasise that "collaborative cultures comprise evolutionary relationships of openness, trust, and support among teachers where they define and develop their own purposes as a community." Trust could be enhanced by showing respect for the professional knowledge that individual teachers bring to a professional learning community (Lock-Horsley *et al.*, 2003). Thus, implicit in the idea of collaboration described in this thesis is a strong acknowledgement of and commitment to the wisdom that teachers have to offer (Goodnough, 2003:514): recognition of teacher knowledge was achieved by forming sub-networks with leaders assigned to them (see Figure 6.2). The strategy of pairing actors was intended to enhance peer mutual support a nd show respect for their expertise.

Yonemura (1982:255), states that one way of showing respect for teachers' professional knowledge is by recognising the value of their conversations and contributions. According to Klentschy (2007), practitioner knowledge is focused on problems of practice and is grounded in the context in which teachers work and needs a supportive framework to result in productive professional development (Yonemura, 1982; Brookfield, 1987; Brookfield, 1995).

Similarly, Brockbank and McGill (1998:58) remind us that a dialogue with others implies that learning is not an individualistic process but a collective one. They, however, alert us to the danger of "mutual collusion" (*ibid*:100). Mutual collusion means that independent thinking or differences can suffer at the expense of consensus by network actors. Sievers (1996), adds that, in a work environment, any attempts to practice participation may lead to a situation in which management and workers get entangled in a 'collusive quarrel' concerning the range of participation. In light of this, I would caution that teachers should be careful not to collaborate for the sake of collaborating, and should be willing to learn as individuals first.

Collegiality

Coupled with collaboration is collegiality (Grimmett & Crehan, 1992; Spanneberg & Brown, 2003). Spanneberg and Brown (2003) posit that collegiality is a necessary condition for professional development. They also view collaboration and collegiality as inextricably linked.

Consequently, in their professional development model, opportunities for collegial sharing and collaboration were built into construction of portfolios[15] (*ibid*:155). The purpose of portfolios was to encourage teachers to document their growth, as they believe that portfolios give teachers opportunities to learn through interaction and reflection (see Section 3.5.1) with others. In such circumstances, teaching becomes a collaborative process with discussion-based evidence from the teachers' portfolios to underpin reflection on their practice (Boud, Keough & Walker 1985; Brookfield 1996). Active interaction is thus regarded as fostering co-construction of knowledge and meaning-making.

Contrasting with collegiality, however, is what is called by some scholars contrived collegiality (Hargreaves & Dawe, 1990; Goodnough, 2003). Hargreaves and Dawe (1990:227) explain that "contrived collegiality consists of administratively contrived interactions among teachers where they meet and work to implement the curricula and instructional strategies developed by others." Contrived collegiality might enhance administrative control rather than self-empowerment. Goodnough (2003:515) cautions us that some collaborative partnerships that are prone to manipulative control might result in contrived collegiality that is orchestrated administratively, in which case "elements of openness, trust and shared goals within a community of teachers" might be lacking. Hargreaves and Dawe (1990: 230) also warn us that:

> Professional development strategies are often presented and interpreted as empowering and emancipatory for teachers, when in actuality they may well be fostering disempowerment and dispositional adjustment. The advocacy of greater collegiality among teachers as a basis for professional development is particularly susceptible to these shifting meanings.

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[15]A professional portfolio is a representative group of documents that provides evidence of practitioners' knowledge, attitudes, beliefs and skills. It is a work in progress that reflects evolution and refinement of professional and personal growth. It is intended to encourage practitioners to become actively involved in monitoring and reflecting on their development. It is also intended to be used as an ongoing tool to encourage and guide future professional development (Spanneberg & Brown, 2003).

Put differently, the guarantee of collegiality cannot be given simply because people work together voluntarily on some shared goals. There are bound to be conflicts and contradictions to be resolved. In my view, conflicts and contradictions are part of a learning experience and can precipitate development.

Reciprocity

Southwood (2000) suggests that in collaborative structures it should be recognised that teachers are human resources who alongside with reciprocity are capable of taking responsibility for their own and other's professional development. According to Keedy (1999:788), "teachers themselves are the best resource for professional growth and support as they engage themselves in changing and improving classroom practice." Therefore, in professional development initiatives or professional networks, ownership and control need to reside with the actors. I would suggest that professional development initiatives should foster reciprocity and should be geared towards capacity-building with the ultimate goal of improving learners' learning (Loucks-Horsley *et al.* 2003). It is recognised that reciprocity demands that teachers are knowledgeable, pro-active and committed.

Prawat (1996) therefore argues that a 'learning community' should be characterised by a process of negotiation whereby the actors are encouraged to see themselves as co-learners throughout the collaborative process (see Chapter 6). This does not mean, however, that conflicts and contradictions would be less; but negotiation might help to put the actors on an equal footing so that they are comfortable in expressing their disagreements. Dyer *et al.* (2002:338) add that in such learning communities "responsivity, inclusivity and democratic practices" necessitate a coherent approach. This should also be based on relationships of mutual respect and appreciation (Grimmett, 1993; Southwood, 2000). However, sometimes such expectations are not easily attainable.

3.3.3 Envisaged professional development

Traditionally, approaches to teacher development in South Africa could be described as 'technicist'. To Gilbert (1994), the technicist thinking assumes that, teachers have limited skills, or lack skills and knowledge, and thus tend to rely on external experts who are seen as having the knowledge, power and authority. Gilbert (*ibid*:512 - 3) points out that in 'technicist' approaches, "teacher professional development is conceptualised as a process of 'training' teachers in such a way that they develop certain skills to certain (pre-set) levels of expertise."

For Gilbert (1994), the technicist thinking is thus equivalent to the 'deficit model'. Brookfield (1996) and Babikwa (2004) warn that the reliance on external experts creates dependent practitioners, adding that in the absence of the expert, practitioners are rendered powerlesss and even disempowered. From my own experience as a teacher, this is typical of the in-service education and training (INSET) that teachers received from the Department of Education and Training (DET) prior to 1994 (see Chapter 8). Nonetheless, although such courses could be labelled as technicist some of them enhanced the subject-content knowledge of some teachers.

Gilbert (*ibid*:154), instead, is in favour of 'liberatory approaches' to teachers' professional development in which "teacher development is conceived of as a process of empowerment of individual professionals." Through such initiatives, teachers are likely to be empowered and subsequently be effective in their practice.

This thinking resonates with the objectives of this study. The kind of teacher professional development envisaged in this thesis is thus concerned with the empowerment of professionals.

It is recognised, however, that, depending on their zone of proximal development[16] (Vygotsky 1978) some teachers might need more support than others. This suggests that professional development initiatives should take into consideration the teachers' diverse educational backgrounds and experiences (see Chapter 7).

As an alternative to the deficit model as highlighted by Gilbert (1994), Richardson and Anders (1994:163) propose a collaborative process in teacher development:

> The collaborative process is not based on a deficit model of change. Rather than beginning with the premise that teachers are not doing something correctly, the collaborative process assumes that reflection and change are ongoing processes of assessing beliefs, goals, and results. The important element, therefore, is the development of a change and reflection orientation to allow the teacher to continue to question both old and new practices.

Questioning the old and new practices sounds great in theory. But what skills and competences do teachers need in order to be able to question both old and new practices critically? In what ways could collaborative approaches enhance such questioning skills? These points are worth pondering; they have been raised in this text as an attempt to show how daunting the task of teachers' professional development can be. And I believe that a superficial interrogation and understanding of collaborative processes might inhibit rather than promote such processes.

Hargreaves and Dawe (1990:230) also seem to be sceptical of those collaborative professional development initiatives which claim to be empowering teachers. They argue that these may sometimes foster disempowerment among teachers. It is for

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[16] The fundamental thesis of Vygotsky's (1978) learning theory is premised on the idea that human psychological processes are embedded in socio-cultural contexts. For example, as learners develop and interact with their social world, their social psychological processes are influenced and transformed by those socio-cultural contexts. Vygotsky refers to this area of directed activity within the social world as the ZPD. Central to Vygotsky's learning theory is mediation, which he formulated as an artefact-mediated action involving the actor, a goal, and mediational tools. Furthermore, the ZPD is often characterised as a distance between the problem-solving abilities exhibited by a learner working alone and the learner's problem-solving abilities when assisted by a more knowledgeable person (Vygotsky, 1978; Lave & Wenger, 1991).

this reason that professional developers should be adept at facilitating empowering collaborative processes for teachers.

Loucks-Horsley *et al.* (2003:xvii) observe that during empowering collaborative processes "teachers become co-learners and co-creators of learning communities both in their classrooms and with their colleagues." Teachers function as part of a learning community (Senge, 1990; Prawat, 1992), taking responsibility for both their learning and their learners' learning. Loucks-Horsley *et al.* (*ibid*:xxii) thus propose a paradigm shift in professional development to bring about

> [a] change in emphasis from transmission of knowledge to experiential learning, from a reliance on existing research findings to examining one's own teaching practice, from individual-focused to collaborative-focused and from mimicking best practices to problem-focused learning.

This was indeed the shift that I endeavoured to discover in this study. It is recognised, however, that this is unfortunately easier said than done. For instance, at the moment, in South Africa there are tensions between curriculum formulation and curriculum implementation. This is exacerbated by the limited teacher support in most schools. As a result, from my own experience most teachers feel disempowered and disillusioned.

As an attempt to avoid disempowerment of the teachers involved in this study, the investigation was conceived as participatory action research (see Sections 5.3.2) with a focus on doing the research *with* the teachers rather than *on* them (Loughran & Gunstone, 1997; Hargeaves & Dawe, 1990; Pillow, 2003). This indeed signals a shift from individual and personal forms of professional development to collaborative and collegial ones as proposed by Loucks-Horsley *et al.* (2003) and mentioned above (see Section 3.2.2).

As Goodnough (2003:513) succinctly puts it, in this study I assumed the role of a "co-learner and co-constructor of understanding", in order to facilitate and create an empowering environment. Hence, I had to revise my own notion of what I value in my role as a professional developer and acknowledge the profound influence of teacher knowledge on the educational process. For these reasons, I gave the research a double focus: how teachers directly perceive their own development and what I as a professional developer learnt in this process.

In the next section I turn my attention to the possibilities and challenges pertaining to teachers' professional development.

3.4 TTCPD network: Possibilities and challenges

In this section, concepts believed to underpin teachers' professional development are discussed. The discussion starts with the teachers' professional landscapes; t hen issues around teachers as agents of change; then teachers' assumptions and beliefs; and finally potential support structures that are needed for a TTCPD network to function are foregrounded.

3.4.1 Teachers' professional landscapes

Professional knowledge and collaborative work cultures

Walker (1991) and Smyth (1996) observe that teachers' professional knowledge (practice), which encompasses SCK and PCK (see Section 3.3.1), is shaped by their own experience of schooling and how they have been socialised in the teaching profession. Teachers who have internalised traditional schooling systems, dominated by patterns of transmission and rote learning, tend to put that into practice in their classrooms.

This suggests that how teachers were taught at school and at teachers' colleges will invariably influence how they themselves teach: teachers are caught in their past histories and tend to operate within the horizons set by the ways of seeing and understanding they acquired through their prior learning (DiBiase 1998). Hence, the transmissive approaches to teaching tend to restrict teachers' creativity and in the process deprive them of meaningful and transformative learning[17] (Mezirow, 1991; Brookfield, 1995; Cranton, 1996; Kreber, 2006). To Kreber (2006), central to transformative learning is construction of knowledge about teaching and learning through reflection (see Section 3.5.1).

Furthermore, in transmissive approaches teachers tend to rely only on textbook knowledge. Smyth (1996) adds that teachers encultured into such traditional ways of thinking and acting tend to see themselves as implementers of other people's ideas rather than being pro-active and responsive. As a result, a schooling system that lacks opportunities for professional growth, support and development can impact negatively on the teachers' effectiveness in their classroom practices (Robinson, 1999).

A word of caution is merited here and it is for these reasons that I regard the TTCPD network as vital in this study. Loucks-Horsley *et al.* (2003) believe that teachers' professional knowledge landscapes could be influenced by collaborative work cultures within and across their diverse schools contexts. Fullan and Hargreaves (1992:6), however, remind us:

> Collaborative work cultures that actively promote ongoing teacher development are very much in the minority, and are held together only by the extraordinary efforts of a few. Ironically, the superficial forms of interaction and absence of support evident in most schools also thwart individuality.

In any case, though, Loucks-Horsley *et al.* (2003:139) advise that collaborative work structures for professional development should be based on the assumption that the quality and effectiveness of science teaching and learning should be the responsibility of the practitioners themselves.

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[17] According to Kreber (2006), individuals develop intellectually as they encounter events that cannot be interpreted through their exisiting mental frames. A frame of reference or conceptual structure is interpreted as a set of assumptions; constructs or conceptions individuals actively form through experience. As assumptions are questioned and transformed in light of contracting evidence, this can lead to change in a frame of reference. Transformation of one assumption may further promote reflection on other assumption.

Loughran and Gunstone (1997) observe that, through collaborative work cultures, teachers could be afforded opportunities to be part of learning communities of practice as further proposed by Lave and Wenger (1991). To Lave and Wenger (1991), learning communities of practice are characterised by situated learning. Patton *et al.* (2005:306) add that "communities of practice present a conceptual framework for thinking about learning as a process of social participation." This suggests that practitioners should embrace that learning is a socio-cultural activity rather than an individual process (Vygotsky, 1978; Lave and Wenger, 1991).

Certainly, both experienced and inexperienced teachers need support to continue learning and growing which is why science teachers are regarded as co-learners in this study. Indeed, I believe that the collaborative work cultures fostered in this study provided the science teachers with socio-cultural contexts that facilitated co-construction of science knowledge. Participation was further based on situated negotiation and renegotiation of meaning resulting in understanding and experiences being in constant interaction, which are believed to be mutually constitutive (Lave & Wenger, 1991:51).

In their professional development initiative, the Rhodes University Mathematics Education Project (RUMEP) endeavours to sustain collaborative work cultures through what they call teachers' collegial clusters within and across schools (Spanneberg & Brown, 2003). According to the latter, their teachers' professional development model based on collegial clusters is intended to provide a structure for mutual support and cooperative work among practitioners. Furthermore, the focus is on building the self-supporting communities of practice alluded to earlier on. In our TTCPD network, however, we had more emphasis on development of inquiry-based teaching and learning support materials.

While I like Spanneberg and Brown's (2003) notion of self-supporting communities of practice, what would add value to this would be the recognition of teachers as capable human resources, encouraging them to work together to identify their needs as we did in this study. I believe that, through helping one another, teachers would in the long term develop inner self-motivation and subsequently an awareness of a need for change, a view echoed by Babikwa (2004). This is critical since teacher learning is a precursor to teacher change, and such change in this thesis is seen as an ongoing process rather than an event.

Unlike Spanneberg and Brown (2003), though, Southwood (2000) is in favour of structures for mutual support and collaborative work rather than mutual support and cooperative work on their own. Southwood (2000:29) warns us that we should not confuse collaboration with co-operation: "inherent in collaboration is a sense of willingness and personal commitment", but not in co-operation. In my view, what would add value to Southwood's assertion would be an explanation of ho w such willingness and commitment come about. However, she acknowledges that collaboration cannot occur without co-operation and that co-operation can occur in one direction, whereas collaboration is mutual and dialogic.

To Zeichner and Liston (1996:18), implicit in collaborative and cooperative environments is the element of trust. The underlying assumption here is that where there is trust actors are likely to be willing and free to learn from one another in more enhanced reciprocal ways. While I agree, I would caution that trust cannot be developed over night. For example, in this study, we had to work as a network for a long time before genuine trust could be developed, which was essential for successful professional development.

According to Clark (1992), collaboration is vital to successful professional development because it helps to break down barriers of isolation in teaching. Loucks-Horsley *et al.* (2003) also emphasise that translating new learning into practice is best accomplished in collaboration rather than in isolation. Yet Lortie (1975) notes that classroom isolation is one of the most pervasive characteristics of teaching; and with teachers separated into classes, they are insulated from one another's work. While isolation might protect teachers from inspection and intrusion, Lortie says that it might also deprive them of opportunities to learn from one another and from collaboratively reflecting on crucial aspects of teaching and learning.

Little (1990) and Lam, Yim and Lam (2002) add that the resistance that results from the culture of isolation is detrimental to teacher development and school improvement as a whole. In South African schools in particular, judging from my experience in historically disadvantaged schools, teacher isolation is the norm. As Southwood (2000:6) puts it, "classroom doors are usually kept closed, both physically and metaphorically." Sadly, though, such isolation and individualism does not guarantee any genuine culture of teaching and learning either.

Culture of teaching and learning

In a research study conducted by Bateson (1995:6) twelve years ago, with schools involved in the Science Education Project in South Africa, his findings partly attribute the lack of culture of teaching and learning to resistance to the apartheid education system (see Section 2.2.1). He vehemently argues that such resistance has resulted on one hand in teachers withdrawing from effective teaching and on the other in learners withdrawing from learning. As a result, commitment was found to be lacking in some schools. This, among other things, resulted in some science teachers not improving science teaching and learning. In such circumstances, teachers who are not dedicated are not keen to run their first mile, let alone an extra one. However, Bateson (*ibid*) himself acknowledges that there were dedicated and hardworking teachers, albeit in the minority.

Lending support, Mason (2005) argues that apartheid left black schools virtually crippled, with almost no resources and with demotivated teachers and learners. Christie (1998:283) has described such schools as characterised by the following features: "disputed authority relations between principals, teachers and students; sporadic and broken attendance by students and teachers; poor school results; conflict and often violence in and around schools; vandalism, criminality, gangsterism, rape, and substance abuse; school facilities in a generally poor state of repair."

Consequently, many historically disadvantaged schools still remain dysfunctional despite changes in policy and law. This suggests that formal changes in policy cannot guarantee better practice. As long as policy-makers take little account of the context and agents of implementation (Enslin & Pendlebury, 1998:262), progress will be retarded.

The dearth of teacher commitment in most schools in South Africa continues to have a substantial impact on the organisational capacity of these schools to change (Mason, 2005). Sadly, although our democracy in South Africa is more than a decade old now, in my own experience, very few people know or even want to know how to teach and learn. We need to develop a positive culture for both.

The prevailing high levels of uncertainty such as teachers' redeployment[18], I believe, further exacerbate the poor culture of teaching and learning in some schools. For example, two network actors in this study reported that they were on the redeployment list at their school, resulting in them being anxious, lacking interest and unproductive.

Reflecting on the effects of uncertainty, Robinson (1999:192) cautions us that transformation in education in South Africa has dramatically changed teaching and learning contexts; and the dramatic change has had adverse implications on the culture of teaching and learning in most schools. This makes the need for collaborative work cultures all the more urgent.

[18] During the redeployment process, teachers who are in excess (in terms of teacher - student ratio) are removed to other schools irrespective of where the new schools are. In some cases, even married couples have been separated.

As Spanneberg and Brown (2003:154) succinctly propose, there is a need for the "establishment of professional development communities". They also believe that if teachers are willing to collaborate with each other, a strong culture of teaching learning could be developed in schools. Fullan and Hargreaves (1992) and Posch (1996), too, emphasise that the culture of teaching should be central to teacher development.

It is for these reasons that in this thesis the TTCPD network is explored as a unit of analysis. However, it is recognised that, without the appropriate opportunities for teachers to learn, the TTCPD network will just be lip service. In the next section I explore literature on teachers in their role as agents of change.

3.4.2 Teachers as agents of change

> Teachers are viewed as important agents of change in the reform effort currently under way in education and thus are expected to play a key role in changing schools and classrooms. Paradoxically however, teachers are also viewed as major obstacles to change because of their adherence to outmoded forms of instruction that emphasise factual and procedural knowledge at the expense of deeper levels of understanding. New constructivist approaches to teaching and learning, which many reformers advocate, are inconsistent with much of what teachers believe, a problem that may be overcome if teachers are willing to rethink their views on a number of issues
>
> (Prawat, 1992:354)

In retrospect, in this study teachers are viewed as important agents of change. For example, Yonemura (1982:239 - 40) reminds us that experienced teachers tend to be neglected as human resources for their own and other teachers' professional development. Yet she believes that experienced teachers might be in a strong position to take leading roles in professional development initiatives.

Brookfield (1995:7), however, disputes Yonemura's (1982) claim and warns that experience should not be equated with commitment and expertise since experience does not automatically confer insight and wisdom. Furthermore, the so-called 'experienced' teacher may be reluctant to accept and embrace change. Lending support, Southwood (2000:25) points out that:

> [An] ideology of mutual professional interaction – a dynamic process of professional support that recognises that each person has different insights to share according to their experience, and that the 'amount' of experience is not proportional to the quality of that experience. In a mutually supportive approach to professional development, a 'novice' teacher is recognised as a contributor to, as well a recipient of, the wealth of knowledge of the professional group.

While I concur with Brookfield (1995), this raises another question about what it really means to be an 'experienced' teacher. I personally would associate experience with lifelong learning as Duggan (1996) and Edwards (2002) suggest. Duggan (1996) holds that lifelong learning is a process that continues throughout a person's entire life and encompasses all forms of education, formal and informal, planned and coincidental. I would further contend that lifelong learning whereby teachers learn throughout their lives is one of the requirements for teachers to be agents of change irrespective of their experience as Southwood rightly points out in the above quote.

In my view, therefore, the experienced teacher Yonemura (1982) is referring to would need to be a lifelong learner in order to be an agent of change and take on such a leadership role. Furthermore, in the context of the democratic South African education system, lifelong learning is even more imperative since the curriculum transformation has heralded many changes and challenges for the teaching profession as a whole. This study particularly considered the strategy of affirming the wealth of knowledge already possessed by all the actors involved in the network.

Nevertheless, while I optimistically regard these science teachers as agents of change in this study, I would not be naïve enough to downplay Prawat's (1992) paradox highlighted above, that teachers can resist change. The question is: Why is it that some teachers evidently resist change?

The answer lies partly, I believe, in the fact that reform in education places numerous demands on teachers. For example, in the reform process, teachers are usually asked to introduce new technologies and new approaches, engage learners in meaningful activities, and create communities in which learners can discuss and reflect on their learning. Yet teachers might not themselves have been sufficiently exposed to such approaches.

Furthermore, at the forefront of reform are questions concerning the practical knowledge that teachers bring to their work and how such knowledge must develop if teachers are to manage the complex demands of reform. Similarly, Sikes (1992:36) posits that curriculum reform impacts upon teachers since it is their responsibility to implement the new curriculum in their classrooms. Likewise, teachers' assumptions and beliefs, which I examine in the next section, play a critical role during the curriculum implementation process.

3.4.3 Teachers' assumptions and beliefs

According to Nespor (1987) and Gee (1990), a teacher's belief system consists of both the personal cognitive understandings based on knowledge and cultural understandings developed in a socio-cultural context. Thus, they propose that professional developers should acknowledge the profound influence of teachers' beliefs and values in the educational equation and processes. How these beliefs and values manifest themselves in classroom practice and how these are amenable to change and development is critical. But, more significantly, beliefs and values impact on the quality and success of the reform.

It is widely recognised that, by and large, what teachers do in their classrooms is a representation of their assumptions, beliefs and values about teaching and learning (Sikes, 1992). It is also acknowledged that putting beliefs into practice can be a complex process. Sonn and Miller (1995) thus suggest that significant change in teacher practice and beliefs requires supportive learning environments. This is particularly critical in the context of South Africa, since we are undergoing transformation in the curriculum.

Sadly, far too often we see that during curriculum reforms teachers are required to change themselves and what they do, even if they believe that such changes are inappropriate in their contexts. In these circumstances, it could be argued that, teachers' professional freedom and autonomy, which are essential for emancipation and empowerment (see Section 4.2.1), are often curtailed in the reform process (Sikes, 1992:38). This provides further evidence that teaching as a profession is a complex enterprise, and thus the need for the TTCPD network is reaffirmed.

This study thus examined ways in which the TTCPD network influenced the teachers' SCK and PCK and subsequently their assumptions and beliefs about teaching and learning. This was done with a view to creating opportunities for teachers to be agents of change. Furthermore, in my view, the TTCPD network is essential in order for teachers to cope with the challenges of the process and implementation of this new curriculum.

The next section is an in-depth discussion exploring the support structures perceived to be essential in teachers' professional development.

3.4.4 Support structures for professional development

The contention of this thesis is that development of environments conducive for teacher support and learning is a necessity since transformative learning is a dynamic and an ongoing process. At the heart of transformative learning is the reflection and critical questioning of what actors practice. In the context of this study, transformative learning also entails learning scientific concepts, how to work collaboratively and support one another and how learners learn. Rodgers (2002) and Loucks-Horsley *et al.* (2003) reiterate that considering how learners learn should be an integral part of teachers' professional development, and can be best understood when teachers reflect and are knowledgeable in their SCK as well as PCK.

Thus, we need to create environments that are conducive to learning for teachers. Little (1992, 1993), Gayford (2001, 2002) and Spanneberg and Brown (2003) believe that such learning environments can stimulate teachers to engage in their own professional developments; as Smyth (1996:54) notes, "make teaching into a genuinely collaborative and sharing community" since teachers are currently neither used to working with their colleagues nor to taking leading roles.

For teachers to freely take leading roles and participate in networks, however, they should be equipped with the collaborative skills and positive attitude they require for working together. At the moment such skills are lacking in most teachers. Yet, to Gayford (2001), for professional development to be sustained, teachers should be in control of their own development. Similarly, citing the complex nature of teaching and learning processes, Pollard and Tann (1993:4) reiterate that professional development should be a supported continuous process. I agree, and that was the contention of this study: teachers need to be central in the process.

Scholars such as Hargreaves and Fullan (1998) and Loucks-Horsley *et al.* (2003) caution that professional development and growth of teachers should not be a 'one size fits all' routine, but rather it should be a combination of strategies that are geared towards the different needs of teachers. This makes sense since teachers and their contexts are not homogeneous. Goodnough (2003:531) adds that professional development initiatives should thus be tailored to cater for the diverse transformative learning needs of the teachers.

It is vital to take teachers' contextual factors into consideration since according to Hargreaves and Fullan (1992), classroom teachers are supposed to play a significant role in determining the success of any reform and this can only be achieved if their actual situation is factored into the professional development equation. Having said all this, however, I feel that engagement in continual reflections (see Section 3.5.1) should be an integral part of any professional development and growth initiative; and according to Hargreaves and Dawe (1990:229 - 30), "reflective practice brings together the principles of practicality, collegiality, and reflection as a basis for professional development."

With this in mind, I discuss the notions of reflective and reflexive practice in the following section as a useful referent for further illumination of the TTCPD network.

3.5 Reflective and reflexive practice in the context of teachers' professional development

A historical background of the concepts reflectivity and reflexivity is useful. Scholars such as Dewey (1933, 1938), Van Manen (1977), Zeichner (1981), Schön (1983, 1987), Zeichner and Liston (1987, 1996) and Steier (1991) contributed to the establishment of the idea of reflective practice. For the purposes of this study, however, I will base and develop my argument on Dewey, Schön and Zeichner's accounts of the notions of reflectivity; and on reflexivity, I refer to the work of Davies (1999), Wasserfall (1997) and Hertz (1997).

3.5.1 An overview of the concepts of reflection and reflective process

Dewey (1933:17) confidently believes that thinking enables us to direct our activities with foresight and insight. According to him (*ibid*:4 - 15), the origin of thinking is some "perplexity, confusion or doubt". Thus, "reflection involves not simply a sequence of ideas, but a consequence - a consecutive or ordering in such a way that each determines the next as its proper outcome" (*ibid*). Dewey (1933) believes that such consecutive reflective thoughts do not displace but rather support one another.

In essence, given the complex and dynamic nature of teachers' work, a century ago Dewey (*ibid*) viewed teachers as reflective practitioners and professionals who could play an active role in curriculum development. He, however, makes an important distinction between routine action and reflective action. He believes that primary impulse, tradition, and authority guide routine action on one hand. On the other, Dewey's (1933:9) conceptualisation of reflective action is best illuminated in his definition:

> *Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends constitutes reflective thought.* (Emphasis original)

Indeed, Dewey's (*ibid*) conceptualisation of reflective action, in contrast to routine action, highlights the iterative process embedded in the process of thinking. Furthermore, Dewey (1938:86 - 7) states:

> To be reflective is to look back over what has been done so as to extract the net meanings, which are the capital stock of intelligent dealing with further experiences. It is the heart of intellectual organisation and the disciplined mind.

According to Dewey (1933), three attitudes are integral to reflective action: open-mindedness, responsibility and wholeheartedness, the last revealing itself in people continuously examining their underlying assumptions and beliefs with a view to learning new things. These qualities were valued and deliberately entailed in our project.

It seems, however, to me at least, Dewey (*ibid*) sees reflection as an individual activity rather than a social process. While Dewey's (*ibid*) notion of reflective action is appealing, he does not explore how teachers can reflect together about their work. Furthermore, Dewey does not explain what skills and competences teachers need before they are able to examine their underlying assumptions and beliefs.

In an attempt to navigate the notion of reflective practice further in this thesis, the influential work of Schön (1983, 1987) has been considered. Like Dewey (1933), Schön (1983) also refers to teachers as reflective practitioners. However, Schön (1987:22 - 6) uses the term *professional artistry* to refer to the kinds of competences practitioners display in situations of practice. To illustrate further how practitioners enhance their practice while they are constantly engaged in it, Schön (*ibid*) uses the term *knowing-in-action*, a term that is linked to actions taken by practitioners.

Knowing-in-action entails that a practitioner is engaged in thinking around a problem at the very moment he or she is dealing with it. Such knowing-in-action, Schön (*ibid*) believes is translated into *knowledge-in-action*. He thus suggests that, reflection-in-action should be seen as the rethinking of the knowing-in-action, which leads to further thinking that affects what practitioners do.

To Schön (1983, 1987), reflection-in-action relates to a more tacit form of knowledge-in-action that is developed especially by skilled and knowledgeable practitioners. Developing knowledgeable and skilled practitioners through collaboratively developing and implementing learning and teaching support materials was one of the missions of this study. Schön (1987:31) succinctly says that "reflection on our past reflection-in-action may indirectly shape our future action." This suggests that action is implicit in Schön's (*ibid*) conceptualisation of the term reflection.

Furthermore, reflection-in-action suggests that professionals are engaged in reflective conversations within practical situations. In other words, knowledge-in-action is dependent on context, and reflection thus becomes the process whereby knowledge is made more explicit, resulting in practice being problematised (see Section 4.2.2) and attended to. Thus, according to Schön (1987), a reciprocal dialogue between practitioners is embedded in reflection-in-action. And when the problem is over, practitioners might then carry on to what he calls *reflection-on-action*. That is, practitioners periodically engage in reflection-on-action once the action is over. Reflection-in-action and reflection-on-action are thus not mutually exclusive, but rather are intertwined. In this vein, Bleakley (1999:319) reflects:

> Reflection-in-action is a 'hands on' business, rooted in shifts in circumstances-the unique and irregular - and forcing improvisation and risk. It is not cold, detached and disembodied rationalising of that practice as a clinical dissection. Reflection-in-action, as described by Schön, feeds on the unique and the indeterminate, and encourages improvisation - it is not a learned technique but surfacing artistry,

> suggesting that we might fruitfully ground reflective practice in an aesthetic, rather than a functional, domain.

Taking the idea further, Zeichner (1981) points out that reflection is something that should extend beyond the techniques relating to the immediate classroom context. He suggests that reflection should take into consideration factors such as the social, historical and institutional constraints, which determine why certain practices have been adopted or not. To Zeichner and Liston (1987:24), consideration of socio-cultural and socio-political contexts is critical since "teachers are encouraged to exercise their judgments about content and processes of their work and to give some direction to the shape of schools as educational environments." In such circumstances, teachers are viewed as creators as well as consumers of educational knowledge (*ibid*:31).

Similarly, viewing teachers as reflective practitioners assumes that they can both pose and solve problems related to their educational practice (McIntyre, 1993; Zeichner & Liston, 1996), thinking about how they frame and solve the problem at hand. Zeichner and Liston (1996:33) elaborate:

> Reflective teaching entails a recognition, examination, and rumination over the implications of one's beliefs, experiences, attitudes, knowledge, and values as well as the opportunities and constraints provided by the social conditions in which the teacher works.

Furthermore, Zeichner (1981) proposes that moral and ethical issues should also be considered in the process of reflection. I agree, there is a need to question the moral and ethical assumptions that underlie practice and contexts. The ethical dimension, according to Bleakley (1999), constitutes a shift from descriptive reflectivity to critical reflexivity which theorises and problematises action. The question is, however, given the teachers' past educational background in South Africa (see Chapter 7), how able are they to act on their beliefs and values? How can the moral and ethical issues pertaining to teachers' practice be enhanced in the schools?

Alvesson and Sköldberg (2004:246) add a further point:

> Reflection means thinking about the conditions for what one is doing, investigating the way in which the theoretical, cultural and political context of individual and intellectual involvement affects interaction with whatever is being researched.

In essence, these authors view reflection as being concerned with constructing as well as constructed self. Thus the process of construction demands something to construct, constructors and a socio-cultural context. For this study, the science teachers involved were co-engaged in the construction of understanding of science with a view to improving teaching and learning; and the ultimate beneficiaries as is encouraged by Loucks-Horsley *et al.* (2003) were their learners. The assumption here is that reflection and construction of understanding of knowledge could be enhanced through collaboration.

To reflect means to take time to think back on an event. And reflection can be undertaken both individually and with others (in a group) as it was conceptualised in this study. Pollard and Tann (1993:16) believe that "the value of engaging in reflective activity is always enhanced if it can be carried out in association with other colleagues." The assumption here is that through collaboratively engaging in reflections with colleagues, teachers could be afforded an opportunity to learn from one another in reciprocal ways.

Lending support, Brookfield (1995:29 - 35) points out that "our colleagues serve as mirrors reflecting back to us images of our own actions." The danger, though, Brookfield (1995) cautions, is that our colleagues who we use as mirrors might share our poor assumptions or adopt them too readily. Colleagues might corroborate our half-baked assumptions in the process, resulting in underlying assumptions being not sufficiently and critically questioned and challenged.

Here too, Biggs (1999:6) warns us that reflection as a term itself can be quite misleading. He explains that "a reflection in a mirror is an exact replica of what it is in front of it." Yet reflection in professional practice, which is the central theme of this thesis, might give back not what it is, but rather what might be an improvement on the original. This suggests that the notion of reflection should not be taken superficially, but rather should be viewed more critically and be interrogated more vigorously (Bleakley 1999).

Following Pollard and Tann (1993), Jay and Johnson (2002:76) state:

> Reflection is a process, both individual and collaborative, involving experience and uncertainty. It is comprised of identifying questions and key elements of a matter that has emerged as significant, then taking one's thoughts into dialogue with oneself and with others.

That is, Jay and Johnson (2002) interpret reflection as a process characterised by a dialogic collaboration, a view echoed by Pugach and Johnson (1990). Smyth (1996), too, suggests that teachers should be prepared to reflect in collective, collaborative and participatory ways when sharing experiences of their classroom practices with their colleagues. This has been one of the focuses of this study. Smyth (1996) further suggests that situating thinking in broader cultural, social and political contexts can promote critical reflection. This is crucial since in the context of this study the science teachers come from diverse backgrounds.

Valli (1993:16), however, states that through reflection teachers need to make "theory and practice problematic". Teachers should be encouraged to challenge taken-for-granted assumptions pertaining to their practice. For example, Brookfield (1995:14 - 16) refers to hegemonic[19] assumptions, such as the benefits of constructivist approaches that have been designed by those individuals that are in position of power where teachers are expected to embrace such assumptions. Given the power relations in terms of some actors' exposure to the curriculum reform activities, it is recognised that the discourse in this thesis was at times guilty of hegemonic assumptions too. Being aware of these, however, was itself an intellectual exercise.

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[19] According to Walker (1991), given the tensions between reproduction and transformation, the concepts of ideology and hegemony are useful tools for understanding change in education.

In the South African context, for instance, the introduction of the new curriculum, which is widely believed to be democratic, has to be embraced by teachers as soon as possible. From my experience, the irony is that teachers are neither taught to be critically reflective of the constructivist principles nor given the theory to be able to do so. Instead, the new curriculum is more of an induction into constructivist principles. In my view, for change to take place, critical reflection is important. The question I have in mind, however, is: Would it suit those who distribute the curriculum if teachers are critical?

In reality, the disparities in schools in terms of resources (both human and physical) are huge. Yet Brookfield (1995) argues that for teachers to be alert to hegemonic assumptions they have to be critically reflective. To him, critically reflective teachers have a "well-grounded rationale for their practice" (*ibid*:16). But it is recognised that to be critically reflective is difficult unless one has a strong theoretical background of, for example, pedagogy. In the context of South African education, would teachers who have been 'trained' for two years at a college have this theoretical knowledge?

Jay and Johnson (2002:79) further state that critical reflection entails the constant returning to one's own understanding of the problem at hand. I would argue that engaging in reflections should be seen as an iterative process rather than being linear. Within this context, Hargreaves and Dawe (1990:229) say that reflective practice thus involves practicality or doing.

This study locates itself within this framework. Hyatt and Beigy (1999:33 - 4) support the idea of praxis[20] (theory and practice) and hence state that the reflection process might promote "interaction and egalitarian pedagogical approaches".

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[20] Freire (1992) and Carr and Kemmis (1986) similarly construe praxis as informed action which, when reflected upon, changes the knowledge base that informs it. Grundy (1987) too adds to these views, arguing that the relation between theory and action (practice) described as praxis reflectively deconstructs the social world.

Through reflection, teachers can learn from both their similarities and differences in practice. While I subscribe to this school of thought, my concern is that teachers in South Africa have been demonised and marginalised, resulting in their sense of self-worth being downgraded.

I emphasise this because reflection implies making a decision through careful deliberation, a decision that might entail curtailing or proceeding with the actions that are reflected on. Further, by taking the broader context of schooling, the assumption is that reflective practitioners might come to see themselves as agents of change (see Section 3.4.2), capable of understanding not only what is, but also working to create what should be.

Hargreaves and Dawe (1990) and Richardson (1990) too acknowledge that reflection is a complex process of skilled and thoughtful judgements exercised in practical situations, and is context-dependent. Brookfield (1995:xiii) says:

> Critically reflective teaching happens when we identify and scrutinise the assumptions that undergird how we work. The most effective way to become aware of these assumptions is to view our practice from different perspectives. Seeing how we think and work through different lenses is the core process of reflective practice.

Pugach and Johnson (1990) and Brockbank and McGill (1998) also believe that it is through reflective dialogue that critical learning could be encouraged, something that could result in assumptions about knowledge being challenged. Otherwise, without dialogue, they argue, reflection might be limited to superficial insights. Furthermore, dialogue that takes place with others upholds the view that learning is socio-cultural activity.

Brockbank and McGill (1998:73) point out that reflective practice should be a core companion for critical reflective learning. Furthermore, Russell (1993) and Calderhead and Gates (1993) argue that through reflection teachers can critically examine their own practice: teachers might also learn to take charge of their own learning, and learn to question the underlying assumptions about teaching and learning. Furthermore, the opportunity to engage with others in reflecting on practice can limit the tendency to take things for granted (Brockbank & McGill, 1998).

According to Hargreaves and Dawe (1990:230), through collaboratively reflecting with colleagues, teacher isolation might be broken down. It is recognised, however, that a teacher might feel isolated by reflecting critically in a group. Or maybe a teacher might feel less isolated by fitting in with the status quo.

Brockbank and McGill (1998:100) state:

> In reflecting on our practice we do this in recognition that it is about, not only our meanings we give to knowledge, but also about ourselves and our actions, not merely instrumentally, but also critically in being able to envisage possibilities of other understandings, self and action that are not yet extant.

To Brookfield (1995:29 - 30), the critically reflective process happens when teachers discover and examine their assumptions by viewing their practices through four lenses:

1. First, there is a lens provided by autobiographical reflection;
2. Second, there is a lens represented by our students' eyes;
3. Third, there is a lens provided by our colleagues' perceptions and experiences - we can ask our colleagues to be our mirrors, mentors or critical friends with whom we engage in critical conversations about our practice; and
4. Fourth, we can view our practice through the lens of literature - locating what we do within alternative theoretical frameworks.

These lenses are, however, not mutually exclusive, but interlinked. Grimmett, Mackinnon, Erickson and Riecken (1990:23) add that the reflective process is context-dependent: the process might be influenced by the context in which teachers are working. They also believe that reflection shapes and restructures a person's personal knowledge and beliefs in space and time. In my view, that is why school-based support is vital in professional development.

As highlighted by Grimmett *et al.* (*ibid*) above, it should be borne in mind that contextual factors might vary from school to school. To Calderhead and Gates (1993:1), "reflection involves values, attitudes and beliefs as well as cognitive skills." Thus, Boud and Walker (1998:191) point out that reflection and reflective practice have become popular features of the design of educational programmes. However, Brookfield (1995:192) warns that there are many examples of poor educational practice being implemented under the guise and rhetoric of reflection.

Pollard and Tann (1993:12) state:

> Teachers are principally expected to plan, to make provision and to act. Reflective teachers also need to monitor, observe and collect data on their own and children's interactions, actions and feelings. This evidence, then needs to be critically analysed and evaluated so that it can be shared, judgements made and decisions taken. It is a dynamic process that is intended to lead through successive cycles or through a spiralling process, towards higher-quality teaching.

In my view, Pollard and Tann's conceptualisation of reflection captures the complexities of teaching and learning. The fact that teaching and learning are dynamic in nature requires teachers to think constantly about and act on their practice.

Likewise, Pollard and Tann (1993), Canning (1991), Wellington (1991) and Edwards and Brunton (1993) believe that reflective practice can encourage teachers to engage in a cycle of thought and action on their professional experience. In such circumstances, Wellington (*ibid*:4) posits that the teacher is thus portrayed as a creative designer rather than a technician: the underlying assumption is that, through reflection on their practice, teachers could become reflective practitioners.

Likewise, Anders and Richardson (1994:2) assert that reflection is "how teachers think about what they do and why they choose to use one practice but not the other."

They further assert that when colleagues reflect together, opportunities to share and support one another in reciprocal ways are likely to be promoted. Fenstermacher (1994:37) too, views reflection as a deliberative consideration of practice. However, as has been noted, the teachers' knowledge base and experience plays a vital role.

To Pollard and Tann (1993:20), the aim of reflective practice is thus to support a shift from routine actions (highlighted by Dewey) rooted in commonsense thinking to reflective action stemming from professional thinking. In my view, theory is important yet teachers may not be immersed in that theory. Perhaps, teachers' professional development could play a role here. Lending support, Costa and Kallick (2000:61) observe:

> Sharing reflections on events validates, expands, and enriches our internal conversations. By sharing, we can demonstrate and practice effective listening skills: probe for clarity and understanding, ask thoughtful questions and share our metacognition.

In the context of this study, development and implementation of learning and teaching support materials was used as a catalyst to promote sharing of ideas, knowledge and experiences among the network actors.

3.5.2 Reflexive practice

To place emphasis on the practicality component in practice, I would rather use the term reflexive practice. Reflexive practice means that the practical knowledge and action of teachers are vital. I will now explore the concept of reflexivity[21] (see also Section 5.3.2). For the purposes of clarity, I have adopted the word reflexivity, a term which is sometimes used in conjunction with reflection.

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[21] Bleakley (1999) cautions us that reflectivity and reflexivity cannot be used as unitary phenomenon. He argues that reflexivity entails dimensions of informed action or praxis.

Some scholars, however, tend to use the concepts reflectivity and reflexivity interchangeably (Alvesson & Sköldberg, 2004). However, these authors later explain that the term 'reflexive' has a double meaning with levels reflected in one another. They also reserve the term 'reflective' for aspects that consist of the focused reflections upon a specific method or level of interpretation (*ibid*:248). Furthermore, they contrast the focused and specialised nature of reflection with the multi-dimensional and interactive nature of reflexivity.

Other scholars take the meaning of reflexivity from its Latin-derived dictionary definition: to turn back on oneself (Steier, 1991; Bourdieu & Wacquant, 1992; Davies, 1999; Bourdieu, 2004). In trying to differentiate between the concepts of reflectivity and reflexivity, Chiseri-Strater (1996:130) states:

> To be reflective does not demand an 'other', while to be reflexive demands both an 'other' and some self-conscious awareness of the process of self-scrutiny.

This suggests that reflexivity entails self-criticality and action-taking. Ashmore (1989) and Davies (1999) also describe reflexivity as a process of self-reference and self-awareness: people have to think about their own concepts and what they bring to the situation. We have to be self-aware in order to extend and further our understanding of our situations. Furthermore, the importance of self-understanding (beliefs, values, attitudes and assumptions) in professional development initiatives or networks cannot be ignored.

It is this focus on the self and one's assumptions that distinguishes reflexivity from reflectivity. Matthew and Jessel (1998:2) explain that reflexivity can be a process for both the inexperienced and experienced practitioners, whereby practitioners are afforded an opportunity to stand back from the demands of the classroom and be open to available support from their peers or colleagues.

Indeed, the creation of a learning community whereby science teachers could support one another has been the contention of this thesis. In my view, embedded in reflexivity is informed action; whereas one can reflect without necessarily taking any action. Pillow (2003:178) also argues that to be reflexive "not only contributes to producing knowledge that aids understanding and gaining insight into the workings of our social world, but also provides insight on how this knowledge is produced." In this study we endeavoured to co-construct science knowledge in order to enhance conceptual development and meaning-making.

Also, the notion of reflexivity is associated with engaging in research, in particular qualitative research (Pillow, 2003:175). Pillow (*ibid*) notes that the use of reflexivity in that context is intended to legitimise, validate and question research practices and representations. Davies (1999) too believes that the process of doing research has an influence on how teachers perceive their practices. According to Loucks-Horsley *et al.* (2003:18), by engaging in research on their own practice, "teachers become actively involved themselves in data analysis and data-driven dialogue." Thus they believe that through doing research on their practice teachers can be encouraged to be responsible for their learners' learning problems.

Reflexivity is thus often understood as involving ongoing self-awareness during the research process. Such ongoing self-awareness aids in making visible the practice and construction of knowledge. Furthermore, "reflexivity as recognition of self imbues the researcher with the ability to be self-reflexive, to recognise an otherness of self and the self of others" (Pillow, 2003:181). To Hertz (1997:vii - viii), reflexivity is "accomplished through detachment, internal dialogue, and constant (and intensive) scrutiny of 'what I know' and 'how I know it."

I find it particularly difficult for social researchers to distance themselves from their actions as it is proposed by Hertz. I would argue that social researchers have to take responsibility for their actions in the process of data generation. In my view, also, what would add value to Herz's idea of detachment would be an explanation as to how this could be achieved without falling into the trap of a positivist ideology. The question I have in my mind is: How is it possible to detach oneself from the realities of the research one is engaged in? This is food for thought for researchers who claim to be self-reflexive.

In this study, unlike Hertz's proposition, co-engagement and dialogue among network actors were promoted through the collaborative development and implementation of LTSMs (see Chapter 6). As reiterated earlier on, our common ground was to improve the teaching and learning of science.

This adds weight to the thinking that to be reflexive is to have an ongoing conversation about experience resulting in some action being taken. Callaway (1992:33), too, posits the idea that reflexivity "becomes a continuing mode of self-analysis" and such self-analysis is best done through research. Self-analysis involves being critical (Hertz, 1996). Wasserfall (1997:151 - 2) adds that "reflexivity is a position of a certain kind of praxis where there is a continuous checking on the accomplishment of understanding", and thus "the research process becomes more mutual."

In the context of this study, all the actors were therefore regarded as both co-learners and co-researchers (see Chapters 6). It is all the more in this context that I believe that reflective and reflexive practice are integral to teachers' professional development.

3.6 Concluding remarks

This study explores key concepts, namely: communities of practice and capacity-building; assumptions and beliefs; learning and self-supporting communities; collaboration and collaborative work cultures; collaborative inquiry; agents of change; lifelong learning; professional network; culture of teaching and learning; isolation, individualism and autonomy; collegiality and contrived collegiality, reciprocality, mutual support and negotiation, mutual respect and trust, dialogic relationships, reflectivity, and reflexivity. These concepts have been woven throughout this thesis and I believe they underpin teachers' professional development.

Professional development and growth of science teachers at the in-service level were considered. However, the ideas explored in this thesis could be applicable to the pre-service level as well. By its nature, this study is intended to develop and support learning environments for science teachers with the view to improving the teaching and learning of science.

The next chapter describes the philosophical underpinnings of the research orientation and framework of this study. First, the socially critical-emancipatory orientation as a guide to the study is explored. This is essential since inquiry in this study is located within the process and context of human experiences. Secondly, actor-network theory as an enabling lens or framework to analyse epistemological and methodological underpinnings of this study is discussed. Blending of this orientation and framework was useful since central to the study was the empowerment of all the actors involved.

Chapter 4

Research orientation

> One approach to making ourselves more accountable and thereby sharing our experiences and insights more fully with readers is to locate inquiry within the process and context of actual human experience. Our experience suggests that research should accept the inevitability that all statements are reflexive, and that the research act is a social act. Indeed, that is the essential rationale for research approaches grounded in the contexts of the people who are actually involved in their settings and arenas.
>
> (Johnson & Altheide, 1990:30)

4.1 Introduction

This research study may be viewed as praxis-oriented (Lather, 1986b; Penney & Warelow, 1999). Praxis-oriented inquiry entails an active pursuit of open-ended questions on practice with the view to improving it. Lather (1986b) stresses that reciprocity (see Section 3.3.2) and respectful interactions between actors are needed in a praxis-oriented inquiry.

In this chapter, I examine the philosophical underpinnings of the research orientation and framework of this study. First, the socially critical-emancipatory orientation as a guide to the study is explored. This is essential since inquiry in this study is located within the process and context of human experiences as proposed by Johnson and Altheide (1990) in the epigraph. Secondly, actor-network theory as an enabling lens or framework to analyse epistemological and methodological underpinnings of this study is discussed. Blending of this orientation and framework was useful since according to Lather (1991a) an important criterion for emancipatory research is empowerment of actors.

4.2 Research orientation and framework

Research orientations, I believe, encompass a variety of methods and are often complementary and overlapping. However, although they may coexist harmoniously within one research context, this does not necessarily imply that there will be no tensions and contradictions among them. An analysis of such tensions and contradictions is the key to a better understanding of the dynamics of research and this is important since research orientations are reflective of certain ideologies.

In this study, a research framework has been developed to provide a basis for more intensive and coherent analysis of the research process leading to the activities of the TTCPD network (see Chapter 6). I would argue that, a research framework needs to be developed to assist in the strategic innovative approach from problem identification to creative solutions and implementation.

4.2.1 Socially critical–emancipatory orientation

> Our emancipatory interests lead to emancipatory knowledge. We have an interest in growth, development, self-awareness, freedom from constraint or oppression, and relational autonomy. Emancipatory knowledge is acquired through critical reflection and critical self-reflection. Our basic human drive for growth can lead us to critically question assumptions, values, beliefs, norms, and perspectives. Philosophically, the underpinnings of emancipatory knowledge lie in critical theory.
>
> (Cranton, 2001:12)

A socially critical–emancipatory orientation was chosen to guide this study. This orientation seemed appropriate since, according to Freire (1970), empowerment in education entails actors identifying the problems as part of a group effort to critically assess the social and historical roots to these problems. In actor-network theory terms, this is called problematisation (see Section 4.2.2).

Freire (1970:35), too, emphasises the need of dialoguing with people about their actions in the process of constructing meaning. Freire (*ibid*:47) adds:

> Critical and liberating dialogue, which presupposes action, must be carried on with the oppressed at whatever the stage of their struggle for liberation... Attempting to liberate the oppressed without their reflective participation in the act of liberation is to treat them as objects which must be saved from a burning building; it is to lead them into the populist pitfall and transform them into masses which can be manipulated.

To Freire (1970), liberation is praxis: the action and reflection of actors in their world in order to change it is crucial. Thus, the purpose of education should be human liberation so that people can be active actors in their own lives and society. To promote this role, Freire proposes a dialogic approach in which everyone participates in the creation of social change. In the context of this study such liberating dialogue was fostered through ongoing science workshops (see Chapter 6). It is recognised, however, that the degree of participation and involvement of actors is not necessarily equal as we experienced in this study.

The basic premise underlying Freire's (1970) work therefore is that human beings have the ability to take actions in order to achieve the critical capacity to make informed choices and transform reality. And critical research is explicit about its intentions to empower, emancipate and transform the socially, economically, politically and ideologically powerless (Lather, 1991a). Furthermore, Lather (1986a:67) notes that the critical tradition is premised on the view that there is neither neutral education nor neutral research.

Robinson (2002:116) adds that a critical approach adopts a "reflexive-dialectical approach to research and practice". Kemmis and Wilkinson (1998:31), too, explain that the reflexive-dialectical perspective on practice recognises that people are capable of taking action and making history. Reflexive research on practice according to (*ibid*:32) calls on actors to

> engage in a collaborative process of social transformation in which they learn from, and change the way they engage in the process of transformation ... adopts an 'emancipatory' view of the point and purpose of research, in which co-participants attempt to remake and improve their own practice to overcome distortions, incoherence, contradictions and injustices.

Such research attempts to build collaborative and democratic relationships aimed at enhancing social justice. In the context of this study, the critical aspect and interest, was pursued through the research process as well as through the content of the research (see Chapter 6). An enabling environment for practitioners who were also viewed as co-learners and co-researchers was created to challenge their underlying perspectives, assumptions, beliefs and theories in order to change their own practice through their own efforts. There was also an attempt to include all actors' *voices* throughout the formulation and interpretation of the research process.

It is indeed my conviction that actors' voices should be heard and that actors should be encouraged to take responsibility to remove themselves from the marginalised positions alluded to above. At the same time, it was intended that the findings of the research study would contribute directly to the improvement of support to schools and ideally, in the longer term, to building of capacity for teachers to take responsibility for their own professional development. It is, however, recognised that a vehicle to achieve such ambitions was needed. Thus, a TTCPD network was seen as essential for achieving such endeavours.

In the next section, I provide a discussion on actor-network theory framework as a catalyst for teachers' activities in the network in order to enhance their continuous professional development.

4.2.2 Actor-network theory: An enabling framework for TTCPD

> The present epoch will perhaps be above all the epoch of space. We are in the epoch of simultaneity: we are in the epoch of juxtaposition, the epoch of the near and the far, of the side-by-side, of the dispersed. We are at the moment, I believe, when our experience of the world is less that of a long life developing through time than that of a network that connects points and intersects with its own skein.
>
> (Foucault, 1986:22, cited in Edwards & Clarke, 2002:153)

As this quote intimates, life and learning is a complex phenomenon. This suggests that there is a need for people to secure spaces for networking; collaborating and learning from one another in order to enhance lifelong learning (see Section 3.3.1). There is an underlying assumption here that collaboration assumes uncritical consensus, yet people can collaborate and negotiate their differences in a collaborative context. Thus, the point I would like to make is that there is a need to strike the balance between collaboration and individualism to ensure that such spaces, as Edwards (2002:362 - 3) puts it, are ones of negotiation, discussion, dialogue, disputation and reflexivity; otherwise an uncritical advocacy of collaboration could be a futile exercise.

Essentially, as far as Strathern (1999:158) is concerned, actors in a network should always negotiate their relationship with others. In my view, such negotiations, discussions and dialogue are vital for the creation of dynamic professional learning communities (Nespor, 1994; Senge, 1990). Professional learning communities engage actors in learning in a supportive socio-cultural context. When ideas are processed in interaction with others, multiple sources of knowledge and expertise are likely to expand. Senge (1990) reiterates that learning starts with dialogue whereby actors suspend their underlying assumptions and engage in a genuine collective thinking process. Senge (*ibid*:3) further advises:

> We can then build "learning organisations", organisations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together.

Senge's (1990) emphasis is essentially on collective human endeavour which, from my own experience as a teacher educator, is essential for capacity-building: capacity-building enhances learning. Indeed, capacity-building through ongoing workshops (see Chapter 6) has been the central thesis of this study; and what individual actors contributed to the network was critical. Gomart and Hennion (1999:224), too, remind us that "action is the performance of a specific collective, rather than an individual agent."

This suggests that actor-network theory (ANT) (Callon & Latour, 1981; Callon, 1986; Latour, 1986; Law, 1986; Latour, 1987; Latour, 1991; Law, 1991; Latour, 1999; Law, 1999), which reflects the interrelated complexity of life and learning, advocates a shift from individuals to the collective. The danger here, however, could be that individual needs might be neglected at the expense of collectivism.

It is also precisely for these reasons that the intent of this research study was to create a learning space and environment to enable a community of science teachers engaged in a teachers' transformative and continuous professional development network (see Chapter 6) with a view to enhance conceptual development and understanding; and ultimately to improve teaching and learning of science. It is recognised, however, that this requires knowledgeable, reflective (see Section 3.5.1) and committed individuals to be willing to learn with others in order to display expansive patterns of thinking as it is proposed by Senge.

In searching for literature that could help explain the methodological and epistemological underpinnings of the TTCPD network in this study; I came across readings on ANT (Callon & Latour, 1981; Callon, 1986; Latour, 1986; Law, 1986; Latour, 1987; Latour, 1991; Law, 1991; Latour, 1999; Law, 1999; Miettinen, 1999). Having digested these, I believed that ANT seemed most appropriate for a study involving a network composed of human agents (science teachers) and physical artefacts (such as learning and teaching support materials), which Dison and Pinto

(1999) and Czerniewicz *et al.* (2000) believe are critical for fostering quality teaching and learning.

Some scholars refer to human resources or physical artefacts in ANT as 'actors' or 'actants' (Callon, 1986; Law, 1986; Callon, 1991; Callon, 1999; Fountain, 1999; Gomart & Hennion, 1999; Strathern, 1999); the terms 'actor' and 'actant' are used for both human resources and physical artefacts interchangeably. Gomart and Hennion (1999) point out that the notion of 'actors' or 'actants' allows researchers to explore the heterogeneity of elements in a network.

In this study I make a distinction and I refer to the science teachers as actors and to the LTSMs as actants; the LTSMs are mediational tools acted upon by the actors within the network. In line with ANT, in this thesis I will refer to the term 'team' as a network and to the 'participants' as actors.

Edwards (2002:355) adds that "educational practices can be seen as actor-networks in which participants and participation are ordered in time and space." It is in such learning spaces where actors' world views and experiences interact, and where the diverse cultures and languages that actors bring into the discourse are respected, affirmed, and validated (Goduka, 2005). In essence, ANT may help to facilitate a process of co-engagement (working together) of both human actors and physical artefacts as proposed by Goduka (2005), an aspect which in my view has potentials for sustainable transformative and continuous professional development. It is for these reasons that in my opinion an understanding of ANT is critical in the context of teachers' ongoing professional development.

Callon (1986) notes that ANT is characterised by four moments, namely: *problematisation*, *interessement*, *enrolment* and *mobilisation*. These should, however, not be seen as being isolated and rigid, but rather as overlapping, intertwined and flexible.

Problematisation is concerned with the framing of a problem area by the actors, in particular, humans within a network: "problematisation describes a system of alliances, or associations between entities, thereby defining the identity and what they 'want'" (Callon, 1986:206). To Edwards (2002:355), "problematisation is about what subjectivities and interests are allowable within specific networks – inclusions and exclusions."

This suggests that each entity enlisted by the problematisation is at liberty to become integrated into the initial plan or can opt not to, and pursue its own interests. In this study, the problematisation process entailed exploring professional development from the teachers' perspectives so that they could see themselves as central in the process. As a vehicle to carry the problematisation process, development of LTSMs (Dison & Pinto, 1999; Czerniewicz *et al.*, 2000; Ottervanger, 2002) was regarded as fundamental.

Interessement, on the other hand, is a group of actions by which an entity attempts to impose and stabilise the identity of the other actors it defines through its problematisation. To interest other actors is to build devices that can be placed between them and all other entities that want to define their identities otherwise. In other words, "interessement identifies the practices through which barriers are built between those who are part of a network and those who are not" (Edwards, 2002:355). However, actors are tentatively implicated in the problematisation of others. In this study, interessement called for commitment on the part of the science teachers (actors) who had to be enrolled in the TTCPD network (see Chapter 6).

Enrolment designates the device by which a set of interrelated roles is defined and attributed to actors who accept them: involves making networks (Law, 1986), with roles assigned to or assumed by the actors. In this study, such roles were negotiated based on the actors' strengths. For this, sub-networks with actors in charge had to be formed (see Figure 6.2).

To Edwards (2002), while interessement sets the barriers to participation, enrolment fashions the alliances within the network. In essence, the enrolment process entails a principal actor (Law, 1986:16) taking a leading role. In this study, two actors who are experienced science teachers and typical examples of lifelong learners (Edwards, 2002) have assumed such roles; albeit at different levels of engagement (see Chapters 6 & 9).

Lastly, to Callon (1986), mobilisations are the practices through which enrolled networks are temporarily stabilised and made manageable and mobile. For the TTCPD network and growth purposes, it was imperative that both human actors (science teachers) and physical artefacts (LTSMs) had to be mobilised to enhance capacity-building among the actors involved in this study.

This was necessary since, in my own experience, even if LTSMs are available; if there is no science teacher who is equipped to use them then effective learning will not necessarily take place. Likewise, an empowered and skilled science teacher might be there, but without the necessary materials his or her efforts might not be actualised. In the latter scenario, however, there might be possibilities for improvising: improvising entails developing and utilising accessible resources in teaching and learning repertoires. These were the reasons for promoting a TTCPD network as an enabling learning space in this study.

To Callon (1986), these four moments constitute the different phases of the process of translation: reorganises relations in actor-networks and is "the process whereby the interests of actors in networks are aligned through change" (William-Jones & Graham, 2003:272). Fountain (1999:344), too, argues that an actor network exists when there is an interrelated set of entities that have been successfully enrolled through the process of translation. Thus, the notion of translation emphasises the continuity of the transformations that occur in an actor network (*ibid*). Furthermore, translation can be understood as the "mechanism by which the social and natural worlds progressively take form" (Callon, 1986:224) in a network.

However, certain entities may seek to control others in a network. To guard against this, Law (1986) proposes that the translation model, in which people's views and ideas are respected, should be adopted, albeit knowledge possession might be one of influential factors, as was the case in this study. In short, it is through translation or mediation that networks are formed and such performances are the translations through which "networks form, reform and dissolve" (Edwards, 2002:355). It should also be recognised that it emphasises the performative nature of knowledge-building (Latour, 1986; Gomart & Hennion, 1999; Law, 1999; Edwards, 2002).

In retrospect, while I applaud the notions of co-engagement in and co-creation of our world as proposed by Goduka (2005), what attracted me about ANT in particular was that ANT calls for a curriculum that reflects socially constructed versions of science (Fountain, 1999:350). This to me is in line with the curricular transformations in South Africa (see Section 2.2.3), which also advocate an emphasis on transformative learning processes. This is where I personally locate and find ANT most appropriate in this study. However, I am mindful of Edwards' (pers. comm. 2005) warning that we should be careful of re-operationalising ANT whereby we focus on human actors and lose the insights regarding the affordances of the physical artefacts.

Thus, Nespor (1994: 1) points out:

> It will be necessary to rethink what it means to 'learn' or 'have' knowledge. I will propose that we shift our focus from individual minds and groups in face-to-face interaction to questions of how activities are organised across space and time, and how organisations of space and time are produced in social practice.

To Nespor (1994), the notions of knowledge and learning are products of socio-cultural activities rather than of isolated minds, a view reiterated by Vygotsky (1978). As a result, the benefit of participating in an actor network can result in actors giving and gaining knowledge (see Chapter 6). However, since knowledge is power, Nespor (1994:134) talks of "power-geometry" to show that in a network there are power relations. For instance, it has become evident in this study that the amount of subject-content knowledge actors possessed proved to be a determinant and stimulant for their level of participation. Similarly, lack thereof has, in many ways, been a potential inhibitor.

Participatory action research (see Section 5.3.2) was thus adopted as a strategy to encourage actors to connect within our network. A PAR approach thus framed a learning and research context/space, within which activities could be understood, analysed, investigated and shared among network actors. Such contexts were thus intended to be landscapes for dialogues amongst the science teachers during their professional development processes in this study.

Edwards (2002:354) emphasises:

> Actor-network theory is part of the shift from individualised, psychological approaches to the understanding of knowledge-building to more social and cultural interpretations.

This suggests that knowledge-building is taken to be a joint exercise within a network. Consequently, in his research study, Nespor (1994) drew upon ANT to examine how physics and management students were organised during learning processes and found these to be varied in many ways. For example, the physics students tended to be structured whereas the management students were much more flexible in their approach.

He thus suggests that, in order to understand how an activity is connected to learning and knowledge, we have to understand the interactions and the networks involved. In educational practices this is essential since in such learning environments the nature of teacher - teacher or teacher - learner interactions is one of the most important factors determining meaningful learning. Interactions between actors are the building blocks of networks.

We can extend Nespor's parallelism even further. In her study of indigenous ways of knowing, Goduka (2005) uses the metaphor of *eziko* (the hearth) to denote the learning space for interactive participatory learning practices by some of the *Nguni* communities in South Africa. As a child, I had vivid experience of such learning spaces from my mother's home in the rural areas of Peddie. Learning there occurred mostly through stories that adults told to children.

Goduka (2005) further explains that intercultural and intergenerational dialogues are catered for in such a learning space. Thus, practices within such a framework "ground culturally situated co-engagement activities that deepen understanding of education/research within an indigenous perspective that is situated in a relationally socio-ecological space" (*ibid*:468) and thus reiterates:

> Key to attainment of sustainable development, which is often reflected in the quality of life of communities and that of their surrounding environment, is the understanding that learning, teaching, and research processes must first be rooted in the local/regional languages, cultural practices and spiritual values that resonate with the worldview and philosophical foundations of a specific ethnic group.

In this study, as an attempt to foster co-engagement in programmes that are relevant to local concerns as proposed by Goduka (*ibid*), I too endeavoured to draw upon ANT to examine the ways and means in which science teachers from historically disadvantaged schools were organised as a network, considering the implications in terms of their professional development pertaining to "knowledge and knowledge-building capacity" (Edwards, 2002:359). Such knowledge-building capacity was, however, fostered through working with science teachers who have established themselves as practitioners so that they could take responsibility for their own professional development (Loucks-Horsley *et al.*, 2003; Reeves and Forde, 2004).

Edwards and Clarke (2002:362), too, make the point that the creation of learning opportunity spaces for teachers is tantamount to enrolling them in a network as lifelong learners. Lifelong learning demands that teachers be prepared to take action. Giddens (1981, 1990) adds that a social space for practice is linked to acting and action: teachers should learn to, as Senge (1990) puts it, walk the talk. Similarly, Nespor (1994:1) sees "knowledge-constitutive activities organised by networks across space and time" as potential opportunities for the empowerment of teachers.

Central to this study too was the co-creation of spaces and time for collaborative acting and action by the actors. We co-created the network and collaboration opportunities as an empowerment forum, and we have been working together for four years. This is in line with Nespor's (*ibid*:12) assertion that a network "points to spatially dispersed elements that have been linked together over time" in order to enhance collaboration. Tapping into the network actors' professional knowledge was regarded as important in this study.

Nespor (ibid:9), however, cautions us that people do not simply join networks in an "apprenticeship mode, but they are defined, enrolled and mobilised along particular trajectories that move them across places in a network." This suggests that professional development cannot be treated as an event but rather as an ongoing process. In contrast to Nespor's (1994) assertion, it emerged from this study that some teachers were initially relegated to an apprenticeship mode due to their educational backgrounds and grades that they teach (see Chapters 7 and 8). Despite this contradiction, all actors in this study were regarded as equally important.

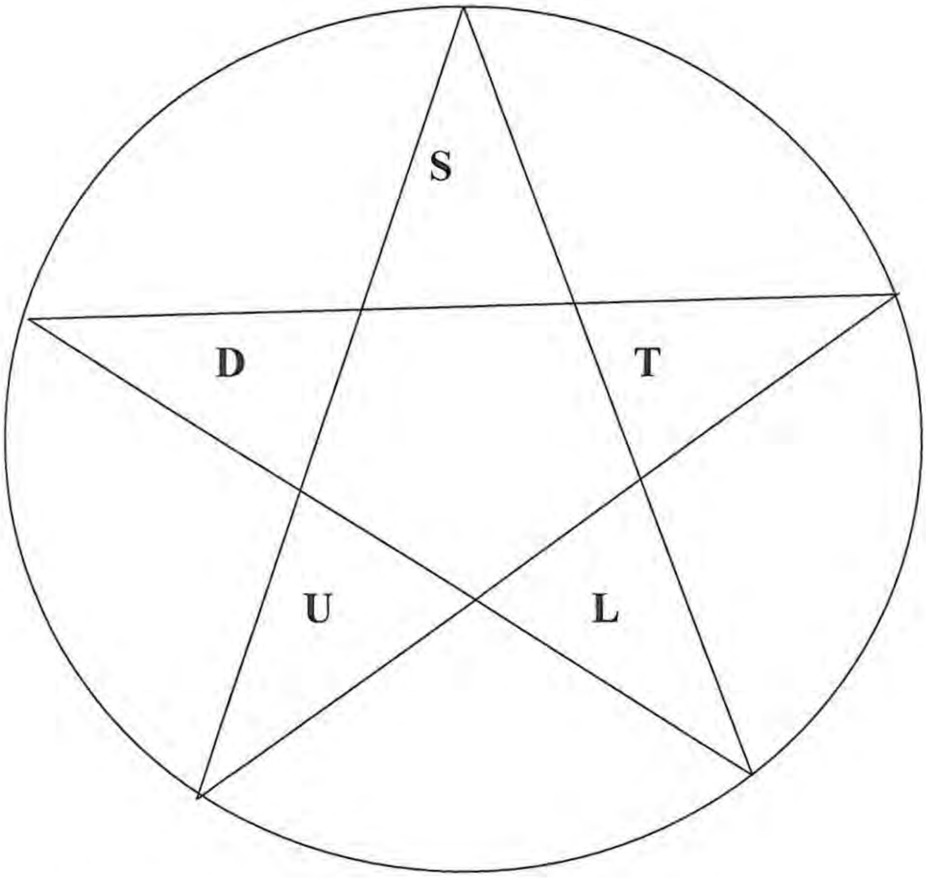
Loucks-Horsley *et al.* (2003:146) reiterate too that "a network is an organised professional community that has a common theme or purpose." Individuals join networks to share their own knowledge and experiences with other actors; thus networks might help to keep teachers from being isolated and "cocooned within the walls of their classrooms" (Edwards, 2002:362): providing professional development for teachers that can be effective in reducing isolation.

Furthermore, networks can provide a forum for interaction with peers from different parts of the community. Teachers thus become part of a collegial and cohesive professional development that examines and reflects on issues related to teaching and learning. Networks are thus intended to provide support, encouragement and motivation as well as intellectual stimulation. In this study, it was hoped that this stimulation would be provided by engaging the science teachers in this network to share their expertise, success stories, challenges and dilemmas.

Loucks-Horsley *et al.* (2003:151) rightly point out that a learning network must have a high level of trust among actors so that "participants may feel free to disclose information about what they think, how they teach, and what they need." I agree with these authors that trust enhances mobilisation as the network acts purposefully and makes collective effort (Selmand & Wragg, 1999:330); otherwise lack of trust might result in networks dissolving, as Edwards (2002) cautions us. However, Selmand and Wragg (*ibid*) warn us of 'black boxing' where beliefs are taken for granted, resulting in reduced negotiations.

The network in this study could be viewed as a school-to-university (I, as the main researcher based at university, and network actors studying at this same university), school-to-district office (one network actor involved with curriculum implementation at district level), school-to-school (four schools involved in the network), teacher-to-teacher (two teachers per school involved in the network), and teacher-to-learner (teaching practice) linkages or collaborations. The linkages between the actors- who are seen as co-learners (see Chapter 6) - in the four schools and the university-based researcher are shown in the diagram below.

Figure 4.2



Key: S - Schools; D - Department of Education; U – University; T – Teachers; L - Learners

This diagram has been drawn in accordance with Fountain's (1999) advice that a network is not a hierarchical structure but a web of connected nodes; and that it is also dynamic and fluid rather than static. This diagram also reflects the interconnections of different aspects – each linking to the other; having its own space and the spaces inbetween. It also resembles the sitting arrangement around the hearth (*eziko*), which is a participatory learning space as proposed by Goduka (2005). The circle thus represents the relational worldview of the connected elements in this network; in addition, the star represents a symbol of hope for collaboration among the actors involved in this study.

Goduka (*ibid*:475) adds that in a "relational/ecological worldview, humans receive from each other and from nature; and give back to each other and to nature." Furthermore, the underlying assumption is that in a relational worldview our world does not consist of separate elements but of relationships among humans, and between humans and physical artefacts.

Law (1999:4), too, asserts that, in an actor network, entities achieve their form as a consequence of the relations in which they are located. ANT may thus be viewed as relational where both human and physical arterfacts are relationally defined. And in a relational orientation, relationships and complexities that exist in a network should be considered. Goduka (2005:475) thus emphatically adds:

> We participate in our world, so that the 'reality' we experience is a co-creation and see that a collective participation is an ecological imperative. This worldview requires us to be both situated and reflexive, to be explicit about the knowledge created within inquiry processes of coming to know.

The underlying assumption embedded in our network was that collaboration among actors could enhance professional development and thus lead to improvement of science teaching and learning. So, actors had to see themselves as valuable human resources who are responsible for their own professional development. Furthermore, since a network is relational, as Law (1999) proposed, it should be seen in terms of what it does, its coherence as well as its heterogeneity: network containing many dissimilar elements.

Nespor (1994:12), however, warns that "networks expand, contract, and shift configuration over time, and even the most stable and predictable of them are constantly re-appropriated and redefined." I agree with Nespor. For instance, in this study contraction has been experienced as some actors left the network. Yet expansion and redefinition have also occurred in terms of the formation of a sub-network consisting mainly of three teachers teaching at Grade 12 levels. Two new Grade 12 science teachers who were not originally in the nework have joined this sub-network. I see this as a new network that has formed. This suggests that space, time and commitment play a critical role in professional development initiatives.

Nespor (1994) supports the idea of learning communities and suggests that communities of practice should consider how their practices are enmeshed within a much more expansive network. It is for these reasons that the research process has been conceptualised as expansive cycles of development (see Figures 6.1 and 6.3). He also proposes a shift towards seeing research as "multi-researcher and multi-site engagement" (*ibid*:136). However, this has other challenges such as time and commitment for active participation by actors.

4.3 Concluding remarks

This chapter discusses firstly the socially critical-emancipatory orientation of this study. Central to this orientation is the assumption that actors are able to understand themselves socially and historically. In my view, this is critical as an approach that has an emancipatory intent and is grounded on the needs of actors. Secondly, the actor-network theory is examined as a theoretical framework for analysing the epistemological and methodological underpinnings of this study whose focus is on science teachers' transformative and continuous professional development network.

The next chapter explains the research design of this study – its methodological theoretical framework; how research design decisions were taken; what factors influenced and affected such decisions. First, to give context to the study, its overview is provided. A discussion of the methodological framework in terms of its qualitative research and the interpretive paradigms follows. Then, a discussion of the participatory action-research and reflexive approaches is provided. Lastly, the research-design process and methodological issues pertaining to data generating techniques, data analysis, validity, and ethical issues as well as our roles as reflexive co-researchers are highlighted.

Chapter 5

Research methodology

> Finding your way through the forest of human interaction requires a blend of science and humanism. Reason and logic are needed to chart your way through the woods. It takes painstaking planning, analysis, and execution, testing the ground every step of the way. However, human compassion and understanding are also necessary throughout the journey.
>
> (Fetterman, 1991:87)

5.1 Introduction

This chapter describes the research design of this study – its methodological theoretical framework; how research design decisions were taken; what factors influenced and affected such decisions. First, to give the context of the study, its overview is provided. Secondly, follows a discussion of the methodological framework in terms of its qualitative research and the interpretive paradigms. Then, a discussion of the participatory action-research and reflexive approaches is provided. Lastly, the research-design process and methodological issues pertaining to data generating techniques, data analysis, validity, and ethical issues as well as our roles as reflexive co-researchers are highlighted.

5.2 An overview of the study

> Research is not about a stable and objective world or about stable narratives, but it is always about change and learning and its relation to actions ...knowledge is a mediational means for focusing our attention on specific aspects of practice.
>
> (Wardekker, 2000:269)

As this quote intimates, practitioners ought to strive to take informed actions in order to bring about change. This is the focus of the research presented in this thesis.

It was based on work carried out over a period of four years with a group of initially eight[22] science teachers from four local historically disadvantaged senior secondary schools in Grahamstown. Two science teachers from each school were represented in the research network.

The rationale for having two teachers from each school was to encourage and sustain ongoing collaboration within the schools involved in the research project. Of importance is that this suggestion was made by one of the experienced teachers involved in our network, who distinguished himself as a key actor as highlighted in Section 4.2.2. This experience confirms what Yonemura (1982) expressed in the literature reviewed in this thesis, that experienced teachers are in a better position to take leading roles in professional development initiatives. The notion of practitioners having to assume key roles in networks is critical in professional development initiatives.

Since professional development does not occur in a vacuum, our research project was initially conceptualised around the exploration and means of applying inquiry-based teaching and learning using the micro-scale science electricity kits. Essentially, we initially collaboratively adapted, modified and developed learning and teaching support materials in the form of teaching and learning units in *electricity* (see Appendix B). The inquiry-based nature of the LTSMs was fostered through the predict-observe-explain (POE) (Gunstone 1990) approach. To Liew (1995), the POE approach encourages interactive learning. In their research on learners' conceptual development, Maselwa and Ngcoza (2003) modified Gunstone's approach into a predict-explain-explore-observe-explain (PEEOE) approach to emphasise the importance of self-directed practical activities and conceptual development.

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[22] Two teachers dropped from the team and this study is based on six science teachers. One female teacher was offered an HoD post in a school outside Grahamstown and the other male teacher was too heavily committed to union work to have time for participating in the network.

These teaching and learning units were implemented and pilot-tested on a group of Grade 10 learners from the local historically disadvantaged senior secondary schools in Grahamstown involved in the Khula Project[23]. The pilot study culminated in a research paper that Zapholo and I co-wrote and co-presented at a SAASTE[24] conference held at the University of the North in July 2002. It is acknowledged, however, that this aspect of professional development has repercussions insofar as the status of anonymity is concerned.

After the pilot test in electricity, Zapholo suggested that for teachers and learners to understand concepts in *electricity* (Appendix B), we should incorporate the topic on *electrostatics* (see Appendix A) in our unit of work. Later, for the purposes of integration within science itself, we decided to add the topic *electrochemistry* (see Appendix C). These three topics were thus utilised as common ground for our network activities. Subsequently, to enhance active participation by all network actors, we adopted the 'division of labour' strategy (Hardman, 2005) and formed three sub-networks, each with its own leader (see Figure 6.2). Our approach was in line with what Southwood (2000:32) recommends: that a collaborative approach to teacher development should be based on mutual peer support (see Section 3.3.2).

In view of this, in this research study, first, a participatory action research approach was employed as an enabling framework; bringing together practitioners from different institutions (schools and university) (see Figure 4.2). This strategy was adopted in order to understand, interpret and make recommendations relating to the teachers' transformative and continuous professional development network. Such understanding is linked to the teachers' educational biographies and experiences of the culture in which they are situated.

---

[23] The Khula Project was sponsored by Lucent Technologies in conjunction with Rutgers University and coordinated by the Education Department, Rhodes University. Its main aim was to empower science and mathematics teachers with computer skills in order to enhance teaching and learning of their subjects.
[24] SAASTE is the acronym of the South African Association for Science and Technology Education.

Certainly, the interpretation was arrived at through what I view as a dynamic ongoing construction of meaning, which has been reflected in the research process outlined in Chapter 6 of this thesis.

Secondly, a PAR approach was seen as a catalyst to create a community of science practitioners (Senge, 1990) and to promote an enabling environment for the enhancement of their conceptual development. This was promoted through science workshops we conducted (see Chapter 6).

5.3 Methodological framework

In this section of the thesis, the methodological framework is discussed. Firstly, the qualitative research and the interpretive paradigms are examined. Secondly, the participatory action research and the reflexive approaches are explored. These informed the research design decisions taken and should be read in conjunction with the research orientation and framework discussed in Chapter 4 (see Sections 4.2.1 & 4.2.2 respectively).

5.3.1 Research paradigm

Two dimensions are examined here; the qualitative and the interpretive paradigms.

Qualitative

> Qualitative research is multi-method in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them.
>
> (Denzin and Lincoln, 1994:2)

The research presented in this thesis is located within a qualitative research paradigm. Hitchcock and Hughes (1989:25) argue that qualitative research places individual actors at the centre and focuses upon a context, meaning, culture, history and biography. This is critical for understanding and meaning-making. Patton (1990:85), too, states that one of the strengths of qualitative research is "the inductive, naturalistic inquiry strategy of approaching a setting without predetermined hypotheses."

Lending support, Erickson (1998:1155) posits that "the essential purposes of qualitative research is to document in detail the conduct of everyday events and to identify the meanings that those events have for those who participate in them and for those who witness them." He further suggests that qualitative research in education is especially appropriate when we want

- detailed information about implementation;
- to identify the nuances of subjective understanding that motivate various participants in a setting; and
- to identify and understand change over time. (Erickson, 1998:1155)

To Dupuis (1999:44), qualitative research is thus, metaphorically, a common *journey* taken by the co-researchers and throughout the journey they influence and are changed by the research process and together co-construct meaning through their interactions (Holstein & Gubrium, 1995:4).

Certainly, in this research study, all the network actors were seen as co-learners and co-researchers. However, as an attempt to highlight the challenges experienced in the journey Dupuis has alluded to, I have chosen to use the metaphor of *changing gears* (see Section 1.7) in order to capture more fully the realities of doing research, including breakdowns, speed traps, potholes, blind spots, and accidents. The *changing gear* metaphor also reflects development and growth during the journey.

Interpretive

> What research in the interpretive paradigm does is to find out what meanings people construct, how they construct them, and how these constructions guide their actions, with the intention of providing 'heuristic schemes' that people may or may not use. Research does not contribute to an ideally ever more consistent 'body of knowledge', but to a relatively loosely ordered collection of such interpretive schemes.
>
> (Wardekker, 2000:266)

This research project is partly situated within an interpretivist paradigm. Wardekker (2000) points out that this paradigm has the potential to provide in-depth meanings, understanding and purposes attached to actors' activities. Woods and Trexler (2001:170), too, assert that in the interpretive paradigm researchers seek to understand phenomena and to interpret meaning within the socio-cultural context of the natural setting. Thus, interpretivists believe that reality is socially constructed.

Within this interpretive paradigm, the conceptualisation of the design of this research can best be characterised as a qualitative case study (Cresswell, 1994; Stake, 1995; Berg, 1998; Cohen, Manion & Morrison, 2000; Stake, 2000; Merriam, 2001; Cresswell, 2003; Yin, 2003). To Yin (2003:2), case studies give investigators an opportunity to explore the holistic and meaningful characteristic of real life events in order to understand complex social phenomena. Similarly, Cohen *et al.* (2000:181) point out that case studies investigate and report the complex dynamic interactions of human relationships, something which occurred during our workshops in this study.

Berg (1998:212), too, adds that case study methods involve systematically gathering information about a particular person, social setting, event, and group to permit the researcher to understand effectively how it operates. Thus, through case studies, in-depth information and understanding of the situation and meanings for those involved can be obtained (Merriam, 2001:19). Merriam (*ibid*) adds that the focus of a case study is the "process rather than the outcomes, in context rather than a specific variable, and in discovery rather than confirmation." As Hitchcock and Hughes (1995) emphasise, at the heart of a case study is focus on practice, intervention and interpretation with the view to improving the situation. In this study, our focus was to improve the teaching and learning of science through collaboratively developing and implementing LTSMs (see Chapters 6 & 9).

Wardekker (2000:265) agrees that the theory implicit in the interpretive paradigm is of human beings as interpreters and constructors of a meaningful world: their understanding guides their practices and helps them in the construction of their world, even though the interpretations could differ from person to person. In this respect, research attempts to find out "what meanings people construct, how they construct them, and how these constructions guide their actions" (*ibid*:266). It is for these reasons that dialogue and the teachers' *voices* were regarded as important in this study.

5.3.2 Research approaches

Participatory action-research

In conjunction with the socially critical–emancipatory orientation, a participatory action-research approach (Dane, 1990; McTaggart, 1991; Charles, 1995; McNiff, Lomax & Whitehead, 1996; MacTaggart, 1997; Taylor & Bogdan, 1998; Bhana, 1999; Kemmis & McTaggart, 2000; McNiff, 2002; Robinson, 2002; Babikwa, 2003) was adopted in this study. According to Bhana (1999:228), the PAR's main purpose is to produce knowledge in an active partnership with those affected by the knowledge. Central to PAR is improving the actors' social, educational and material conditions. Robinson (2002:101) adds that PAR is based on the principle that the knowledge gained through the research process is owned by the actors so that they reflect and modify their practices in an ongoing way. Actors take responsibility and control of their lives and contexts (McNiff, 2002).

The PAR approach thus seemed most appropriate in this research study since development and capacity-building is central to it (Senge, 1990): the reason for the PAR approach was to create an enabling and empowering environment. In essence, the main focus of this study has to do with teachers' transformative and continuous professional development. According to Babikwa (2003, citing Chambers 1997, Schwandt, 1997), PAR emphasises a deliberate move by people to learn continuously from their own experiences in order to keep on improving their situation in life. The underlying assumption is that actors are active agents capable of taking responsibility for addressing issues of importance affecting them. In the case of our research study, the teachers were viewed as being capable and responsible in promoting the teaching and learning of science.

David (2002:130) states that PAR

- seeks to go beyond traditional forms of research; and
- seeks to avoid the ethical and epistemological pitfalls of covert forms of research by involving actors in the formulation and conduct of research.

Some advocates of PAR (Kemmis, 1995; Kemmis & McTaggart, 2000) reiterate that without the involvement of actors in the formulation and conduct of research, all research remains opaque. According to Wardekker (2000:269), "research is always a dialogue between co-researchers: they form a 'community of inquiry'". The community of inquiry entails active co-engagement of all involved in research, and offers the actors opportunities for the kind of collaboration and reflection needed to build a learning organisation (Senge, 1990; McNiff, 2002; Robinson, 2002); that is, "learning and the resulting change are objects of the research and should be interpreted as a result of change and development" (Wardekker, *ibid*:269).

Robinson (2002:108), too, contends that PAR is an approach to research which emphasises two key principles in its research design: the active participation of all actors in the process, and the link between research and the improvement of practice. It thus brings together participatory research and action research. But where does participatory action feature?

Interestingly, I found that most PAR advocates seem to break participatory action research (PAR) down into two dimensions: participatory research (PR) and action research (AR) (Kemmis & McTaggart, 2000; McNiff, 2002). From my own experience of rural communities in particular, participatory action is being practised. For instance, in the *Xhosa* culture, when people from the community come together to plough collaboratively the fields, this is called *ilima*[25], whereas when people from the community collectively build a house this is called *ibhoxo*[26]. This communal way of doing things is premised on the principles of *ubuntu*, which embodies participation to improve people's situations. The purpose of this background is to show that collective participation is embedded in some cultures. It is with regret, however, that the notion of *ubuntu* is not evident in the educational context and this is one of the main points that I address in my thesis.

Certainly, embedded in the concept of participatory action is the notion of recognition and optimal utilisation of skills community members possess. In this study, there had to be a search for the skills that network actors possessed too. The analogy of *ibhoxo* seems most appropriate here since participatory action was utilised as a stepping-stone to participatory action research. Indeed, I see this as an endeavour by the network actors to work collaboratively with the aim of improving their own practice as an ongoing process building on culturally embedded ways of working.

Robinson (2002:108) points out that, participatory research entails a close relationship between co-researchers; in fact, the beneficiaries of the research are 'active actors' in the entire process. Furthermore, there is an emphasis on co-ownership and shared power over the research.

---

[25] *ilima*: community members bring their resources (human and physical) to plough the fields.

[26] *ibhoxo*: both skills and resources are essential in building community members' houses. In fact, this is how we built our houses in Xolani, Grahamstown.

Participatory research has historically been understood by some as having a political motive, with a particular commitment to the empowerment of oppressed communities (Freire, 1970). In the context of this research study, PAR seemed most appropriate as a catalyst for the empowerment of all of us involved in the TTCPD network (see Chapter 6).

PAR also emphasises the collective participation of all actors and seeks to involve the co-researchers in all stages of the research process, which should be seen as a developmental process. This involvement includes the conceptualisation of the problem, the formulation of the questions, the development of the methodology, the generation of data, and the analysis of the findings. Essentially, research becomes a form of capacity-building, and the process of knowledge production is seen as a democratic and empowering exercise. Kemmis and Wilkinson (1998:108), too, posit the idea that participatory research is a "deliberate strategy for social action and social improvement". It is recognised, however, that the participation of actors might vary; and this was the case in this study.

Action research, on the other hand, is viewed as being where actors identify problems from practice and develop strategies to address them. This suggests that strategies are implemented by the actors who research and reflect on them as a way of addressing the problems with the view to improving practice. McNiff (2002:5) calls this self-reflective practice in which the focus is on learning, and appropriate support may be needed. Robinson (2002:109) agrees that "an emancipatory or critical paradigm of action research will emphasise the role that action research can play in social transformation."

AR is a collaborative socio-cultural process of learning, realised by the actors who are committed to changing their own practice (McNiff, 1992; Kemmis & Wilkinson, 1998). In contrast, "a positivist paradigm which tends to focus on action research that may improve practice, but does not challenge the injustices and inequities within the status quo" (Robinson 2002:109), is one when people are not central in the process.

Kemmis and Wilkinson (1998:21) see action research as involving a spiral of self-reflective cycles of

- planning change;
- acting and observing the processes and consequences of the change;
- reflecting on these processes and consequences; and then
- re-planning, and so the spiral continues (see Figure 5.1).

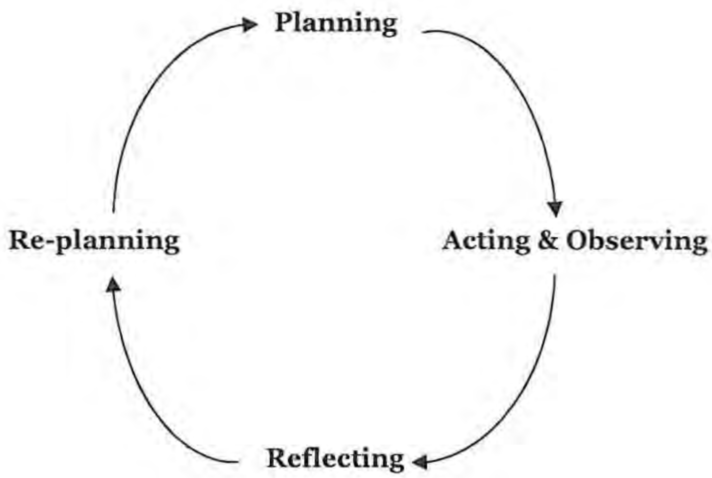

Figure 5.1: Spiral of self-reflective cycles

Kemmis and Wilkinson (*ibid*) further emphasise that this process is not linear but iterative: actors undertake the steps in the spiral of self-reflection collaboratively. Also, success is not judged by following these steps rigidly, but is judged by the actors' demonstration of understanding of their practice and the context in which they practise it (Kemmis & Wilkinson, 1998; McNiff, 2002).

It is for these reasons that the research process in this study is presented as expansive cycles of development (Foot 2001) (see Figures 6.1 and 6.3). The process of expansive cycles of development implies that expansion and transformation in development is not linear. Rather, the process of development should be seen as an expanding spiral (McNiff, 2002:11). McNiff (*ibid*) further points out that practice is non-linear and it should be recognised that actors may not necessarily follow routine paths during their actions.

Fullan and Hargreaves (1992) point out that teacher development entails establishing opportunities for teachers to confront their assumptions and beliefs about their practice (see Section 3.4.3). Like Loucks-Horsley *et al.* (2003), they suggest that professional developers need to create a learning community of teachers to enable them to discuss and develop their purpose collaboratively. Although Prawat (1996) believes that such socio-cultural contexts can be conducive to conceptual development among the actors, he warns that "one builds a learning community both at the classroom and school levels by engendering commitment in individuals, not by manipulating control" (*ibid*:101). Actors should not be coerced to join a learning community but should join voluntarily as was the case in this study where all the actors saw the need to work collaboratively in order to improve the teaching and learning of science.

Thus, by adopting the PAR approach in this study, it was hoped that "a learning environment would be created for teachers that allowed them to set their own priorities in which their collective experience was integral to the way that their learning took place" (Gayford, 2002:100). In this way, it was envisaged that the teachers could share their own knowledge, expertise, experiences, success stories, illuminations, failures, heartbreaks and, most importantly, appreciate the value of their own expertise.

Likewise, Hammel, Finlayson and Lastowiski (2003) argue that PAR by its nature is an approach that involves a dynamic collaboration among actors. Gayford (2002:99) reiterates that "the PAR method is more likely to be successful with professionals who are encouraged to feel relatively empowered and have motivation to develop their practice collaboratively with their peers". Furthermore, PAR seems appropriate when the actors are investing in a common goal. In the context of this study, the ultimate common goal was to develop teaching and learning support materials with the view of improving teaching and learning of science.

In my view, it was therefore necessary to mobilise the six science teachers to constitute a network so that we could support one another as the current democratically driven transformation in education in South Africa has had profound implications for change in teaching and learning in schools' contexts. Bear in mind that the past schooling and professional educational experiences of most teachers make it difficult for them to meet the demands and challenges of the new curriculum (see Chapter 7). This is aggravated by the disparities in schools in terms of, among other things, human and physical resources.

Also, I would like to point out that the realities and challenges of the education system, particularly in South Africa, do not resonate with the PAR authors' idealistic and ambitious beliefs. The fact that PAR is a long-term, intensive process of collaboration, negotiation and commitment (Kemmis & McTaggart, 2000; McNiff, 2002), should be borne in mind. That itself poses a challenge when one works with teachers who have been exposed to an individualistic approach throughout their teaching careers. An exploration of appropriate research framework landscapes is thus worth discussing.

Reflexive

> A reflexive research methodology explicitly incorporates the researcher and her or his experience into the analysis process and into theory-building endeavours, and it demands the conscious and deliberate inclusion of statements and disclosures of our selves and our personal experiences in written accounts of the research.
>
> (Dupuis, 1999:64)

Davies (1999) points out that reflexivity refers to the ways in which the products of research are affected by the personnel and the process of doing research.

Lending support, Dupuis (1999:59) explains that "our selves and our emotions and personal experiences can no longer be removed from the research process": by embracing reflexive research methodology, qualitative researchers recognise, document and employ both the researcher and the human self and their emotions and experiences in the research process.

Fraser (1993, cited in Dupuis, 1999:60) states that "a reflexive methodology means making personal experiences, belief systems, motivations, and tensions as well as political agendas explicit." Dupuis (*ibid*) explains that a reflexive research methodology recognises the active collaborative role that co-researchers play in the meaning-making process. Since reflexivity acknowledges experience as a continual flow over time (Penney & Warelow, 1999), Dupuis (1999) suggests that reflexive researchers need to detail the following in their written accounts:

- how the research process developed over time;
- how research – design decisions were taken throughout the process; and
- what factors affected those decisions.

Dupuis (1999:60) emphasises that "reflexive knowledge, stories, and theories highlight not only the commonalities in experience, but also focus on the fundamental contradictions and inconsistencies observed and being reported by participants." Here Pillow (2003) argues that qualitative researchers use reflexivity as a methodological tool to legitimise or interrogate their data. Hertz (1997, cited in Pillow, 2003:178) adds that "the result of reflexivity is to produce research that questions its own interpretations and is reflexive about its own knowledge production towards the goal of producing better, less distorted research accounts." According to Pillow (*ibid*), reflexivity is thus understood as:

> involving an ongoing self-awareness during the research process which aids in making visible the practice and construction of knowledge within research in order to produce more accurate analyses of our research.

5.4 The research design process

> To be engaged in a research project, I believe, is like undertaking a journey into the dark wilderness. Before undertaking the journey, you need to prepare provisions to sustain yourself along the journey. Most important is to stay focused and look for some light ahead. During the journey, you also need to be prepared for the unexpected.
>
> (Maselwa, 2004:25)

The research process presented in this section of the thesis encompasses data-generating methods and techniques, data analysis and interpretation, validity issues, ethical considerations and finally, our roles as actors in this study. All these aspects should be understood within the confines of the socially critical-emancipatory orientation and actor-network theory framework (see Sections 4.2.1 and 4.2.1); the qualitative research and interpretive paradigms (see Section 5.3.1) and finally, the participatory action research and reflexive approaches (see Section 5.3.2).

5.4.1 Data generating methods and techniques

> To do research is to pay unusually close attention and to reflect deliberately on what we have seen and heard. 'Researching' is to seek and seek again.
>
> (Erickson, 1998:1158)

Erickson (*ibid*:1159) points out that, data-generation strategies can be planned at the outset. However, he warns us that "in designing data collection strategies one needs to anticipate the variety in kinds, sources and amounts of evidence that will be necessary in order to draw credible conclusions and present them in a report" (*ibid*). Based on my experience in this research, I would add, we also need to be flexible and alert during the entire research process.

I have thus deliberately chosen to use the term 'data generation' as an attempt to highlight the dynamic nature involved in generating data in this study. In essence, the actors all generated data in various ways. It was hoped that involving actors who are regarded as co-learners, reciprocators and co-researchers in this study in all forms of data generation would help strengthen the findings of this study.

For the purposes of this study, data was thus generated in the following ways:

- workshop discussions with reflective notes;
- interviews;
    - active interviews;
    - focus group discussions;
    - follow-up active interviews; and
- co-teaching, participatory observations and videotaped lessons with reflective notes; and
- research journal.

Table 5.1 Data generation methods

Method	**Purpose**	**Actors**
Workshops:	To develop teaching and learning support materials and co-construct scientific knowledge.	All network actors
Interviews: • **Active interviews**	To find out the science teachers': • Educational background • Experiences, assumptions and beliefs about teaching and learning	Individually conducted with each actor
• **Focus group discussion**	To explore the benefits of our workshops To discuss experiences on co-teaching and participatory observation.	All network actors
• **Follow-up active interviews**	To do a follow-up on issues that were raised during the active interviews.	Individually conducted with each actor.
Co-teaching; participatory observation and videotaped lessons:	To experiment with inquiry-based practical activities. To enhance teaching and learning of science through collaborative efforts. To enhance collaborative reflections.	Zapholo, Ngwenya and myself.
Research journal:	To document experiences on the research journey.	All network actors.

I underscore both the strengths and weaknesses of these data-generating techniques. Using a multi-method approach to generate data (see Section 5.4.1) capitalises on the strengths of each technique and minimises weaknesses inherent in a single technique (Woods & Trexler, 2001:74). It was also hoped that the generation of such a wide range of data would enable plausible explanations to be constructed (Cresswell, 1994; Kuiper, 1997; Berg, 1998; Erickson, 1998). Similarly, Arksey and Knight (1999:22) contend that approaching research questions from different angles and bringing together a range of views has the potential to generate new and alternative explanations. In the next section I examine in detail each of these data-generation techniques.

Workshop discussions with reflective notes

My practical first-hand experience with workshops was acquired at the start of the Science Education Project (SEP) in the Grahamstown district in 1993. At that time, I was appointed a coordinator of this project. SEP was a non-governmental organisation (NGO), whose main mission was "to promote science education through maintaining contact with modern ideas in the teaching and learning of science (e.g. activity-based, constructivism, hands-on, minds-on...) while adhering to long-standing, proven methods and being realistic in terms of what the present cadre of South African teachers are capable of accomplishing, given their education and training" (Bateson, 1995:69). What would add value to the SEP workshops would be the inclusion of the research component.

Lotz (1996:92 - 3) explains that the "use of workshops has gained an impetus as an INSET strategy in South Africa due to mostly the growth of the non-governmental organisations, who have been largely responsible for the provision of INSET because of unequal or inadequate INSET provision by the apartheid regime." To Bateson (1995:5), the fact that "Blacks were denied free access to quality education, particularly post-secondary education, and positions of responsibility for decades means that there are few highly trained and experienced Black educators and educational researchers in South Africa." Thus, INSET and teachers' continuous professional development should be viewed as "one of the necessities of educational life for all educators" (Southwood, 2000:22).

Babikwa (2003:60), too, points out that workshops are useful capacity-building and learning environments since during workshops actors are given opportunities to engage actively in the programme. However, McNaught and Raubenheimer (1991, cited in Lotz, 1996) point out that workshops should be responsive to the actors' needs with sufficient interaction opportunities. Wardekker (2000:271) recommends that actors in change processes should be able to maintain and further develop the resulting changes in their practice. That is, the new practice should become part of their "zone of actual development" (*ibid*): ZAD reflects the zone where actors can demonstrate their development and actions taken on their practice.

In this research project, we approached workshops as an opportunity for co-learning and co-construction of scientific knowledge (see Chapter 6), during which actors could continually reflect on their practice and on the value of collaboratively developing LTSMs (Czerniewicz *et al.*, 2000:iii) on electrostatics, electricity and electrochemistry.

Central to these workshops was capacity-building and an exploration of the three topics was useful in promoting conceptual development and understanding as well as integration within science (see Figure 6.2). Also, the workshops gave us opportunities to collaborate and discuss recursively as the research progressed (Hitchcock and Hughes 1989; Stevenson 1995). These workshops were also used as occasions for data generation and the discussions recorded were interpreted to identify emerging themes and patterns (Varelas, Luster & Wenzel, 1999) (see Section 5.4.2 on data analysis and interpretation).

Interviews

> Interviewing allows a researcher to investigate and prompt things that we cannot observe. We can probe an interviewee's thoughts, values, prejudices, perceptions, views, feelings and perspectives. We can elicit their version or their account of situations, which they may have lived or taught through: his- or her-story.
>
> (Wellington, 2000:71)

In the traditional or conventional interview process, the researcher's task is to ask questions and the respondent's role is simply to provide answers (Dupuis, 1999:53). Holstein and Gubrium (1995:7 - 8) add that respondents are conceived of as passive 'vessels-of-answers' for the experiential questions put to them by the interviewers. They argue, the assumption is that "if the interviewer merely asks questions properly, the respondent will emit the desired information" and the interview process is "treated as a pipeline for transmitting knowledge" (*ibid*:3); consequently, the respondents become epistemologically passive and not engaged in the production of knowledge. Davies (1999:101) adds that, during such interviews, interviewers are deterred from expressing their opinions.

Such an approach to interviewing does not resonate with what is advocated by a reflexive approach (see Section 5.3.2). I thus searched for alternative interview approaches in which the actors in this study would be able to engage in conversations and communicate freely. In this study, interviews were employed to generate qualitative and rich data sets. These were in the form of active interviews, focus-group discussions and follow-up active interviews. To facilitate a recursive and reflexive process of data generation (see Figure 5.1), these interviews were done as conversations.

Active interviews

Like Dupuis (1999:56), I envisaged an approach that would give credit to actors as active, interpretive people in their own right. Dupuis believes that "such give-and-take, back-and-forth approach would actually help participants to sort out their own ideas and perceptions about their experiences" (*ibid*:56). Potter (2001:30) calls this a "holistic approach." However, it is recognised that such an approach requires a good rapport to be established with the actors.

Fetterman (1991:89) points out that sincerity and trust help establish rapport, which may then enable actors to communicate openly. Such relationships are further strengthened by reciprocity (see Section 3.3.2). According to Kumar (2002:177), mutuality and reciprocity are the underlying principles of existence, and where there is reciprocity; everyone has the context of community, environment, tradition and culture.

When I suggested to my supervisors that I could use the idea of an alternative way of interview, they welcomed the idea. They recommended interviews that were conversational but indicated that I would need to have some guidelines. Patton (1990:283) notes that an interview guide keeps the interactions focused while allowing perspectives and experiences to emerge. My supervisors alerted me to the challenge I would face in analysing such complex, voluminous and rich data sets. Patton (1990:282) also warns that the use of different questions tends to generate different responses, making it difficult to find emerging patterns.

With these challenges in mind, I began to search for literature on conversations and I came across a paper written by Dupuis (1999), in which she had adopted the philosophy of active interviews as proposed by Holstein and Gubrium (1995). I chose to follow suit and adopt this philosophy of active interviews (Holstein & Gubrium, 1995; Ellis, Kiesinger & Tillmann-Healy, 1997; Davies, 1999). Ellis *et al.* (*ibid*:122) state:

> Active interviewing reflects the way relationships develop in real life: as conversations where one person's disclosures and self-probing invite another's disclosures and self-probing; where an increasingly intimate and trusting context makes it possible to reveal more of ourselves and to probe deeper into another's feelings and thoughts; where listening to and asking questions about another's plight lead to greater understanding of one's own; and where the examination and comparison of experiences offer new insight into both lives.

They thus view interactive interviewing as a collaborative communication process occurring between the co-researchers, where feelings, insights, and stories that they bring to the interactive encounter are regarded as important. Davies (1999:101 - 3) adds that during the active interview co-researchers are engaged in knowledge co-construction. It is recognised, however, that this has potentialities for bias.

Rejecting the 'vessel-of-answers' approach, Holstein and Gubrium (1995) point out that the active interview takes a constructionist perspective on the interviewing process: shifts to focus to people in relationships and examines how meanings are constructed. To them, interviews are social productions, whereby actors are seen as narrators or storytellers: the co-researchers actively construct a story and its meaning, so that interviewing is inherently collaborative. Ellis *et al.* (1997:122) warn us that active interviewing can be emotionally demanding and time-consuming. Holstein and Gubrium (1995:4) describe the interview process thus:

> Both parties to the interview are necessarily and unavoidably active. Each is involved in meaning-making work. Meaning is not only elicited by apt questioning nor simply transported through respondent replies; it is actively and communicatively assembled in the interview encounter. Respondents are not so much repositories of knowledge – treasuries of information awaiting excavation – as they are constructors of knowledge in collaboration with interviewers.

To Holstein and Gubrium (*ibid*), "interviews are interpretively active, implicating meaning-making practices on the part of both interviewers and respondents." Lending support, Dupuis (1999:57) argues that "the active interview is much more conversational in style and capitalises on the dynamic interplay between the researcher and the respondents." Patton (1990:280) argues that informal conversational interviews rely on the spontaneous generation of questions in the natural flow of an interaction.

Holstein and Gubrium (1995:37) point out, too, that "treating the interview as active allows the interviewer to encourage the respondent to shift positions in the interview so as to explore alternate perspectives and stocks of knowledge." Consequently, the interviewer is free to become responsive to individual differences and situational changes (Patton, 1990:282). In this study, the active interviews enabled the actors and me to have freedom in engaging in rich conversations and in collaboratively co-constructing our thoughts: we were able to generate detailed and rich data sets.

Focus-group discussions

The goal of focus-group discussions is to elicit information on a specific topic, and to seek an in-depth understanding of the meanings that are socially constructed or developed by the actors within the group setting (Vaughn, Schumm & Sinagub, 1996; Schurink, Schurink & Poggenpoel, 1998; Berg, 1998; Southwood, 2000; Babikwa, 2003). The assumption is that actors are valuable sources of information and that, and within a relaxed environment, a more in-depth understanding of issues can be obtained (Vaughn *et al.*, 1996:17).

Babikwa (2003:59) emphasises that the issues discussed in a focus group should be of mutual interest to the co-researchers. Of mutual interest among the actors in this study was the improvement of teaching and learning in science. However, Davies (1999:105) suggests that the researcher should take the role of the key actor and it should be ensured that the actors are given a *voice* (Wellington, 2000:72) in the process.

In this research project, the actors are viewed as co-learners and co-researchers (see Chapter 6), something that made the focus group research strategy most appropriate. Thus, the focus-group discussions were utilised as part of teacher development throughout the research process. After the individual active interviews, as an attempt to retain the 'network spirit' and the collaborative nature of our research project, focus-group discussions with the entire network actors were conducted.

The focus-group discussions helped me to engage more personally with the actors who were treated as sense-making agents in the process. Schurink *et al.* (1996:316), too, state that "focus group interviewing has a great potential for the development of a methodology for participatory action research, which will empower community members to gather information on and gain control of their own lives."

One of the characteristics that distinguish focus groups from other qualitative interview procedures is the dynamic and interactive group discussion (Vaughn *et al.*, 1996; Cohen *et al.*, 2000). Cohen *et al.* (*ibid*:288) argue that actors' views emerge from interaction d uring focus groups. Thus, the synergy may allow solutions to problems to be generated collaboratively and the give-and-take interactions may lead to spontaneous responses (Berg, 1998:101 - 4).

Southwood (2000:51) adds that "the synergetic effect from the focus group can encourage people to open up more, freeing people up to be more honest and critical." As Lotz (1996:96) suggests, during focus-group discussions, interaction between participants should be informal to stimulate in-depth discussion and reflection on the topic. According to Morgan (1997:2, cited in Davies, 1999:105):

> The hallmark of focus groups is the explicit use of group interaction to produce data and insights that would have been less accessible without the interaction found in a group.

Although focus-group data may reflect the collective notions shared and negotiated by the group (Berg, 1998:112), the purpose of a focus group is not on consensus building but to obtain a range of opinions (Vaughn *et al.*, 1996; Schurink *et al.*, 1998). Furthermore, during focus groups, 'researchers' may be non-directive, allowing the group discussion to develop its own dynamic and pursue topics as they arise and capture the interest of the group (Davies, 1999:105). Furthermore, actors may also stimulate each other's responses and even pose questions to one another.

It is recognised, however, that while the focus-group approach may be conducive to productive discussions, the group dynamics can pose challenges for the researcher (Southwood, 2000:51). For example, Berg (1998:111) points out that one of the difficult tasks of a key actor is not to disrupt the social dynamics of the group when controlling dominating respondents while simultaneously encouraging passive group actors.

Follow-up active interviews

Hitchcock and Hughes (1989:157) point out, that, semi-structured interviews are flexible compared to structured interviews. Thus, the follow-up semi-structured interviews conducted with the actors in this research study were intended to provide an opportunity to probe and expand their responses to allow depth to be achieved (Hitchcock & Hughes, 1989; Patton, 1990; Seidman, 1991; May, 1993; Miller & Glassner, 1997). Hitchcock and Hughes (*ibid*) point out that during semi-structured interviews, "interviewers can alter the sequence of questions and provide room for negotiation, discussion and expansion of the respondent's responses."

Patton (1990:324) posits too that, during semi-structured interviews, probes are used to deepen the responses to a question to increase the richness of the data being obtained. However, he suggests that probes should be conversational and offered in a natural style. I found the follow-up semi-structured interviews very useful in this study as the actors had to make further clarifications based on their active interviews. It could be argued that this process also served as a data validation technique (see Section 5.4.3).

During the semi-structured interviews, data was tape-recorded and transcribed, but not verbatim as suggested by Kvale (1996). This is because actors were allowed to use both English and *isiXhosa* (our mother tongue) during the interviews and the transcription was mainly in English. This has implications for validity issues (see Section 5.4.3).

Co-teaching, participant observation and videotaped lessons

In this study, a combination of co-teaching, participant observation and videotaped lessons were employed. In my view, co-teaching fosters opportunities for collegial work and improved classroom instruction as a result of practitioners sharing responsibility and developing better methods of teaching. Furthermore, reflection and collaborative efforts are sustained. In this study, a professional relationship was built on respect and trust and this was enhanced through co-planning and co-construction of knowledge during our workshops (see Chapter 6), a view echoed by Murawski and Dieker (2004:52). Co-teaching, as enacted in this study, allowed us to experiment with the supportive learning activities and was useful in fostering support among us, and learners benefited from a variety of teaching and learning strategies. We also exchanged roles and engaged in participant observation.

Taylor and Bogdan (1998:24) state that the term participant observation refers to research that involves social interaction between co-researchers; and participant observation, combining participation and observation as it does, implies immersion in the culture of the actors (Fetterman, 1991:94). This allows co-researchers to interact and get closer to each other in order to get first-hand information (Schurink, 1998; Cohen *et al.*, 2000; Scanlon, 2000; Yin, 2003). With this advantage, we were able to get a great deal of experience in how meaning-making and scientific knowledge were co-constructed by learners in this study.

Schurink (1998:279) adds that, co-researchers who make use of participant observation are interested in ways in which actors make sense of or attach meaning to the world around them. This is critical since the worldview and social construction of reality - the process through which actors make sense of their lives - can be understood best through a co-interpretation of their worldviews.

Another advantage of participant observation is that co-researchers get an opportunity to interact in a natural setting. Concomitantly, as an analytic research method, participant observation depends upon the recording of detailed field notes and discussions (Taylor & Bogdan, 1998:66); the co-researchers, informed by a continuous cycle of data construction, attempt to provide descriptions and explanations (Hockey, 1996; Roth & Boyd, 1999; Thomas, 1999). Videotapes and photographs are also useful in the process.

Lotz (1996:95) points out that videotapes and photographs are useful in generating visual data about situations and events. Maselwa (2004) adds that videotaping and taking photographs in teaching and learning scenarios can be useful for close observation of the interactions while learners are working in their various groups. Furthermore, he argues that this can help teachers to record their involvement in the activities as well as their body-language reactions.

For the purposes of our research study, participant observation was encouraged, and this enabled us to videotape lessons and take photographs while the key teacher was facilitating the lesson. We observed how learners co-constructed knowledge in their groups and how meaning-making was enhanced through the inquiry-based practical activities. Then the two teachers and I reflected on the lesson and these reflections were shared with the entire network. Thereafter, the three of us watched the videotape and discussed what transpired during the lesson. The discussions were tape-recorded, transcribed and read to validate data (see Section 5.4.3) by the two science teachers.

Research journal

> Reflective writing could be likened to using the page as a meeting place in which ideas can intermingle and, in developing, give rise to new ideas for new learning.
>
> (Moon, 1999:18)

An essential component of rigorous inquiry is the ability of the researcher to provide a transparent account of his or her journey throughout the research process. Accordingly, I used a research journal in this study. As Borg (2001:156) points out, forms of reflective writing such as diaries and journals are widely acknowledged as important tools in promoting both development and understanding during the research process.

Many other scholars who are advocates of journal writing too have supported this view. For example, Moon (1999:22) argues that professional development reflective practice (see Section 3.5.1) has led educators to use journals. Moon's comments encapsulate my views. She argues that writing a journal provides a "focusing point, an opportunity to order thoughts and to make sense of a situation or information" (*ibid*:20). As Borg (2001:157) points out, "reflective writing can provide insight into the personal and often implicit processes which teachers experience in their work and development." By documenting and reflecting on their experience, teachers may benefit from an enhanced awareness of themselves as people and as professionals.

The term 'journal' has been used in this thesis to refer to research-focused reflective writing: records my personal reflections of my research journey. I found the research journal useful in illuminating insights during the research process. Lotz (1996:92) adds that a journal can "provide a place where the research focus and the researcher's role could meet methodological and analytic concerns." Similarly, Penney and Warelow (1999:262) contend that "the analytic process enables the revisiting of the experience to find new understanding and meaning."

Taylor and Bogdan (1998:150) propose too that researchers should stand back from their data and write analytic memos on what they think they have learnt. They add that memo-writing provides an opportunity for the researcher to think about the process and reflect on, for example, what additional data they may need to generate. Lending support, Borg (2001:172) further adds:

> The database of experience in a journal greatly enhances the researcher's ability to make informed decisions about the research process, provides a global picture of patterns and themes in the researcher's work and thinking, and also allows for both greater precision and wider use of the researcher's voice in the reporting of the study.

The point I would like to make here, then, is that reflective writing can be a useful tool during the research process. My motivation to explore the issue of journal-writing stemmed from my personal experience of keeping a research journal when I was doing the Master's course. Indeed, I had a great opportunity to reflect on and document my learning experiences during the research process. However, as an inexperienced researcher, initially I did not know how to incorporate the rich information that was in my journal into my thesis write-up. Instead, I used the information in writing and enriching my chapter on my critical reflections on the research process.

The reflective process of writing the journal proved to be useful in this study. As Southwood (2000:50) points out in her research project:

> Writing the journal proved to be a fundamental aspect of the research process facilitating greater personal insight, greater connection with 'events' and greater realisation and understanding.

Regrettably, in my case I struggled to use journal writing as well as I would have wanted. Time constraints, limitations of language, and a lack of insight into journal-writing proved to be barriers. Furthermore, unlike Babikwa (2003:62), who encouraged actors in his research project to keep diaries, my attempts to achieve this were not realised. From the reaction of some of the network actors, the diaries that I bought proved to be threatening. I thus had to devise other strategies to encourage them to reflect, which tended to be somewhat erratic and isolated and thus lacking in continuity. I was also mindful of 'professional coercion', which would contradict the ideals of a socially critical-emancipatory research (see Section 4.2.1)

In the light of these experiences, although I agree with Borg's (2001:157) view that "research journals can play a central role in collaborative research contexts by providing all participants in the research process with a means of expressing, recording, and sharing their experiences", it seems that this is easier said than done.

5.4.2 Data analysis and interpretation

> Analysis involves working with data, organising it, breaking it down, synthesising it, searching for patterns, discovering what is important and what is to be learned, and deciding what you tell others.
>
> (Bogdan & Biklen, 1982:154, cited in Woods & Trexler, 2001:74)

As it is stated in this epigraph, data analysis is a continuous process of making sense of the data sets generated from different methods. In this qualitative case study, the data sets generated were in the form of narratives. Poggenpoel (1998:335) notes that "data in qualitative analysis are usually in the format of textual narrative (transcribed interviews), written descriptions of observations (field notes) and reflections (ideas and conjectures recorded in the researcher's diary)." Thus, data analysis involves interpreting and making sense of such texts (Hitchcock & Hughes, 1989; Wilkinson, 2000; Cresswell, 2003). Like Cresswell (2003), Taylor and Bogdan (1998:140 - 1) contend that data analysis is an "ongoing, dynamic, iterative and creative process". Erickson (1998:1162) adds:

> Analysis consists of recursive review of information sources with a question or assertion in mind, deciding progressively which information bits to attend to further and, perhaps even more importantly, which not to attend to.

According to Taylor and Bogdan (1998:140 - 1), data analysis is a process that encompasses inductive reasoning, thinking and theorising, whereby researchers attempt to gain a deeper understanding of what they are studying by refining interpretations, identifying themes, and developing concepts and propositions recursively. Poggenpoel (1998) and Merriam (2001) explain that the inductive reasoning in qualitative research ideally requires the researcher to start out without any explicit conceptual framework. Dey (1993:53) points out too that, since qualitative data analysis is iterative, a spiral rather than a straight line represents it better.

Taylor and Bogdan (1998:150 - 1) and Wilkinson (2000:79), however, suggest that qualitative data must be coded in order to provide some structure and meaning. Patton (1990) and Taylor and Bogdan (1998) explain that the coding process involves consolidating and analysing all the data bearing on major themes, ideas, concepts, interpretations and propositions. Thus, coding is intended to help the researcher develop insights and generate theoretical understanding.

In this study, data generated from workshop discussions and the audiotaped interviews (active interviews and focus-group discussions, follow-up active interviews) were analysed by means of open-coding, a qualitative approach for analysing data where trends which emerge as data are repeatedly reviewed, allowing for categorisation of those trends in a coherent fashion (Schumaker & Mcmillan, 1993, cited in Erickson, 1998). A constant comparative method (Taylor & Bogdan, 1998; Merriam, 2001) was used to search for similarities and differences, developing these into categories.

Taylor and Bogdan (1998:137) argue:

> In the constant comparative method, the researcher simultaneously codes and analyses data in order to develop concepts. By continually comparing specific incidents in the data, the researcher refines these concepts, identifies their properties, explores their relationships to one another, and integrates them into a coherent theory.

In contrast to Taylor and Bogdan, even though some concepts were found to be interlinked in this study, it was difficult to integrate them into a coherent theory as they claim in the quote above. Once categories were established as underlying themes were further identified to see those that cut across several categories. Data generated during fieldwork (during co-teaching, participatory observation and informal discussions), workshop discussions, reflections and the research journal were helpful in guiding the research process. Since this is a naturalistic study, the results are presented in a descriptive and narrative form (Cresswell, 1994; Thomas, 1999) and in a confessional way to allow for problems and limits to be described (Cresswell, *ibid*).

5.4.3 Validity issues

Stake (1995:108) points out that, researchers recognise the need not only for being accurate in measuring things, but logical in interpreting the meaning of those measurements. Thus, reliability is one of the chief characteristics researchers consider when judging the quality of data used in their studies. Within the positivist paradigm, data are typically quantified, and thus it is relatively easy to derive estimates of reliability. Within the qualitative inquiry, however, reliability and generalisability play a minor role (Cresswell, 2003:195). The final sample size for this study was six science teachers from four schools and it would therefore be difficult to generalise the results. It is recognised and acknowledged, however, that the focus on qualitative research imposed a selection criterion limiting the research sample.

Nonetheless, Lather (1986a:67) suggests that data-credibility checks are essential for self-reflexivity. To Cresswell (2003, citing Cresswell & Miller, 2000), validity is used to determine whether the findings are accurate from the standpoint of the researcher, the actor, or the readers of an account. Maggs-Rapport (2000:221) states that "validity of meaning, understanding of phenomena is concerned with reading beyond description towards explanation." To Lather (1986a), validity in qualitative research is associated with rigour and relevance. In this study, I would argue that relevance was encapsulated in the actions and contexts of the actors, while its rigour was reflected in its reflexive nature. This meant that justification of what was done and how it was done in this study was imperative.

As a result, data validity issues involved

- triangulation;
- member checks or face validity;
- prolonged engagement;
- catalytic validity; and
- peer validation.

This variety of data-validation techniques was employed to cater for the recursive nature of the research process in this study (see Figure 5.1), which precipitated ongoing co-engagement and feedback among the actors. The range of data-validation techniques depicts both the importance and complexity of the notion of validity in research.

Triangulation

To novice researchers like myself, the term 'triangulation' can be confusing. In most cases, in my view, it ends up being used merely as windowdressing. Given my mathematics and science background, when I first encountered this term, I was reminded of the concept 'trinomial', meaning 'three terms'. In science a triangle connotes a rigid structure, which led me to envisage triangulation as entailing three rigid data-generation techniques. Meijer, Verloop and Beijaard (2002:145 - 6) point out that the term triangulation originates from the practice of land surveyors which uses three measurements to determine the exact position of a point in the landscape.

The term in social science is used differently again. There triangulation refers metaphorically to a process by which a researcher verifies findings by crosschecking and interpreting data by drawing from multiple data sources, methods, and theoretical schemes (Lather. 1986a; Denzin, 1988; Woods & Trexler, 2001). Thus, triangulation is often thought of as a way of checking out insights gleaned from different sources of data (Taylor & Bogdan, 1998:80). Denzin and Lincoln (1994) too, argue for a triangulation of multiple methods and theories saying that they can improve the likelihood that interpretation will be acceptable, through the support they provide to each facet of data generation.

Data was triangulated in this study, firstly through the composition of the research network actors which I refer to as reciprocators: information was generated from different categories of science teachers from different school contexts, teaching multi-grades. Secondly, triangulation was employed in using a variety of data-generation techniques (see Figure 5.1).

Prolonged engagement

Scanlon (2000) and Woods and Trexler (2001) recommend that a long-term engagement with the actors may help the co-researchers to internalise what they are studying. Here, Fetterman (1991:88) emphasises that "a lifelong commitment to learning is essential to grasp the inner workings of any group."

Woods and Trexler (*ibid*:75) point out that engaging in prolonged research study can promote trustworthiness of data and its interpretation. Guba and Lincoln (1989:237) agree that substantial involvement is necessary to establish the rapport and build the trust necessary to uncover constructions, and to facilitate immersing oneself in, and understanding, the context's culture. Lincoln and Guba (1985:301) also claim that prolonged engagement, persistent observation, and triangulation can increase the probability of producing credible findings. Such a validation strategy thus seems appropriate in this research study.

In essence, our research network has been working together continuously for four years. Such prolonged engagement with the actors has been invaluable in ensuring sustained collaboration and subsequent quality of data generated.

Member checks and face validity

The terms 'member checks' and '*face* validity' are often used interchangeably. To Lather (1986a:67), face validity is integral to the process of establishing data credibility. She further adds that member checks entail recycling analysis back to the actors. However, Southwood (2000:67) emphasises that in her research study "recycling analysis through the participants was not merely regarded as a strategy for 'checks' or 'validating' the interpretation of the data, but was fundamental in supporting the construction of the research process and instrumental in generating further data." Like Southwood, Stake (1995:115) too contends that research actors play a major role during the research process since they may also provide critical observations and interpretations, examine rough drafts of writing, and review the materials for accuracy and palatability.

There seems to be some common ground in this debate. From a similar stance, Lincoln and Guba (1985), Guba and Lincoln (1989), Kvale (1996) and Manning (1997) all point to the establishment of credibility of interpretive research data, when they state that member checks involve the process of checking interpretations with the actors in order to refine their interpretations. Taylor and Bogdan (1998:159) also say that comments from actors can enrich the interpretation of data. It is recognised, however, that this process entails a close communicative relationship with the actors, which enables effective checking to be conducted.

In this study, feedback to actors and checking of information was integral to the research process, and it took various forms: asking actors to read transcripts of workshop discussions; reflections made during co-teaching and participatory observations; videotaped lesson discussions; active interviews (conversations); follow-up active interviews; and focus group discussions.

To ensure plausibility of interpretations (Woods & Trexler, 2001:75), actors were asked to indicate any misinterpretations, and where necessary to clarify aspects or make amendments. However, time constraints and actors' workloads proved to be a barrier, resulting in some of them taking too long to read and critique the documents. Furthermore, the level of critical engagement varied. Nonetheless, I found member checks very useful in enhancing reciprocity (see Section 3.3.2) among actors and in fostering the dialogic nature of the study.

Catalytic validity

'Catalytic validity' gauges the degree to which the research process "re-orients, focuses, and energises participants" (Lather, 1986a:67). Lather (*ibid*) suggests that catalytic validity entails having some documentation that demonstrates that the research process has led to insight and, ideally, activism on the part of the actors; it strives to ensure that research leads to action (Cohen *et al.*, 2000:111), and action is usually linked to empowerment. Similarly, central to emancipatory research is empowerment. At the heart of this research study too was emancipation and empowerment of all actors, and we endeavoured to achieve it in various ways and co-ownership was regarded as essential.

This study is henceforth concerned with the process of transformation through the process of empowerment and development as reiterated by Babikwa (2003:43).

Kincheloe (1998) and Kincheloe and McLaren (2000) further explain that those who seek emancipation attempt to gain the power to control their own lives.

Peer validation

In this research study, 'peer validation' has been conceptualised in both formal and informal terms. My supervisors, research network actors, research support group, PhD weeks[19] and the research winter schools have been classified as formal peer validation, albeit not strictly.

Meanwhile, informal peer validation has occurred through more natural interactions with critical friends, including our colleagues in the Rhodes University Education Department, Masters and PhD students in the Department, colleagues we met at the Department Research Methodology and Interpretation courses, and conferences (local and international), and peers of network actors.

Collegial responses we have received have proved invaluable for validation in this study. We found talking and discussing (including e-mailing) with colleagues to be a vital part of the validation process.

The notion of critical friends has been conceptualised in two ways in this thesis. First, some of our critical friends were mainly playing the critical role on language, supporting grammatical constructions. Secondly, some were chosen for their expertise in the methodology underpinning of this research study. Worth noting is that, thanks to the mutual and collegial support that I received from my supervisors, I tended to see them as my critical friends too as they played an important role in the validation of data.

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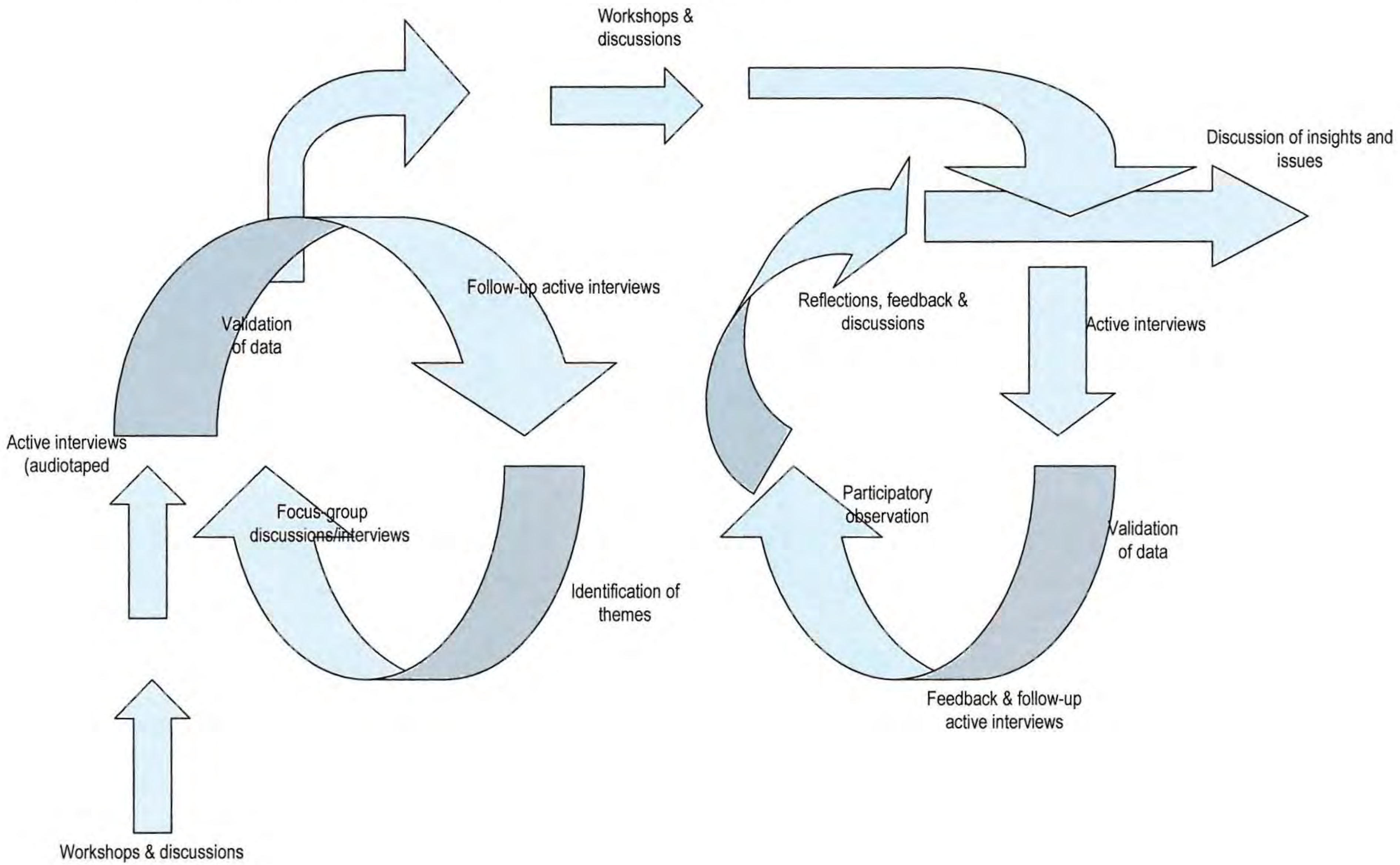
[19] The PhD weeks are organised by the Education Department, Rhodes University to enhance research capacity for both potential PhD students and those who have completed their PhDs. This is a wonderful opportunity for students to share their research and in the process learn from one another.

To cite but one example, when we co-presented at the Research Methods and Interpretation course, one of my supervisors attended our presentation and documented some comments by the participants. I also co-wrote a research paper on our research project with my supervisors. Likewise, some science teachers in our network became critical friends rather than just actors. This could be seen as a form of empowerment on the part of some network actors.

Figure 5.1: Data generation and analysis: A recursive process



5.4.4 Ethical considerations

Soltis (1990), Strydom (1998) and Merriam (2001) warn us that, in qualitative studies, ethical dilemmas are likely to emerge on the generation of data and in the dissemination of findings. Erickson (1998:1160) suggests that "researchers are obliged ethically to anticipate what will be done in data collection, analysis and reporting" during their research studies. Erickson (*ibid*) further recommends written agreements when the conditions of research are specified. This is called mutually informed consent and participation was negotiated among the actors.

Berg (1998:48) points out that confidentiality and anonymity are critical during research: explicitly researchers need to assure actors that anything discussed between them will be in strict confidence. In this research study, the identity of the actors was concealed through the use of pseudonyms. Actors were given the freedom to choose their own pseudonyms and their schools' pseudonyms.

However, maintaining confidentiality and anonymity within the network proved not to be practical. For example, co-writing and co-presenting at the Research Methodology and Interpretation courses and at conferences made it difficult to conceal some network actors' identity. Nonetheless, active participation at these courses and at conferences proved to be an empowering and emancipating experience, as is emphasised in the section on socially critical-emancipatory research orientation (see Section 4.2.1).

Erickson (1998:1161) points out that since qualitative research requires active participation and commitment by those involved in the study, trust is all the more essential. Cresswell (2003:201 - 2) reiterates that "the researcher has an obligation to respect the rights, needs, values and desires of the informant(s)." In this study, I made available to the actors all transcripts, written interpretations and reports.

5.4.5 Our roles as actors

Initially, our conceptual understanding of PAR and critical-emancipatory research (Kemmis & McTaggart, 2000; McIntyre, 2003) were, indeed, very limited. Kemmis and McTaggart (2000:573) point out that, in the PAR, actors take an active and agential role in changing the processes of construction of social reality. Lending support, McIntyre (2003:48) explains:

> PAR is a process whereby people reflect on particular aspects of their lives so to engage in individual and/or collective action that leads to useful solutions, which benefits the people involved.

However, Kemmis and McTaggart's and McIntyre's views did not help us immediately to distinguish between 'participation' and 'collaboration'. According to Grimmett (1993:200), collaboration involves the mutual negotiation of purposes and interests by the actors. He further emphasises that collaboration respects individual and collective autonomy (*ibid*). However, Grimmett does not offer any explanations as to how such mutual negotiation is reached. Unlike other scholars who claim that actors involved in their PAR projects saw the need for development, in the case of our research project, it would have been so helpful if we were introduced to PAR before we engaged in this study.

Like other actors in the network, what I regret is that when I was a science teacher at school my quest for scientific knowledge and development was solitary and unconnected with my colleagues from other schools. Meanwhile, my previous experience working with science teachers was unfortunately, contaminated with power relations in the sense that I was a science subject adviser and later a science education lecturer in the period when this study was conducted. Thus, as actors in the processes of this research study, we were challenged to explore ways in which to involve ourselves as co-learners who could support sustainable empowerment and development (Lotz 1996:108) in the TTCPD network.

Coming from a similar background with comparable experiences to the other actors in this study, we needed to collaboratively find ways of involving everybody in the organisation of our empowerment and understanding of our teaching and learning situations. It was thus essential that in order to understand each other's lives, we had to work together over an extended period of time (see Section 5.4.3). Throughout this period, we endeavoured to ensure that our roles were interactive ones, at an individual and collective level. This is consistent with the socially critical-emancipatory orientation and the actor-network theory framework (see Sections 4.2.1 and 4.2.2 respectively) and was done through the collaborative development and implementation of LTSMs.

In essence, it could be argued that we were engaged in a praxis-orientated research (Lather, 1986b:259), whose focus is on improvement of practice. To Lather, reciprocity and reflexivity are essential in such research (see Sections 3.3.2 and 3.5.2 respectively). McBeth (2001:35) explains that "reflexivity is a deconstructive exercise for locating the intersections of author, other, text, and the world." Pillow (2003:176) adds that one of the most noticeable trends to come out of the use of reflexivity is increased attention to researcher subjectivity in the research process - the focus on "who I am, who I have been, who I think I am and how I feel I affect the data collection and analysis" (*ibid*). Although I read and internalised the literature on reflexivity to the best of my ability, putting it into practice proved to be a challenge for me.

5.4.6 Presentation of data

In this thesis I referred to generating data rather than 'gathering' or 'collecting' data. I did this deliberately because I wanted to draw readers' attention to the idea that data are not 'out there' waiting to be 'excavated', but are actively generated or constructed by researchers: in this study, data were generated and co-constructed by the actors who were regarded as co-learners and co-researchers.

Analysed and interpreted data has been presented in several formats in this thesis. I have used boxes to present the co-constructed scientific knowledge, diagrams and a table to clarify certain concepts. As the text represents an attempt to reflect a collaborative process, I have used direct quotations to highlight the network actors' *voices* and to illustrate some of their views. Some concepts and metaphors have been italised.

The use of the first person (I, we, our and us) has been used for two reasons. Firstly, 'I' has been used to ascertain my position as the authentic responsible author of the thesis. This is in line with the socially critical-emancipatory research orientation whose premise is that knowledge is socially constructed and research is a social process that is not neutral (Lather 1986b). Secondly, I also deliberately used the pronouns 'we', 'our' and 'us' to emphasise that this research was a collaborative endeavour undertaken by a group of practitioners, with me included. Central to this research, too, is a strong notion of ownership.

5.5 Concluding remarks

This chapter locates the methodology within the qualitative research and the interpretive paradigms. Within these paradigms, the research may be described as a qualitative case study: employing the participatory action research approach (as discussed in Sections 5.3.2) as a way to understand and promote the science teachers' transformative and continuous professional development. The dynamic and dialogic relationship among all the actors who are regarded as co-learners and co-researchers (see Chapter 6), is paralleled by the dialectic nature of data generation and analysis (see Figure 5.1) described here, and related research issues. All the actors in this study were actively involved in the generation of data; therefore the reflexive approach is discussed to illuminate the active collaborative role of the actors in this study.

The next chapter deals primarily with our research network's activities and reviews the process and development of this research project. It explores how the science teachers involved in this study were mobilised to form a network. Paying attention to the contradictions and tensions that surfaced, this chapter also provides an account of the teachers' different stages of development and growth. Foundational to the network, capacity-building activities were the ideals of fostering improvement in science teaching and learning in secondary schools, in particular, historically disadvantaged schools in Grahamstown. Summaries of findings are thus presented on activities and relations within the network as it is proposed in the actor-network theory. I also focus on the evolution of the network's goals, development and implementation of mediating artefacts which are in the form of learning and teaching support materials. I conclude by highlighting the key issues that emerged during this part of this research process.

Chapter 6

Research process and development:

Data analysis and findings

> Teaching involves complex and multilevel knowledge and understanding of learners, curriculum, learning materials, cultures, and society and its communities and institutions. Working together, teachers develop their interpretation of good teaching and learning.
>
> (Kosunen & Mikkola, 2002:143)

6.1 Introduction

The focus of this chapter is on the process and development of this research project. It explores how the science teachers in this study were mobilised to constitute a network, working together, as the epigraph suggests, to 'developing their interpretation of good teaching and learning'. It also provides an account of the teachers' different stages of development and growth. As this was a reiterative process, the research process is presented as expansive cycles (Foot, 2001:2) of development during the period 2000 - 2003 (see Figures 6.1 & 6.2).

In this chapter, I illustrate the development of the teachers' transformative and continuous professional development network. Summaries of findings are thus presented on activities and relations within the network as it is proposed in the actor-network theory (see Section 4.2.2). I also focus on the evolution of the network's goals, development and implementation of mediating artefacts (Vygotsky 1978) which are in the form of learning and teaching support materials, as well as building of the community of practice as proposed by Lave and Wenger (1991). I conclude by highlighting the key issues that emerged during this part of the research process.

6.2 Research process: Illuminating the development of teachers' TTCPD network

This section considers the network's activities in the period 2000 - 2001. They are presented as an expansive cycle of development (see Figure 6.1), adapted from Foot's (2001) expansive cycle, to highlight the participative methods that lead to the transformative learning that took place during our workshops.

6.2.1 Expansive cycle 1: period 2000–2001

When this research project was first conceptualised, I was working as a science subject adviser in the Grahamstown district. Interestingly, in some of our science subject advisers' meetings we often talked about the need to form subject committees in our districts; however, the logistics for putting this into practice were not clear. This motivated me to envisage a research project that would support capacity-building for science teachers. Lave and Wenger (1991), propose that, through a community of practice, practitioners are afforded opportunities to learn together. My interest in this study, however, focused on how the actors contributed to their own professional development.

In February/March 2000, in keeping with Edwards's (2002) mandate that spaces of negotiation are critical when a network is formed (see Section 4.2.2), I initially approached seven[20] senior-secondary-school science teachers individually rather than writing letters to them: I approached two teachers from two former Model C schools, one teacher from a former House of Representative (HoR) school, and four teachers from four former DET schools, to constitute the network.

[20] The initial network was composed of seven science teachers from the former model C schools, former HoR school and former DET schools; the heterogeneity of the network was in terms of the geographical location of the schools, socio-economic background, race, gender and so on.

The rationale behind approaching teachers from such a wide range of schools was informed by my assumption that a variety of skills, expertise and knowledge would be obtained and shared among the science teachers. Gomart and Hennion (1999) too propose that heterogeneity of elements in a network is useful for bringing different perspectives (see Section 4.2.2).

In this study, it could be argued that heterogeneity was thus in terms of race, gender, teachers' experiences, qualifications, school contexts and so on. Nonetheless, my initial assumptions overshadowed the realities of practitioners as being heterogeneous. Although all the science teachers that I approached agreed to be part of our network, judging by the body language of some I could sense that there were still some questions in their minds which unfortunately I could not read. Such reactions were not a surprise to me, as a network of science teachers from different schools was indeed something new to them.

To my mind also, the fact that, at the time when this study was conceptualised and negotiated, I was a science subject adviser based at the district office could have possibly influenced some of the science teachers' feelings and thoughts; it could be argued that I was given my own medicine to drink because in my own experience as a teacher, we used to view the district office as imposing regulations on us teachers. Our attitude widened the gap between the schools and the district office.

Thus, my position and power in relation to the science teachers could not be overlooked. I had to be vigilant: it dawned on me that I could not take things for granted and assume that since I had established a good rapport and working relations with these science teachers in the past, this would guarantee that I could work with them in a network context. This is another reason why it was so important to negotiate with these teachers face-to-face rather than telephonically. Also, what could have inspired the teachers that I approached could be that I promised them science equipment as an incentive.

After I had visited all the potential network actors, I then wrote letters thanking them for their time and for agreeing to be part of this initiative. In the letter, which I hand-delivered to the network actors to ensure that all of them received it, I had also included the proposed agenda, date, time and venue for our first meeting. To encourage co-ownership of the project from the onset, I encouraged the science teachers to add items they felt needed to be included on the agenda. They all seemed happy with the proposed items.

When I visited one of the science teachers at his home, we had a long discussion about the poor Grade 12 results in science and mathematics in some of the historically disadvantaged schools in Grahamstown. He attributed the high failure rate to the following issues which I recorded in my research journal:

- not enough resources (both human and material) in some schools;
- lack of knowledge and skills to do science experiments by some teachers;
- lack of confidence in delivering subject content knowledge by some science teachers;
- poor time management in some schools;
- high rate of absenteeism by both teachers and learners;
- science teachers' attitude towards the science subject;
- learners not given opportunities to question things in science classrooms;
- learners not doing their homework;
- high failure rate linked to stupidity on the part of learners; and
- learners' attitude towards studying. Why study when there is no work after completion of Grade 12? (Research journal 5/04/2000)

What is interesting about the issues raised here is that they pertain to both teachers and learners. From these issues, it could be argued that things are indeed not working well in some of these schools. Essentially, informally chatting to the science teachers was useful in that I was able to get their perspectives, and contexts, and grow to know them better as individuals.

One issue that was raised and emphasised at our first meeting was that we needed to have workshops (see Section 5.4.1) rather than meetings so that teachers could benefit from our activities. The science teachers saw having workshops as an opportunity for capacity-building as well as enabling environments, collective contexts and an appropriate relational worldview to enhance learning, allowing for a dynamic network (Stetsenko & Arievitch 2004; Goduka 2005; Hardman 2005): they embraced the notion of a collective human endeavour reiterated in actor-network theory (see Section 4.2.2).

In keeping with the ideals of ANT it was also proposed, that during our workshops, individual actors would be required to take leading roles in their areas of expertise within the science curriculum. This was critical since according to Foot (2001), an activity manifests itself in actions in a network by the actors involved. Vygotsky (1978), too, argues that activity systems are realised through interlinked tool-mediated actions by which actors collectively engage, a view embraced by the actors in this study.

For me it was inspiring to hear that the actors recognised and acknowledged that there was a need to tap into each other's expertise and knowledge and were also keen to utilise workshops in situating learning in a collaborative process (Lave & Wenger 1991). However, some of the actors from the historically disadvantaged schools pointed out that they had limited resources at their schools. Thus, it would be much appreciated if they could be provided with some additional science equipment. In the context of a study which professes empowerment of teachers, consideration of their needs was and is of critical importance.

Fortunately for me, I had already secured some funding from Somerset Educational in the form of micro-scale science kits, and I thus reassured the science teachers that they would get this additional science equipment. We then agreed that we would use the micro-scale science kits as mediational tools as proposed by Vygotsky (1978) and as a catalyst to drive our initial activities: we recognised that physical resources are essential in a network.

We also agreed to start our activities with the topic of *electricity*, focusing at Grade 9 level so that we could interact with the new curriculum in South Africa. It could be argued that it was also strategic to focus on this last grade of the senior phase (in which science is compulsory) since in Grade 10 learners would have to choose whether to do science or not. Hardman (2005) points out that the changes in curriculum can be useful in constituting a guideline in a network. Those teachers teaching at Grade 12 levels were, however, encouraged to find their own time to discuss Grade 12-related work. It became evident that the goal of the network would be to adapt and develop learning and teaching support materials (Czerniewicz *et al.* 2000) with the view to improving the teaching and learning of science.

Development of LTSMs was seen as a useful strategy in enhancing learning since some science textbooks' knowledge were perceived as out of touch with reality. Furthermore, it was also acknowledged that in order for teachers to be self-innovative and pro-active they ought to be knowledgeable in their subject areas first. Thus, there was a need to strengthen actors' subject-content knowledge as proposed by Shulman (1986). Towards the end of our meeting we negotiated about ethical issues and the actors' rights to participate in this initiative. All actors indicated that they were willing to take part as this was an opportunity for them to co-engage in professional development.

In our first workshop, held on the 20 July 2000, all seven actors that I had approached attended. They were given an opportunity to share their experiences of using the micro-scale science kits with their learners. It was reported that both teachers and learners were experiencing problems using the small components of the kits; as a result, some teachers were reluctant to use them. It was also generally agreed that crocodile clamps could have been useful components in the kit.

The reflections on the use of the kits were revealing in that the different school contexts were put into perspective. However, as we did some practical activities on electricity using the kits and co-learning some new techniques, the science teachers in my view seemed to be more comfortable.

My reflections and impressions of our first workshop was that the science teachers seemed willing to collaborate. Also, what inspired them was that on this day they received additional micro-scale science kits as promised. For our next workshop which was scheduled for 22 September 2000, it was suggested that actors should prepare a demonstration practical activity on Ohm's Law. Also, the idea was proposed of visiting each other's schools so that actors could be exposed to the different school contexts; however, the logistics for this were not made explicit at this stage.

In our second workshop, held on 22 September 2000, three out of seven actors had done their homework and were ready to share their demonstrations. They had also prepared some worksheets that they used. Interestingly, two versions of Ohm's Law were shared, one using the conventional science equipment and the other using the micro-scale science kits. It became apparent that some teachers preferred to use the conventional apparatus, as this was available at their schools. Worksheets on these practical activities were shared and the importance was also emphasised of drawing knowledge from a wide variety of resources.

On a less positive note, though, it was disappointing that four actors did not make an effort to do their homework, something I sensed could result in tensions in the network in the long run if it continued. Possibly also the ideological inconsistencies of the past education that teachers had received (see Chapter 7) could have manifested themselves in the passiveness of these actors. At this stage this was not a cause for concern as such; but I would argue that the need for emancipation and empowerment of teachers became more evident as suggested in the socially critical-emancipatory orientation (see Section 4.2.1).

Box 6.1: Some highlights on Ohm's Law

Ohm's Law: Ohm's Law is a mathematical equation explaining the relationship between **Voltage**, **Current** and **Resistance** within electrical circuits. It is defined as

$$\boxed{V = IR}$$

Voltage: is an electrical potential difference between two points on a conducting wire. It is measured in volts (V) and comes from various sources such as electric outlets and batteries.

Current: is charged particles which flow from the voltage source through the conductive material to a ground. It is measured in ampere (A).

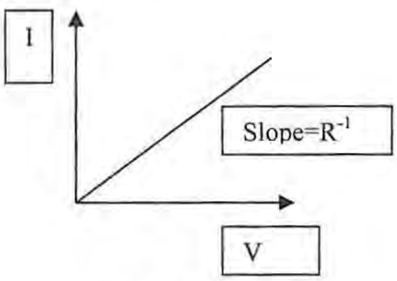
Resistance: is the opposition that a material body offers to the passage of an electric current. It is measured in ohms (Ω).

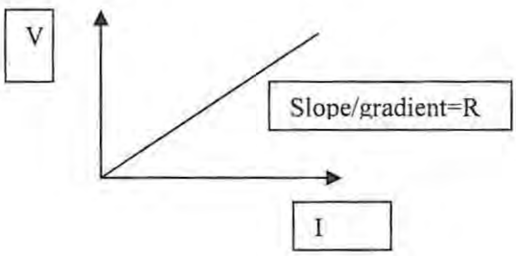
If the potential difference is measured in volts (V) and the current is measured in ampere (A), then the quotient **V/I** is defined as the resistance of the conductor. Conductors which obey Ohm's Law are said to be **ohmic**.

If the conductor obeys Ohm's Law, the current will be **directly proportional** to the potential difference across it, provided its **temperature** remains constant: if you double the voltage, the current will also double.

Voltage and current are thus related by **linear functions** for ordinary resistors and are related by **power functions** for light bulbs. Experimental error to note in Ohm's Law using bulbs, a switch is an important component in this experiment since, if the the electrical current is allowed for too long between readings, the conductor heats up resulting in resistance being increased, and incorrect readings will be taken.

Graphs:





<u>**Note:**</u> **y = mx + c**

Vy=RmIx + 0

Lessons learnt, and implications

According to Babikwa (2003), assumptions about practitioners as homogenous and ready to collaborate for a common goal is an oversimplification of the dynamics that characterise them. In asserting this, I would contend that, just as teachers might appear alike as professionals and in the subjects they teach, great individual differences might still exist in outlook, interests, aspirations, capacities, experiences, cultures and histories, as highlighted by Babikwa (2004).

Furthermore, while it is good for every individual to get involved, the reality is that it is not possible for everybody to participate positively and equally. This implies that participation does not always mean everybody being involved and playing a positive role. Refusal to take part or contradicting the network's agenda, however, can be useful for the growth of the network system. Professional developers should be aware of this and not feel disappointed when only some of the practitioners participate in programme activities.

In light of this experience, I found that my assumptions of a relational worldview as being mutual and a two-way traffic (Law, 1999; Goduka, 2005; Nhamo & Lotz-Sisitka, 2005) were squarely challenged. I was also concerned that some actors might have joined the network in an apprenticeship mode as described by Nespor (1994), expecting only to receive from other actors in the network and not to contribute anything themselves. Yet Loucks-Horsley *et al.* (2003) argue that individuals ought to join the network to share their own knowledge and experiences with other actors. I later found that this idea, which I had assumed too, was not only the case but was contested by some of the network actors.

It emerged that the science teachers' backgrounds and contexts (see Chapter 7) in this study varied, and that could have had an impact on the level of their participation. Arguably, given the seven teachers' diverse backgrounds and contexts, possibly emancipation and empowerment meant different things to them. Furthermore, given their different teaching experiences and qualifications, their zone of proximal development (ZPD) (Vygotsky 1978) (see Section 3.3.3) in terms of knowledge possession could be at different levels.

Possibly, also, language barriers could have an impact. I had noticed during the discussions that some network actors were not as actively involved as I would have liked. In a study of this nature, identifying the factors that could inhibit or stimulate the teachers' professional development and growth would itself be an intellectual exercise. As I reflected on these experiences, some questions came to my mind regarding a research project of this nature:

> Although it was inspiring to learn that teachers appreciated and needed collaborative support, however, how such support could be formulated to reflect the principles of emancipation and empowerment so that teachers could take responsibility for their own professional development was still a challenge and a reality I needed to face in this research project. Thus, a number of questions kept on coming into my mind. What did individual actors need to bring to the party in order to own this research project? Were teachers equipped and ready to do this? Would teachers be willing to open up and be honest about their strengths and weaknesses? How best the teachers' strengths could be utilised to enhance our collaborative efforts? (Research journal 22/09/2000)

Clearly, from my reflections it became evident that striking the balance between collaborative learning and emancipatory empowerment was not an easy task, as I initially assumed. Furthermore, it dawned to me that the science teachers' diverse cultures and worldviews required a clear understanding of the socially critical-emancipatory orientation (see Section 4.2.1) I claimed to be most appropriate in this study. It could be argued that on paper some of these theories are self-explanatory, yet they are complex.

My assumptions were further challenged when some network actors from the historically disadvantaged schools confided that they were not comfortable communicating in English all the time as they interspersed it with *isiXhosa* or spoke mainly *isiXhosa* at their schools. I concur and sympathise with these science teachers; their concern was legitimate.

I also wondered if I should consider Goduka's (2005:3) suggestion that learning must first be rooted in the local languages, cultural practices and spiritual values that resonate with the worldview of actors (as discussed in Section 4.2.2). For this study, this idea suggests that the network would then be composed of teachers speaking the same language. I recognised, however, that might have its disadvantages as actors would be deprived of exposure to different cultural practices and opportunities to learn another language. This was indeed a learning experience and food for thought for me although I was not sure how to resolve this matter.

In our last workshop held on the 6 October 2000 all seven network actors were present and we had an opportunity to reflect on our activities thus far. I was impressed and motivated by the commitment displayed by these actors, who seemed determined to be agents of change (see Section 3.4.2). At this workshop, the following were emphasised:

- need to work as a team;
- commitment by all actors;
- network actors' roles needed to be negotiated and made clear (see Section 4.2.2);
- research funding for science equipment and other resources essential;
- revisiting focus of our research project and research goals (that is, what we ultimately wanted to achieve in the network) needed to be made clear; and
- Focus on professional development with the view to improve practice was emphasised. (Research journal 6/10/2000)

In my view, revisiting our research goals (see Section 1.4) was critical so that the objectives of the study could be reflected in the outcomes. Network actors were thus reminded that our workshops (see Section 5.4.1) were part of a development process, and thus individual actors' contributions were vital and no one person had all the answers. Workshops thus needed to be a joint effort in finding solutions to problems in the network. This was critical since, according to Nespor (1994), the notion of knowledge co-construction and learning are products of socio-cultural contexts.

It was also reiterated that everyone had equal powers and therefore equal responsibility, an idea which was clearly unfounded in fact. For a start, the notion of equal powers was contestable and questionable since language and possibly knowledge possession already proved to be potential barriers in this study. This suggests that although theorists such as Vygotsky (1978) portray language as a mediational tool, it actually hinges on whose language is being used. As I reflected on these deliberations and suggestions, I thought to myself:

> Some of the issues raised in our workshop discussions were indeed idealistic given the fact that knowledge is power. Whether we like it or not, participation by network actors would by and large be determined by the subject content knowledge as well as practical knowledge teachers possessed. From my own experience as a teacher, I was also mindful of the fact that experience in teaching at Grade 12 level could put some actors at an advantage over those teaching in the lower grades. Likewise, I anticipated that those teachers teaching the lower grades would be more knowledgeable when it comes to the new curriculum. (Research journal 6/10/2000)

In short, what I initially thought would be an opportunity in terms of diversity in the network proved to be a threat. My assumption that diversity would enhance knowledge capacity-building as proposed by Edwards (2002) was challenged. Such diversity proved to be an inhibitor rather than a stimulator, something which could impact negatively on genuine co-engagement (Goduka, 2005) in future.

It also became evident that the idea of having seven teachers from seven different schools seemed not to be a viable strategy for enhancing collaboration within the schools. It was with regret that two network actors were unable to be involved in this initiative due to their studies. In fact, one of the science teachers from the former Model C schools resigned from teaching to further her studies full time. Likewise, one science teacher from the former DET schools indicated that she was also committed to her studies with the science department at Rhodes University and thus found it difficult to be involved in the network. In all fairness, I did not see this as a false start but rather as a learning curve.

One of the experienced network actors proposed that we needed to have at least two teachers per school so that teachers could continue collaborating in their school contexts. This proposal was welcomed and three actors even went to the extent of suggesting names of science teachers they could recruit at their schools. It was sensible that they recruited these teachers themselves since they would be working together with them. What inspired me also was that the teachers' *voices* were heard and respected, something which is in line with the socially critical-emancipatory orientation (see Section 4.2.1) professed in this study. It could further be argued that that itself was a form of emancipation on the part of actors in this study.

Nonetheless, although the idea of continuity was an excellent one it had its bottlenecks. For instance, it was difficult to get a second teacher from the represented former Model C and former HoR schools. As a result, the two science teachers from these schools decided to pull out.

Towards the end of year 2000, I approached another science teacher (choosing a female teacher as we had only one other teacher in the network at the same time) who had fortunately attended our initial workshop when we launched the project. The advantage was that she was aware of our objectives and getting her on board would be a smooth process. As she also saw this as an opportunity for professional development, she even recommended and negotiated with her colleague at her school to join the network.

After the new science teachers had been recruited, I did a follow-up visit to ensure that they were willing to be part of our network. I also explained our objectives, in which they were also free to contribute. Our new network was thus composed of four former DoE senior secondary schools, with two teachers per school. Of the eight teachers, three were in the initial network. What was unique about the formation of our new network was that teachers themselves were involved in the recruitment of other teachers. My assumption was that this would help to enhance collaboration among the science teachers in their school contexts; later I learnt that this idea was unfounded. This should indeed be a lesson to professional developers.

Another change in my life occurred when I was offered a post as a lecturer in the Education Department, Rhodes University, and I had to vacate my post as a science subject adviser at the end of 2000. My new position meant that I was given more powers and I had thus to rethink my strategies for working with the network actors. For example, to further help facilitate progress in the network we decided to engage in a pilot project: teaching the Khula Project learners (see Section 1.3). Two actors from the network were involved in this initiative since they were teaching up to Grade 12 at their schools. Other network actors were only teaching up to Grade 9.

One of the highlights of engaging in this pilot study was that it culminated in a research paper which I co-wrote and co-presented with one of the actors. This was also useful in enhancing research skills in the network, albeit on a small scale. In hindsight, although this strategy could be seen as an ethical dilemma as far as anonymity (see Section 5.4.4) was concerned, it proved an empowering exercise in many ways.

What I also found useful during this research *journey* was having informal conversations with individual actors in the network. In an informal conversation with one of the actors he said that some teachers in the historically disadvantaged schools felt threatened on hearing they would have to teach in the higher grades. He thought this sense of alarm could be due to their inadequate subject-content knowledge, thus felt there was a need to empower teachers with such knowledge.

Similarly, on pedagogy, he said that transmissive approaches to teaching and learning resulted in some learners being passive in science classrooms. This suggests that the practical aspects and implications of outcomes-based education needed to be looked into; for him, OBE was not necessarily a viable solution for some of the problems in the schools. He further proposed that teachers needed to be equipped with skills before they could play key roles in the curriculum. I found these suggestions very stimulating and re-energising.

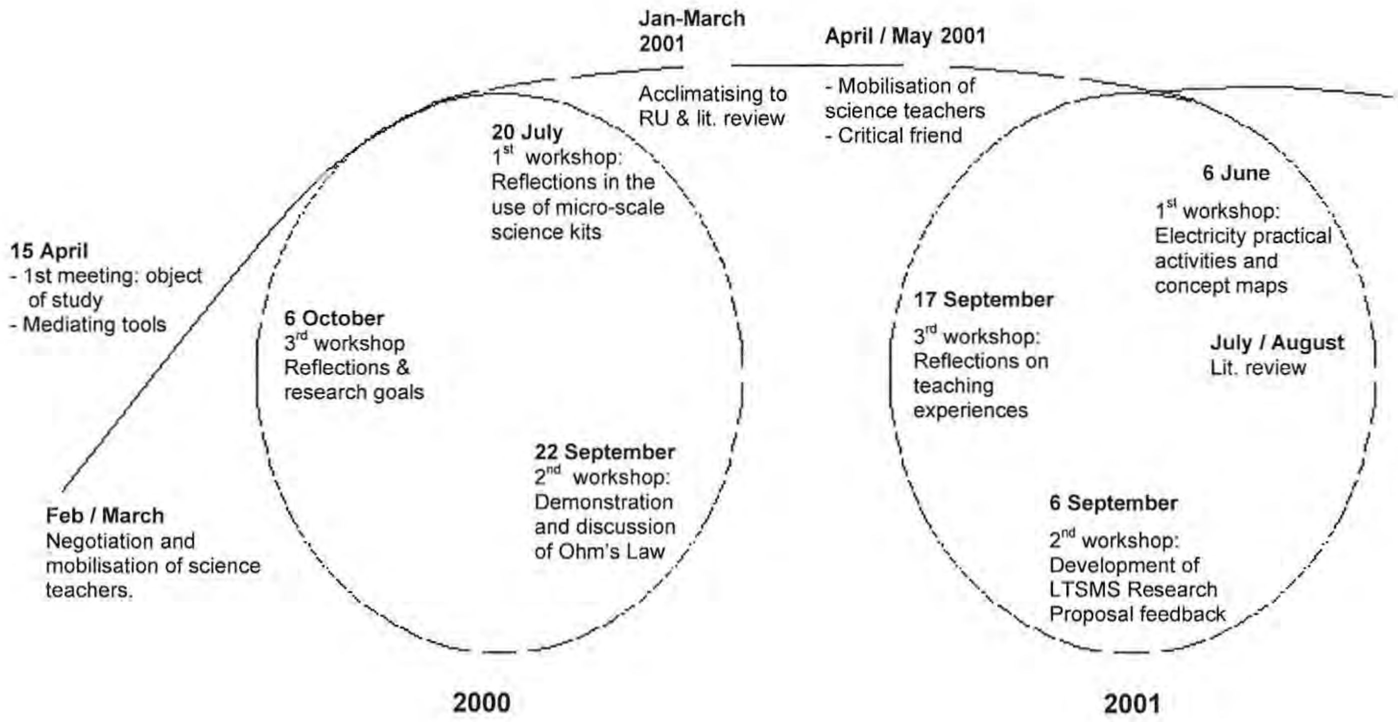
In our workshop on 6 June 2001, we did practical activities with *electricity*. At this workshop I also observed that the teachers were more familiar with using the micro-scale science kits. Furthermore, as a result of the pilot study we had conducted on the Khula Project learners, we were able to modify our worksheets on *electricity*. A lesson also learnt was that knowledge is not static but dynamic. Furthermore, keeping in mind the importance of learning subject-content knowledge with understanding, the role of concept maps was also introduced and discussed.

Based on the teachers' reflections on their teaching experiences, in our two September workshops we decided to put more emphasis on the development and adaptation of learning and teaching support materials, as proposed by Czerniwiecz *et al.* (2000). To strengthen this aspect, I also thought that it might be beneficial for the actors in the network to be engaged in studies outside their teaching sphere. Although I learnt that some of them had Advanced Certificates in Education (ACEs) in management, I encouraged them to register for an ACE in science in our department in 2002. This thinking was also informed by the notion of teachers being seen as lifelong learners (Duggan, 1996; Edwards, 2002).

In my end-of-year meeting with my supervisors to update them about my research, they advised me that it was important for me to demonstrate how to bridge the gap between theory and practice as this project was concerned with the co-construction of knowledge. Also, they recommended that it would be useful to tape-record our discussions during our workshops so that rich data was not lost. However, they advised that this should be negotiated with network actors to ensure that they agreed (see Section 5.4.4).

Our activities in 2000 - 2001 are presented as an iterative and an expansive cycle (see Foot, 2001) in Figure 6.1 below.

Figure 6.1: Diagram for the expansive cycle 1: 2000 - 2001



6.2.2 Expansive cycle 2: period 2002-2003

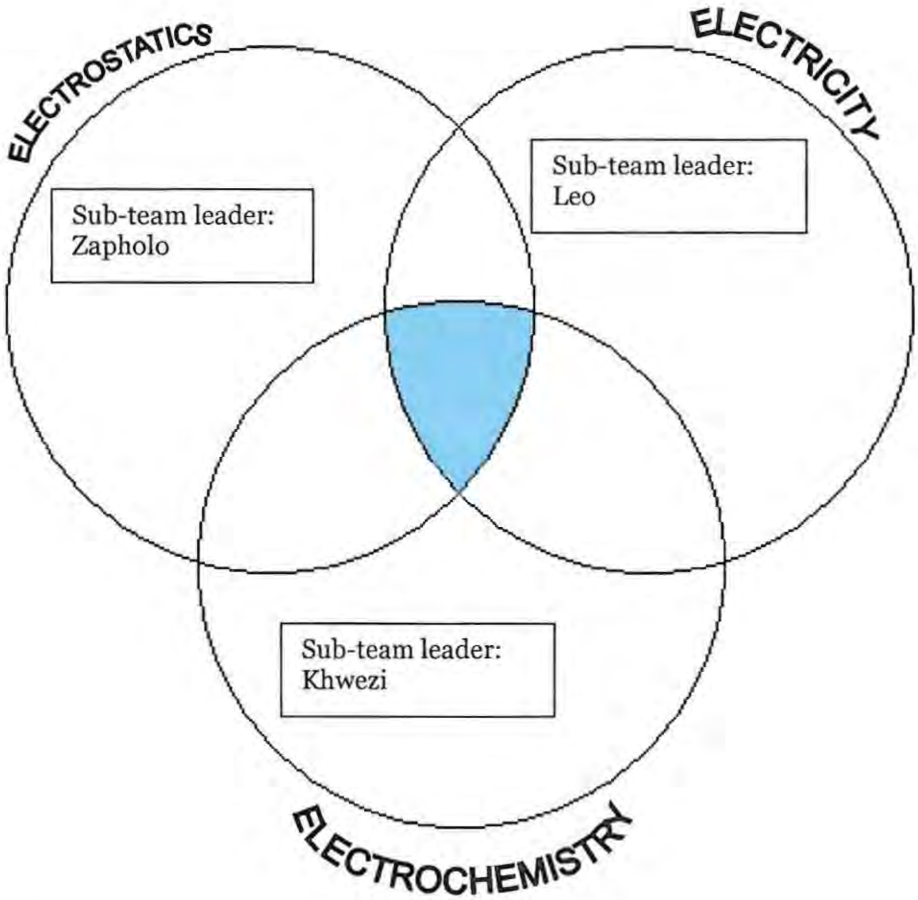
We held our fourth workshop on the 19 April 2002 with seven network members in attendance. At this workshop, actors were afforded an opportunity to reflect on their experiences in their science classrooms. Concerns raised included learners not being actively involved during teaching and learning. Similarly, language barriers were highlighted as potential inhibitors to learning. The actors also expressed the need for assistance with development of teaching and learning units of work as they realised the need to plan over a period of time. I must say, it was deeply motivating that the actors were honest about what needed to be improved in order to enhance teaching and learning. For me, their readiness to point out difficulties showed many strengths, clear thinking, shared analysis, humility and above all a wish to grow as teachers.

In our follow-up workshop we revisited and did practical activities with *electricity* and the focus was on how to identify the key concepts to be developed. During our discussions it became evident that, without enhancement of language, encouraging students to talk science was difficult. Furthermore, one actor (who subsequently became a sub-network leader for this topic) suggested that we needed to understand *electrostatics* in order to understand electricity. Similarly, to understand how cells or batteries work we needed to understand *electrochemistry*. Exploring these three science topics would also provide actors with opportunities to learn about and experience integration (see Figure 6.2) within science itself.

To ensure maximum participation of all the actors we thus decided to form three sub-networks: *electrostatics*, *electricity* and *electrochemistry* (see Figure 6.2). For each sub-network, a leader was elected. This division of labour (Popov, 1998; Foot, 2001; Hardman, 2005) was important in ensuring that network actors owned the project. It was also hoped that such active involvement would help accelerate actors' development and growth. Furthermore, through visiting and interacting individually with actors at their school contexts, I realised that they felt free to share their ideas.

This suggests that for a collective human endeavour to be effective, consideration of individual actor's opinions and feelings is critical.

Figure 6.2 The three Es



The shaded region in this diagram represents the space for integration opportunities and may be referred to as a 'transformative zone' (Bresler, 2003, cited Russell, 2006) of learning. It is in this region, I believe, where conceptual development, understanding and meaningful learning take place among actors in a network.

On 16 May 2002, with Leo and Khwezi in charge, we had a follow-up workshop on *electricity* where we discussed how to design a series of practical activities that build on one another. This proved to be a positive shift towards the development of units of work. It was also suggested that there was a need for a resource file to be kept in my office so that actors could access and use whenever they wanted additional information for their lessons. This suggests that actors were willing to shift from relying only on the prescribed textbooks as the only source of information as they have been doing in the past (see Chapter 8). Such a shift of mindset was important as the transformation in curriculum in South Africa is resource-based. It is recognised, however, that this curriculum requires competent and skilful teachers.

On 23 May 2002, Zapholo conducted a workshop on *electrostatics* (see Box 6.3) to demonstrate how key concepts could be developed. Before he engaged the network actors in 'hands-on', 'minds-on' and 'words-on'[27] (Maselwa & Ngcoza, 2003) practical activities, he demonstrated how to elicit and mobilise learners' prior everyday knowledge on lightning (see Box 6.2). This proved to be useful in sensitising network actors about the importance of taking learners' prior everyday knowledge into consideration for teaching and learning repertoires.

[27] During 'hands-on', 'minds-on', and 'words-on' practical activities learners are encouraged to co-construct knowledge through making predictions, experience science first and document their observations. Throughout this process they are encouraged to discuss in order to enhance their meaning-making. The role of the teacher is to be a facilitator, scaffolding those learners needing help and consolidating and linking key concepts to be developed.

Box 6.2: Some highlights on mobilisation of prior everyday knowledge

Mobilisation of prior everyday knowledge on lightning
Before enagaging in 'hands-on', 'minds-on' and 'words-on' activities on electrostatics, we discussed how students' prior everyday knowledge could be mobilised through exploring our cultural beliefs about lightning. Various beliefs were shared such as: not running when there is lightning; covering of mirrors; not eating when there is lightning; not smoking; not urinating near the house; putting a car tyre on top of a roof (especially in rural areas); putting a saucer in a container of traditional beer (*umqombothi*) etc. Scientific explanations for some of these beliefs were explored. For example: no running when there is lightning was associated with electrolytes; covering of mirrors associated with reflection and not smoking associated with ionisation of air particles.

It emerged from the discussions that it was difficult to replace students' beliefs. However, mobilising and taking into consideration their everyday prior knowledge during teaching and learning repertoires was seen as a useful starting point. Also, we believed that it enhanced student participation as they had to share their experiences (from parents and community) rather than just reproducing textbook knowledge. To this end, one network actor shared his assumptions and beliefs about teaching and learning and commented:

> I never bothered to link what I taught to my students' everyday experiences. It was only my information that I regarded as important. And in most cases I regarded my students' information pertaining to their culture as just superstitions (Neon: Active interviews 6/04/04)

Charge distribution on conductors:
Charge distributes itself uniformly over flat surfaces but if the surface is curved, the charge density is greatest at the regions of greater curvature. The following should be borne in mind when considering charged conductors:

- All charge on a conductor lies on the surface;
- There can be no potential difference between two points on the surface of a conductor;
- The surface of a conductor is an equipotential surface (all points have the same potential, and over which no work is done when moving a test charge). The equipotential surface surrounding a point charge would be a spherical shell;
- The electric field lines are normal to the surface of a charged object;
- Field lines originate and terminate normal to the surface of a charged object; and
- Charge distribution is denser in areas with greater curvature.

Lightning conductors
The intensity of the **electric field** in a region of greater curvature can be so intense as to cause a corona of discharge in this region. Lightning conductors rely on this principle to discharge electricity from buildings when a highly charged cloud passes overhead. The same principle is used to discharge aircraft where friction with the air particles can cause the buildup of considerable charge. Wire brushes attached to the wings discharge static electricity to the air. (Source: *Experiencing Physics* by Len Victor 2000)

What was also fascinating about our practical activities was that easily accessible resources such as transparencies, scissors and cloths were used, and we were able to illustrate Coulomb's Law (see Box 6.1) ourselves. The lesson learnt from this workshop was that teachers do not necessarily need sophisticated materials to put scientific concepts across to their learners. Also, some actors felt that there was a need for us to have workshops on assessment, since they felt that they were still grappling with this aspect. This makes a lot of sense: teaching, learning and assessment are inextricably linked.

On this day also, Khwezi shared his draft learning programme unit, which he was still developing. That stimulated a lot of discussion in the team, and the need for thorough planning over a long period of time was emphasised. Likewise, Leo and Nomfundo (who have studied together at the teachers' college) shared how they collaborate at their school, which was very inspiring and a learning experience on how to enhance collaboration among network actors within their school contexts. It emerged that involvement in the network has helped actors to strengthen their working relations.

These actors also committed themselves to sharing the scarce resources available at their schools. For example, Zapholo passed on some conventional science equipment to Leo and Nomfundo at Phandulwazi. My part in facilitating the process of sharing on resources among the network actors enabled me to interact more frequently with them.

On reflection, one of the challenges we experienced in the network was that we found it difficult to plan over a period of time due to uncertainties on the part of the DoE. However, every time we had a workshop we agreed on what we would do in the next one; and whenever unforeseen circumstances arose, I was responsible for contacting the actors to change the scheduled dates. Although these discontinuities impacted on our momentum and at times I felt deflated, I thought to myself:

> I was very much impressed with the level of trust and openness that was developing in the network. Indeed, this was essential in shaping our common goals as espoused by the socially critical-emancipatory orientation. Network actors were free to point out areas where help was needed and another inspiring aspect was the willingness to share the scarce resources. In my view, without blowing my own trumpet, what also made our initiative unique was that in the Grahamstown district we did not previously have a group of science teachers committed to working together as a team with the view of improving teaching and learning of science. Our research project thus proved to be a wonderful opportunity or model for a cluster system or network amongst science teachers. (Research journal 11/06/02)

From my own reflections it could be deduced that trust does not develop overnight. Also, the fact that practical activities were first performed in the network was useful in developing respect for each other's ideas and confidence among the actors. Here, I would suggest that professional development initiatives pay attention to the subject-content knowledge and pedagogical-content knowledge as well as to the practical work skills of teachers.

Although the workshop on assessment proved to be a learning experience to the whole network actors, some actors indicated that large numbers in classes were a barrier to the implementation of quality and effective assessment. They indicated that they were not coping with the required assessment standards as outlined in the policy documents. Also, assessing students while working in groups was highlighted as a potential challenge for most teachers (see Ngwenya's comment in Chapter 9). This suggests that in some schools there are tensions when it comes to putting theory into practice and for these reasons I argue in this thesis that teacher support is essential.

Box 6.3: Some highlights on electrostatics

The laws of electrostatics:

1. Like charges exert *expulsive* forces on each other; unlike charges exert *attractive* forces on each other (Note: not force of repulsion and force of attraction).
2. The total amount of electric charge in a closed system remains constant (Law of Conservation of Charge).
3. Coulomb's Law (see unit of work): What Coulomb wanted was a mathematical expression for the forces that charged objects would exert on each other. Two point charges exert forces on each other which are *directly proportional* to the product of the charges and *inversely proportional* to the square of the distance between them.

$$\boxed{\mathbf{F=kQ_1Q_2/d^2;\ k=9x10^9\ Nm^2/C^2}}$$

The electric field

The **electric field** is a region of space in which a charged particle experiences a force. Hence, the electric field intensity of a particular point in an electric field is the quotient of the force on a positive test charge placed at that point and the magnitude of the charge (**E=F/q**). The electric field intensity is a vector and is measured in N/C. The direction of the field at any particular point is the direction of the force which would be exerted on a positive test charge placed at that point.

Field lines always begin at positive charges and end at negative charges. They are closer together where the field is stronger and further away where the field is weaker. Field lines originate and terminate at right angles to a surface, and may never cross. A **uniform electric field** can be achieved using a pair of oppositely charged parallel plates. In a uniform electric field the force exerted by the field on a test charge will be the same everywhere in the field, except for positions near the edges, where there is end effect.

Note that the electric field intensity for a pair of oppositely charged parallel plates is measured in V/m. It is for this reason that E for parallel plates is referred to as the 'potential gradient'. Also, there is no field outside the parallel plates.

How to make your own simple parallel plates:

Wear a plastic glove in one hand and then rub your two hands together (see the Triboelectric Series in Appendix C). The bare hand will be positively charged whereas the one with a glove will be negatively charged.

In revisiting our objectives, the actors in the network highlighted the following aspects:

- Cluster system/network vital;
- Collaboration within/across schools needs to be sustained;
- Subject and pedagogical content knowledge is essential for meaningful learning among learners;
- Designing and implementing teaching and learning units of work:
  - Videotaping of lessons and
  - Reflections on lessons
- Researching own practice is essential; and
- Research skills need to be enhanced.

On promotion of research skills, presenting our activities at a Research Methods and Interpretation course at Rhodes University gave me an opportunity to have a better understanding on how to go about engaging in this kind of research study. As I was presenting our work, I felt that it would have been useful if one or two actors from the network had also been involved to illuminate the collaborative nature of our study. Also, one of the questions raised by the participants at this course was: What were the individual actors going to benefit through being involved in this study?

It should be borne in mind, however, that there are many ways in which teachers could be exposed to environments that could contribute to their professional development. For example, co-writing and co-presenting a paper at the SAASTE conference proved to be a wonderful and an empowering experience for both Zapholo and myself. What was inspiring about the SAASTE conference was that many school teachers participated, something that proved to be a motivational factor for Zapholo. Also, hearing that some of the educational challenges teachers were faced with in Grahamstown also affected other teachers elsewhere was very reassuring.

I personally saw the strategy of co-writing and co-presenting at conferences as a useful strategy for individual actors to benefit professionally, academically, socially and personally. It is recognised, however, that their anonymity (see Section 5.4.4) would be compromised.

On 8 August 2002, Zapholo and I presented a paper at the Research Methods and Interpretation course on our network's activities and research *journey*. Participants at this course were greatly impressed with the fact that at least two network actors made the presentation and they were looking forward to seeing more getting involved, especially females. This convinced me that teachers' *voices* are important in articulating their own professional development initiatives. Hearing first-hand-information on what teachers do and how they do it does help to illuminate what happens in the classrooms. Also, what impressed and inspired the course participants was to hear that the network actors were all furthering their studies.

In one of our workshops we also had an opportunity to analyse and discuss common tasks for assessment (CTAs). From this workshop it emerged that one of the disadvantages of CTAs was that the focus was only on certain areas in the curriculum, neglecting others. For example, in some CTAs the focus was on *electricity*. As a result, those learners who had passed Grade 9 were not fully prepared for Grade 10 as there was very little content knowledge covered in certain science topics.

This was exacerbated by the fact that other teachers simply revised these CTAs, neglecting conceptual development. It was generally agreed that the way the new curriculum was being implemented in some schools was flawed. It is for these reasons that I believe that it is critical to engage teachers in a TTCPD network (see Chapter 6). This, however, has its challenges.

For example, although we had negotiated and agreed in principle in this study that it would be ideal to videotape actors' lessons as an attempt to enhance collaborative reflections, it seemed that some actors were not yet ready for this and we had to respect their feelings. Also, it was difficult at times for us to meet, and I started to panic.

It dawned on me:

> Time and space proved to be a challenge in many ways since teachers had to prepare examinations at their schools. This was further exacerbated by the assessment pressure which has been highlighted as being problematic. In addition to their school work, network actors had to concentrate on their studies as well, and studying part-time while working fulltime can be quite a challenge. In addition to these aforesaid challenges, family and community commitments interfered and these cannot be underestimated. (Research Journal 4/09/2002)

This suggests that when engaging in a research endeavour which claims to be emancipatory, empowering and concerned with capacity-building, time and space, are very important factors in the equation. Notwithstanding, actors need sufficient time to develop and there are no short cuts whatsoever. This revelation also motivated me to read more literature on collaboration and collegiality as I realised that my understanding of some concepts as reflected in Section 3.3.2 of this thesis was still superficial.

Another lesson that I learnt from this experience was that at certain times of the year one needs to be sensitive to teachers' work commitments, otherwise you will find that even if teachers have attended a workshop they might not be able to concentrate because they are worried about their own work. In my view, what matters most is probably not how frequently you meet in the network but rather the quality of what you strive to achieve together.

Another question that kept on haunting me was: "What new knowledge would our study contribute in science education?" With this question in mind, I had thus to use this research time in a more productive way, and so I revisited my conceptual orientation (literature review), research orientation and methodology chapters.

We also found co-presenting at courses and conferences to be a very useful strategy in constantly reflecting on our research project. Similarly, the process of co-writing papers and giving those papers to critical friends in the department has been indeed a wonderful learning and empowering experience. This approach seemed appropriate since I claimed that, in this study, research was done *with* teachers rather than on them, a view echoed by McNiff (2002) whose discussion of action research I found to be accessible and very inspiring. However, it is acknowledged that my role as a principal researcher could not be compromised and this was further strengthened by reading literature on reflexivity (see Section 3.5.2).

> As I was pondering about the appropriate data generation techniques for this research project, I felt I needed to encourage network actors to reflect in their journals too. However, I recognised that, as this was something new to them, the frequency of engaging in such reflections would vary from teacher to teacher and it had to be made explicit to actors that reflecting was not about recording all that happened step by step and in detail, but rather it was about critically reflecting on what went right or wrong, what was learnt, and how could things be improved. In this study I felt that this could be enhanced through co-teaching so that teachers could collaboratively reflect on their lessons. (Research journal 23/09/02)

In this study, the science teachers saw the need to reflect on their practice. However, what proved to be a challenge to them was putting their thoughts in writing. Furthermore, although in principle we agreed that co-teaching would be a useful strategy to enhance engaging in collaborative reflections, some actors seemed not ready to experiment with this and we had to appreciate that.

On 18 March 2003, we had our ninth workshop; its focus was on how to design teaching and learning units of work and subsequently LPUs. At this workshop it was emphasised that an LPU was not a lesson plan. As a catalyst to drive this process in the workshop, we revisited and utilised practical activities on *electricity* (see Box 6.4).

Box 6.4: Some highlights on electricity

Eletric current

The terminals of a battery are the source and sink of the charge. The rate at which the charge flows is the electric current. The SI unit of electric current is ampere (A). The direction of the electric current is always taken to be the direction in which the positive charge moves from the +terminal through to the external circuit to the –terminal.

Charges in a wire have **electrical potential energy** and will move to a region of lower or zero potential energy when a path is provided. If there is a resistor in a circuit, the charges dissipate energy in the resistor. If the resistor is in the form of a light bulb, the energy dissipated is so great that it raises the temperature of the filament to being white hot.

Electric field in a uniform wire

When the length of conducting wire is connected between the terminals of a battery, the electric field set up propels charges along the wire from one end to the other. The field lines tend to concentrate within the conductor and follow the conductor. If the conductor is uniformly thick and smooth, the electric field intensity in the wire is given by $\mathbf{E=V/l}$ (V is the potential difference, l is the length of the conductor).

The charge carriers in a metallic conductor accelerate in the electric field established in the wire but suffer a very rough passage through collisions with the particles that make up the metal. This is called resistance.

Electric circuits

Connecting cells in parallel allows for greater electric current because the internal resistances of the cells are then also in parallel, reducing the overall effective resistance. The electric current through a circuit will depend on the emf of the source (battery) and all the resistance in the circuit (including the internal resistance of the source).

$$I=E/R+r$$
$$E=I(R+r)$$

$$V_{term}=E-Ir$$

Here, the term Ir is often referred to as 'lost voltage' as that voltage not available to the circuit outside the battery.

Resistors in series (e.g. Christmas tree lights)

1. The same current flows through each resistor.
2. The sum of the potential difference across separate resistors is equal to the applied potential difference.

Resistors in parallel (Car headlamps; lights; household appliances)

1. The potential difference across each resistor in parallel is the same.
2. The total current is equal to the sum of the currents through each separate resistor.

We also revisited and discussed the assessment strategies, as this had been requested by some actors. One of the advantages in our network was that, Zapholo, was involved with the OBE workshops at district level and he was thus able to feed us with information from these workshops. However, the ball was now in the hands of individual actors to put into practice the knowledge and skills acquired from the network.

> My heart was filled with joy since I noticed that this in year, compared to the past years, network actors were more committed to attending our workshops. Also, what was inspiring was the level of participation and the level of critical discussions and engagement. I however realised that a key actor is very important, and indispensable in research initiative of this nature. (Research journal 22/03/03)

Our network's activities gave me an impression that collaboration might be the route to take to enhance participation and involvement of teachers in the implementation of the new curriculum in South Africa. However, support structures are essential for the network to be successful. This also suggests that there is a need to create conducive learning environments in which teachers themselves take leading roles. Also, what became evident in our workshops was that it was useful not to cover too many things at a time. Furthermore, as all actors spoke *isiXhosa*, we felt much more comfortable communicating in the mother tongue.

> What I also learnt from our workshops was that there was a need to model and provide guidelines to support teachers. As a result of this strategy, actors seemed pleased that some of their previous OBE workshop concerns organised by the DoE around assessment were addressed in the network. Maybe, the fact that we were a smaller group of practitioners might have impacted positively on encouraging discussions and questioning by actors. (Research journal, 16/04/03)

Likewise, developing a solid subject-content knowledge for teaching in the lower grades could have a positive impact on the learners when they get to the higher grades. I continue to believe that the intervention and catch-up programmes at Grade 12 levels might be too late to bring about improvements in schools. Thus, in our follow-up workshop on *electricity* we focused on how to solve problems and on enhancing conceptual development through diagrams. The discussions were very useful in clarifying some actors' misconceptions about electrical currents.

In the ninth workshop, we also discussed the 'hand-battery' (*electrochemistry*) (see Box 6.5), which prompted a lot of discussions in the network. It is recognised, however, that to further strengthen actors' subject-content knowledge it would be useful to discuss more Grade 12 work in future.

Box 6.5: Some highlights on electricity and chemistry

The 'hand battery'
Your skin and the two different metals create a battery which is a source of **electrical energy**.

Resources
Galvonometer, copper plate, aluminium plate and two connecting wires. Make sure that the metal surfaces are clean as dirty or greasy surfaces could block the flow of electric current.

Activity:
Network actors predicted that there would be a deflection on the galvonometer needle if one of us could hold the copper plate and aluminium plate connected to it. On experimentation, we were pleasantly surprised that the galvometer readings varied and two actors had the greatest readings. It was concluded that these two members were more warm-blooded than other actors in the network, suggesting that the flow of blood and warmth contributed to the deflection of the galvanometer needle. That fact stimulated a lot of curiosity, discussion and enthusiasm. Those actors who had the least galvanometer readings were asked to make their hands wet and try again. "What would happen if two people held the free hands together while the other hands touched the plates?" (Nomfundo) Working in pairs, one actor held the copper plate and the other held the aluminium plate and then let the free hands touch and we observed that the Galvonometer reading was less.

Scientific explanation
Even if one's hands are clean, they are still slightly damp and salty. When you touch the two metals, the thin film of sweat on your hands acts like the acid in a battery (or acts like an electrolyte solution), and reacts with the copper plate and with the aluminium plate. This is a chemical reaction and different reactions happen with different metals. In one of these reactions, your hand takes negatively charged electrons away from the copper plate, leaving positive charges behind. In the other reaction, your hand gives electrons to the aluminium plate, causing it to become negatively charged. The difference in charge between the two plates creates a flow of electrical charge or electrical current. Since electrons can move freely through metals, the excess electrons on the aluminium plate flow through the galvonometer on their way to the copper causing it to deflect. In your body, both positive and negative ions move. Negative electrons move through your body from the hand touching the copper plate to the hand touching the aluminium plate. At the same time, positive ions in your body move in the opposite direction. As long as the reactions continue, the charges will continue to flow and the galvonometer will show a small current. The charge flows back to the aluminium plate to make up for the missing charge. At the same time the extra charge which you have in your hands flows through your body to the other hand. Fortunately for everyone, the currents are so small that we cannot feel them.

Your body resists the flow of current and most of this resistance is in the skin. By wetting your hand you can decrease your resistance and increase the current flow through the galvanometer. Two people holding hands together will have more resistance than one person, hence the flow of current will be less. Most batteries use two pairs of different metals in a circuit to produce current and an electrolyte solution to create piles of charge and thus a voltage. When the terminals of a battery are connected with a wire, this voltage produces current.
(Sources: Scifest and hhtp://www.exploratium.edu/snacks/hand_battery.html)

On 21 May 2003, Zapholo, Khwezi and I presented at the Research Methods and Interpretation course. To ensure that the other actors' *voices* were heard, we had consulted with them first. The participants at this course were very much impressed to witness such a capacity-building project for science teachers, and some wanted to know if the initiative could not be extended to other subjects such as mathematics. One participant at this course commented: "I like it because it is so real." Such a comment gave us an impression that it was critical for teachers to be in the forefront in finding and communicating solutions to their classroom problems. In their reflections, Zapholo and Khwezi commented that

> It was a learning experience to present to/in front of such an enthusiastic learned audience. The input made by the participants after our presentation enabled me to improve and modify my research proposal and related aspects. (Zapholo's reflections 23/05/03)

> The course has made me realise that education is a lifelong process and you always learn new things. (Khwezi's reflections 23/05/03)

From the two science teachers' comments, it is evident that presenting work at this course was an empowering learning experience. This suggests that teacher development takes place in many forms. Another spin-off of presenting at this course was that we were able to form a research sub-network, which was another form of division of labour as proposed by Hardman (2005). Our long-term mission, however, was to equip all network actors with research skills so that they too could be afforded opportunities to speak at conferences and at these courses. All these efforts were an attempt to shape our research project constantly and continually. I would like to caution readers, however, that engaging in this kind of research has no recipes. Instead, you learn as things evolve, and hence this research could be described as a transformative process.

Here, it could be said that our endeavours are in line with the socially critical-emancipatory orientation, central to which is emancipation and empowerment (see Section 4.2.1). In this study, the actors were empowered to learn to share knowledge and listen to each other's views.

Also, it was decided that we should embark on a fundraising mission so that actors could attend conferences. We agreed that each actor should contribute R20.00 every month towards attending conferences, and a small committee of three was appointed to oversee this process. The formation of such a sub-network was instrumental in further enhancing ownership of the project. It could be argued that this scheme was further evidence for the growing level of trust in the network.

On 31 July 2003, Zapholo took a leading role and did some practical activities on *electrostatics*, and shared his version of his unit of work which he had been able to modify through using actors' contributions. Also, at this workshop, Khwezi shared his modified Grade 12 physical science LPU that he had designed during the school holidays. Although some network actors were not teaching at Grade 12 level, they were encouraged to adapt the LPU to suit the grades they were teaching and they were happy to do that.

Another issue that was reiterated at this workshop was that we needed to think of strategies to encourage learners to ask questions in class. It was recognised, however, that learners' participation would be influenced by how practical activities were designed or organised. For example, in the ritualised teaching approaches, learners are required to follow recipes, with little room for them to ask questions. Yet, Edwards (2002) notes that questions are useful in enhancing understanding.

It should be borne in mind, that asking questions depends on how much knowledge has been acquired: if you happen to have limited knowledge in your subject area, how could you then encourage your learners to ask questions? Would you want your learners to ask questions you yourself might be unable to answer? And what is the best way to protect yourself from such an embarrassing situation? These questions have been raised here to illuminate the realities some teachers, in particular science teachers, are faced with in their school contexts, a situation which merits the teachers' professional development and support.

I was really pleased that we started the term on a high note and I was looking forward to more co-engagement by all network actors.

> The joy of engaging in research of this nature is that you find yourself continually thinking about how to make things work. However, I realised that one could be easily sidetracked ending up biting more than you can chew. That is, potentialities can easily be destructors and I had to try get focused. Furthermore, although I was pleased with the network's progress thus far, it became evident that the gestation period for this project was difficult to specify, and that was another source of my panic. (Research journal 9/05/03)

Thinking about how to make things work was a wonderful learning experience during this study. Furthermore, in an attempt to encourage actors to use optimally the resource file kept in my office, a photocopying card was bought so that actors would be able to photocopy resources. What would be ideal, though, would be to have a resource file in each of the four schools involved in this study. In addition to this, Zapholo made an offer; that actors could photocopy at his school at a reasonable cost. This offer was another indication of willingness on the part of actors to share the scarce resources.

On 28 August 2003, I celebrated my birthday in style. On this day in the afternoon, I went to do co-teaching and participatory observation together with Ngwenya at Matyana School. Zapholo taught an activity-based lesson on *electrostatics* to his Grade 9 class. Ngwenya videotaped the lesson while I took some photographs (see Box 6.5) and inbetween we both assisted the learners in their groups whenever they needed help.

This was a major breakthrough and highlight in this study since it is seldom that we see teachers doing co-teaching. What inspired me too about Zapholo's learners was that they were prepared to stay in the afternoon for the lesson. This suggests that if teachers could show some commitment towards teaching, the culture of learning can be restored among learners. Initially, Zapholo's learners looked surprised, as they were not used to seeing three teachers in their class, especially a Grade 8 science teacher (Ngwenya) and a stranger (myself). However, as the time went by they seemed relaxed.

Zapholo conducted the lesson in a very interactive manner. What would be interesting, though, would be when Zapholo and I do co-teaching with Ngwenya in the driving seat. It is recognised that this has to be carefully negotiated as power relations, (with Zapholo being an HoD at this school) might be an inhibitor.

Box 6.5: Activity-based teaching and learning: Teachers and learners in action

Teacher demonstrating and scaffolding learners on how to rub strips to get them charged.

Learnersactively involved in 'hands-on', 'minds-on' and 'words-on' practical activities.

Learners look fascinated by the strips that are charged.

Learners engage in discussions to make sense of concepts in electrostatics.

I found interacting with colleagues in a teaching and learning context very empowering and an eye-opener. It also became evident that teaching for understanding was a complex phenomenon.

> I must say, on this day, I experienced what Prawat and others refer to as a 'community of learning'. As the lesson progressed and learners were busy doing the practical activities, what I found to be inspiring was how Zapholo consolidated the key concepts to be developed on the chalkboard. I believe the notion of 'chalk and talk' has stigmatised the use and value of this resource as, in our quest for new ways of teaching which are claimed to be democratic and progressive, we should be warned not to swing too far with the pendulum and end up 'throwing the baby out with the bathwater'. It was also inspiring watching learners interacting in their various groups and how they attempted to discuss in English, which is a medium of instruction foreign to them. What I missed, however, was questions raised by the learners. It is my belief that during teaching and learning processes, teachers should encourage their learners to ask questions. (Research journal 28/08/03).

This suggests that, while it is good to embrace change, practitioners have to learn to be constructive and critical. What became evident on this day too was that in order to be able to encourage learners to engage in science talk, thorough and careful planning is essential. Encouraging teachers themselves to learn to talk science with their peers could further help. That was the contention of this study.

In our workshop held on 9 September 2003, Zapholo, Ngwenya and I reflected on the co-teaching and participatory observation that was conducted on 28 August 2003. Ngwenya and I noted that we were both impressed with how Zapholo used 'hands-on', 'minds-on' and 'words-on' practical activities to enhance conceptual development (Maselwa & Ngcoza 2003). Another of his strengths was ability to consolidate key concepts developed on the chalkboard. Our intention sharing this experience was to encourage other actors to come forward and do likewise.

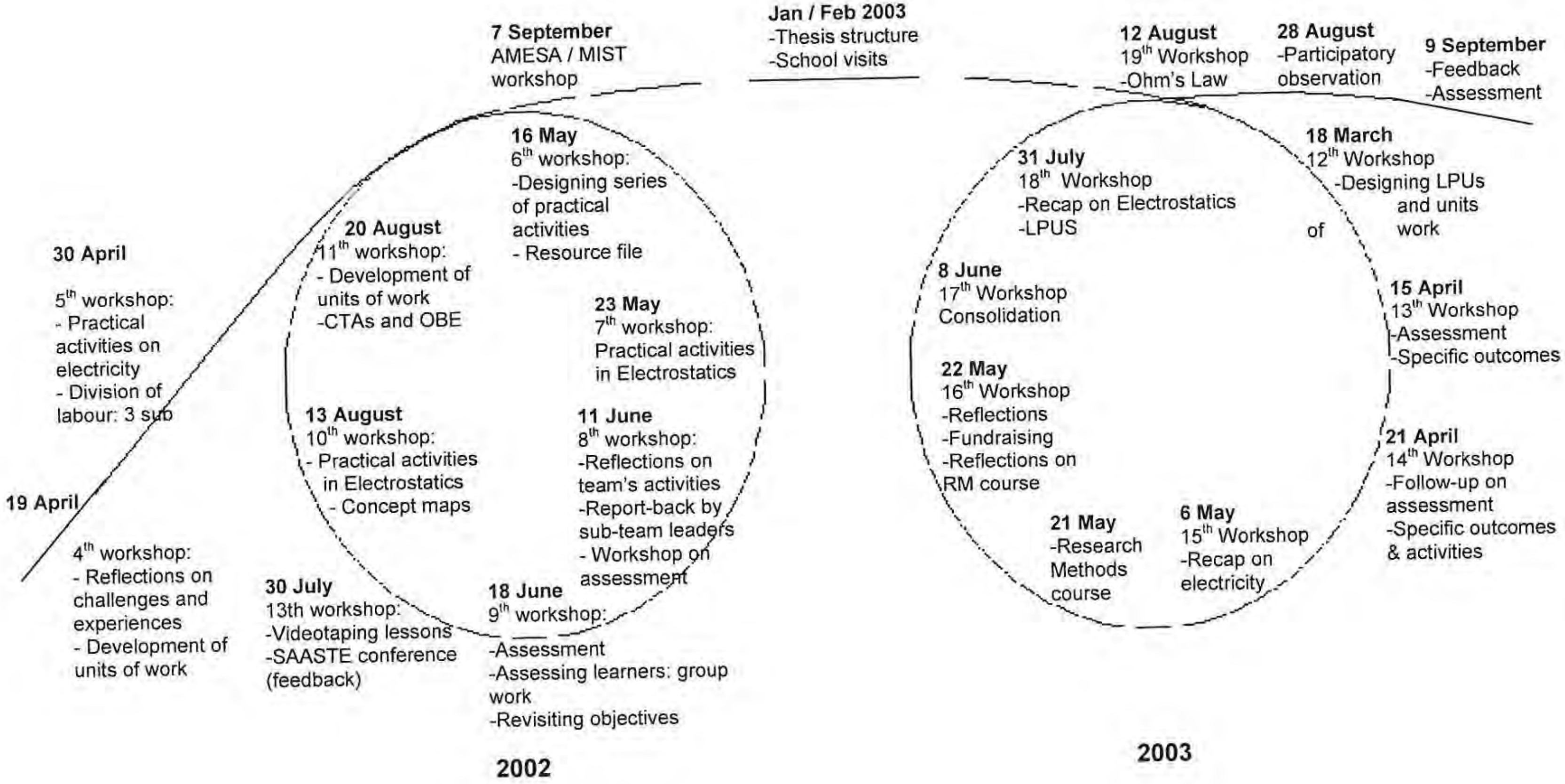
However, we recognised that it was already late in the year to implement this as actors were rushing to complete the syllabus at their schools. Another potential destructor was the OBE workshops teachers had to attend, something which interrupted our workshop schedule as well as the teaching and learning in schools.

All these had to be juggled for priority. What was useful, though, was that a head start had been made on putting theory into practice as reiterated by my supervisors.

After this workshop, Zapholo, Ngwenya and I agreed that we three would find time to watch the video on 11 September 2003 and we met as planned. The reflections on co-teaching and the video discussions proved to be a learning experience for all of us. Such collaborative reflections (see Section 3.5.1) were useful in encouraging thinking more of what teaching for understanding really entails. The next challenge would be to encourage other actors to engage with this strategy.

Our research network activities for the period 2002-2003 are presented as an iterative process as reflected in Figure 6.3 below.

Fig. 6.3: Diagram for expansive cycle 2: 2002 - 2003



In my end-of-year meeting with my supervisors they advised me to keep on reflecting on the following issues:

- What is your research interest/area? What triggered you to engage in this kind of research?
- Draw a mind-map of how you see your research project developing.
- What readings (literature search) do you think you need to better conceptualise your research study? Has the relevant literature been used to inform your study?
- Methodology: How do you hope to generate and analyse your data? How are you going to document the research process?

In addition to these, they advised me to start working on the framework for my thesis and conceptualise it into chapters. After this meeting, I felt really motivated and inspired to carry on with my research study.

In January to May 2004, I spent some time working on the structure on my thesis and mapping out the bigger picture, as my supervisors had advised me that a thematic approach would be useful in structuring it. I also revisited my methodology chapter, as I was preparing to interview network actors. What I found very useful during this period was visiting actors at their schools to find out what kind of support they needed and also to make appointments for the interviews.

As I had established a good rapport with the actors, I felt that the interviews needed to be conversational; as a result I opted to do active interviews with them. I thus had to put together a framework for the active interviews (see Appendix D). My supervisors also cautioned me that during these conversational interviews I still needed to assume a steering role while at the same time it was important for the teachers' *voices* to come through in the thesis.

6.3 Concluding remarks

In this chapter, the research process and development of the TTCPD network has been documented and presented so that the teachers' *voices* were foregrounded (see Chapter 6). Although the workshops were found to be a learning experience for all network actors, it emerged that teacher development occurred at different paces and to different degrees. As a result, this process took longer than had been anticipated. This suggests that teachers' professional development initiatives should be an ongoing process rather than once-off events. Likewise, it became evident that before teachers could take responsibility for their own professional development, they needed to be equipped with competences in their subject content knowledge so that they could confidently engage with and take leading roles in the TTCPD network.

The next chapter examines the experiences of the six science teachers at school and at teacher's colleges. The investigation of these science teachers' educational background was intended to provide insight into potential factors that could play a role in influencing their practice in teaching science. This was critical since teachers' professional knowledge is shaped by their own experience of schooling and how they have been socialised in the teaching profession: how teachers were taught at school and at teachers' colleges will invariably influence how they themselves teach.

You taught me
You taught me the names of the cities in the world

But
I don't know how to survive the streets in my own city.
You taught me the minerals that are in earth

But
I do not know how to prevent my world's destruction.
You taught me how to speak and write in three languages

But
I do not know how to say what I feel in my heart.
You taught me all about reproduction in rats

But
I don't know how to avoid pregnancy.
You taught me to solve mathematics problems

But
I still can't solve my own problems.
Yes, you taught me many facts, and thank you,
I'm quite clever

But
Why is it that I feel I know nothing?
Why do I feel I have to leave school to go and learn about coping in life?
(Author unknown)

The significance of this poem, in my view, is that the way learners are taught will influence how they cope in the world. In the context of this study, the actors' educational background could not be underestimated.

Chapter 7

Teachers' educational background: Data analysis and findings

> Partiality and subjectivity, however, are not the research and writing disadvantages that positivist empiricism proposes. Because knowledge is always partial, limited, and contextual, there is no escape from subjectivity. Subjectivity is constructed in specific contexts; it is not eternally fixed. As qualitative researchers, we can more easily write as situated, positioned authors, giving up, if we choose, our authority over the people we study, but not the responsibility of authorship of our texts.
>
> (Richardson, 1990:28)

7.1 Introduction

In this chapter, the experiences of the six science teachers at school and at teachers' colleges are outlined, keeping in mind that 'knowledge is always partial, limited and contested' as proposed in the epigraph. The investigation of these science teachers' educational background was intended to provide insight into potential factors that could play a role in influencing their practice in teaching (see Chapter 8).

In this study, this was critical since as Walker (1991) and Smyth (1996) state, teachers' professional knowledge (practice) is shaped by their own experience of schooling and how they have been socialised in the teaching profession: how teachers were taught at school and at teachers' colleges will invariably influence how they themselves teach (see Section 3.4.3).

Walker (*ibid*), for instance, argues that teachers who have internalised traditional schooling systems, dominated by patterns of transmission and rote learning, tend to put that into practice in their classrooms. Lack of genuine learning communities (Nespor 1994; Senge 1990) could exacerbate this. Equally important to know, though, is how some teachers strive to achieve a sound quality of teaching despite their educational background as well as the difficult contextual conditions they face at their schools.

This chapter focuses on the six science teachers' diverse educational backgrounds both at school (see Section 7.2) and at teachers' colleges (see Section 7.3). Some concluding remarks are provided to pull the information together.

The following questions were considered as an attempt to illuminate the teachers' underlying issues pertaining to their own educational background:

Does the way science was taught at school have an influence on the science teachers'

- subject-content knowledge?
- assumptions and beliefs about learning?

Does the way science was taught at the teachers' colleges have an influence on the science teachers'

- subject-content knowledge?
- Pedagogical-content knowledge?
- assumptions and beliefs about teaching and learning?

Answers to these questions have been interwoven throughout this chapter.

7.2 School science educational background

This section discusses the six science teachers' diverse school backgrounds in order to contextualise and give insight into professional development and the following themes emerged in this study: presentation of science, relevance of science, language of learning and teaching, gender issues and peer support.

7.2.1 Historical background

Zapholo, Ngwenya, Leo and Khwezi were scholars at Matyana Senior Secondary School, in Grahamstown, where both Zapholo and Ngwenya are currently teaching. Neon studied at Pioneer Senior Secondary School in Grahamstown, where he is also currently teaching; and Nomfundo studied in Port Elizabeth. This indicates that three out of six teachers in this study teach at their former schools.

Zapholo said that after passing Standard 8 (Grade 10) with good symbols he was advised by his former primary school principal to go to Healdtown Senior Secondary School near Fort Beaufort, which was well-equipped and regarded as a good school in science and mathematics that would expose Zapholo to more intensive and better science teaching than he would have at Matyana Senior Secondary School. This was intended to stimulate him to pursue science further. This suggests that some teachers do rate schools according to their quality of education.

The questions that come to my mind, though, are: If Healdtown Senior Secondary School was regarded as a school of excellence, what attempts were made by the Grahamstown community to raise the quality of education at Matyana Senior Secondary School to that level? What skills and competences do teachers need to ensure that there is quality education at their schools? How can changes in government policies be translated into quality education in schools? These questions have been posed in this text as an attempt to provide further insight into the school background of the six science teachers involved in this study.

Unlike Zapholo, Ngwenya and Khwezi did Physical Science up to Standard 10 (Grade 12) at Matyana Senior Secondary School. Zapholo taught them both, and they enjoyed the way he taught science. Also, what motivated them to do physical science was its practical nature; they regarded practical work as central to learning science.

Hodson (1990) makes the point that practical work is a means by which learners can understand abstract concepts. However, the value of practical might vary from context to context and may not always be a cornerstone of meaningful learning. Furthermore, he contends that practical work is often done only because it is less boring rather than being an alternative way to learn.

Here, Neon said that his class was taught physical science by a biology teacher who did not do any practical work with them. Their teacher was evidently unqualified to teach physical science, which tended to weaken the teacher - learner interaction. However, that did not discourage him from pursuing physical science.

Leo indicated that she developed an interest in science at primary school and continued with it at high school level, at Matyana Senior Secondary School. No doubt other learners would benefit as she did by getting a solid basis in primary school to sustain their enthusiasm for science in the higher grades. However, due to the unrest at Matyana Senior Secondary School in 1975, she could only do physical science up to Standard 8 (Grade 10). Subsequently, she wrote matric as a private candidate, and she replaced physical science with biology.

Unlike Leo, Nomfundo declared that when she was at school she did not have much interest in science. Instead, she liked mathematics, since her brother helped her with it. As a result of her attitude towards physical science, she ended up doing it only up to Standard 9 (Grade 11). This decision was strengthened by the fact that her friends also convinced her that physical science was difficult; they influenced her to drop it and do history instead. Like Leo, she also did biology up to Standard 10 (Grade 12). In contrast to Nomfundo, Khwezi mentioned that when he was at school he enjoyed physical science more than mathematics.

The heterogeneity of teachers in this study is thus reflected in many ways (see Section 4.2.2). Of special concern to me, Leo and Nomfundo are examples of the most disadvantaged science teachers in this study since they both did physical science only up to Grade 11. It could be argued that they are likely to have gaps in their subject-content knowledge. Furthermore, they reported that when they were at the teachers' college they did subjects with little in-depth science-content knowledge (see Section 7.3) - yet they had to teach science at their school. But how could such science teachers strive to close the gaps in their subject-content knowledge?

In such circumstances, it is advisable that teachers should try to collaborate and support one another, as documented in Chapter 6 of this thesis. Unfortunately, from my own experience when I was a teacher, this did not happen in my school. Possibly, my assumption is, some teachers might be afraid to be seen as not knowledgeable in their subject areas. In light of this, I would contend that there is a need for teacher development opportunities to enable teachers to cope with their work. Fullan and Hargreaves (1992) also say that teacher development should aim at enabling teachers to take responsibility for their own intellectual and professional growth.

The six science teachers' school historical background discussed in this section sheds light on the importance of understanding factors influencing the heterogeneity of actors in a network. Such understanding, in my view, could be of great help to the professional developers to use such baseline data for their professional development initiatives.

7.2.2 Presentation of science

At Matyana Senior Secondary School, Zapholo, Ngwenya and Khwezi indicated that they were taught by good, experienced, and knowledgeable science teachers who explained the scientific concepts in an enthusiastic manner. As a result they found science interesting. Unlike Zapholo, Ngwenya and Khwezi both said that what made physical science exciting for them was the fact that their science teachers did practical work and demonstrations with them.

In contrast, Neon indicated that his class was most unfortunate at Pioneer Senior Secondary School in that they had no physical science teacher in Grade 11 until late in the year. A biology teacher taught them and she focused mainly on theory. Even though science equipment was available at their school, they did not get an opportunity to do either practical work or demonstrations. From Neon's account, it could be deduced that their teacher was not familiar with the science equipment.

Such a teacher is likely to transmit knowledge to learners with little or superficial focus on conceptual development.

In this study Khwezi indicated that his class did practical work in groups so that they could help one another. From my own experience, however, in most cases teachers tend to use group work so that learners can share the scarce resources rather than for purposes of helping one another. Yet, in my experience, group work (if planned properly) could afford learners opportunities to co-construct understanding of knowledge. It is recognised, however, that if a science teacher is not knowledgeable in the subject, there is the danger that learners could agree on incorrect conceptual explanations. It is for this reason that a teacher's intervention is important for ensuring that correct scientific concepts are learnt.

What Khwezi also found interesting and said would remain indelible in his mind was discussions and giving report-back in class. Through such discussions, he explained, they were afforded opportunities to make sense collectively of what was taught. It seems that the teacher - learner interaction was healthy at Khwezi's school; this was reflected in their science teacher's ability to encourage them to ask questions in class. From my own experience as a teacher educator, encouraging learners to ask questions seems to be a challenge for some science teachers.

Inability to ask challenging questions as well as to encourage their learners to ask questions might be, in my view, exacerbated by both the limited SCK and PCK, as Sherin (2002) says. I would contend that a balanced combination of SCK and PCK might have a greater potential to result in effective teaching and learning.

In retrospect, however, when I asked how Ngwenya found the way science was taught at his school, his response was:

> At high school we solely depended on our science teacher for everything. He did experiments for us and we used to watch him. It was unlike today, the teacher did everything. Also, due to the shortage of equipment we were not given an opportunity to handle apparatus. So, it was only the teacher who handled science apparatus during the demonstration lessons. (Active interview 4/05/04)

From Ngwenya's comment, it is clear that the fact that their science teacher relied on doing demonstrations unfortunately resulted in him being the only source of information; and although the demonstrations that they did with their science teacher were useful, these deprived the learners of opportunities to handle science apparatus. As such, demonstrations were used only as a means to illustrate scientific concepts (Gott & Duggan, 1996).

Yet, the overriding importance of teacher - learner interaction during practical activities could be enhanced by allowing learners to discuss alternative experimental designs. In this way, learners could be afforded opportunities to determine the direction of the inquiry: internalise and personalise the experience. Furthermore, during such demonstrations learners could observe the scientific phenomena rather than just 'watching'. Meaningful learning could further be enhanced through encouraging them to make predictions, preferably in writing, which would improve both their writing and investigative skills.

Failure to involve learners actively might be problematic: they might end up being merely passive receivers of information given by the teacher. For example, Ngwenya said that he and his class would have loved to do experiments themselves, since their thinking was that if you do something yourself, you would understand it much better than when it is done by someone else. It is recognised, however, that limited physical resources proved to be a barrier.

What was an advantage though, Ngwenya indicated, was the fact that there were a smaller number of learners than usual in their class. As a result their science teacher was able to give them individual attention whenever they did not understand. This reminds us that the number of learners in class can have a negative impact on teaching and learning. However, I would like to point out that in some cases it is possible to find that there are fewer learners in class, yet the results might not reflect that potential advantage. This happens particularly when teachers are not committed and knowledgeable in the subject area, hence affecting their conceptual negotiation and mutual projection. Conceptual negotiation encompasses co-construction of meaning making. Mutual projection is a term given for the process whereby learners' ideas are taken seriously, and converging from learner prior experience towards scientifically accepted concepts (Reiner & Gilbert, 2004).

In hindsight, it appears that Ngwenya's science teacher used group work not to encourage discussions among learners, but because of the shortage of science equipment. Yet when learners are working in groups or are guided through questions, they have the benefit of having to communicate their internal ideas in order to share them with other learners. Ngwenya did say that their science teacher tried his best to make science interesting; this led to him pursuing the subject at the teachers' college.

In contrast, Zapholo, Leo, Nomfundo and Neon reported that their science teachers did neither practical work nor science demonstrations with them when they were at school. As a result, they felt that they were deprived of opportunities to experience science hands-on. The focus was mainly on theory instead; and they had to write notes from the chalkboard most of the time. As a result, they had to learn through rote learning and memorising at the expense of transformative learning (see Section 3.1), something which subsequently resulted in their lack of conceptual understanding and development.

In such circumstances, it could be argued, the centre of gravity (Zion & Slezak, 2005) was more towards their science teacher. This is also referred to as teacher-centredness. Consequently, some of them found science boring. Nomfundo commented:

> Science at school was too much theory and there was very little practical work done. As far as I am concerned, what makes science interesting is the practical work. So, if you do not do practical work, science becomes boring. Also, there was this attitude that girls cannot do science. If you did science being a girl, other learners saw you, as someone who thinks she is clever. (Active interview 3/08/04)

From her comment, it is clear that Nomfundo seems to be convinced that practical work is essential for making science exciting. It should, however, be borne in mind that whilst science can be made more exciting through practical work this might not guarantee that learning will take place: practical work should not be seen as a panacea. Instead, it should be viewed as one strategy, in addition to others, for enhancing learning.

Furthermore, the teacher - learner interaction during practical work is one of the most important factors determining its value. By letting the activity and its development grow from the goals, knowledge and reasoning of learners, they might gain confidence in owning the knowledge. This suggests that a teacher's role is critical in teaching and learning repertoires and that person is expected to provide guidelines and a framework for the inquiry as well as actively assessing the process and learners' participation and involvement. Similarly, Leo commented:

> At high school, science was not interesting because our science teacher was a 'know it all'. And so most of the time he used to make us write notes on the chalkboard, but there was very little time for practical work. So, I would say we did science theoretically and he used to just come and give us notes written on the transparencies for the overhead projector, and would go and sit and do his own things in a nearby room. I don't know whether he was studying or not. (Active interview 7/04/04)

From Leo's comments, it seems their science teacher was the only source of knowledge, which he transmitted to them in the form of notes. Rather than explaining the notes to them, he would do his own things. Referring to their science teacher as a 'know it all' does not suggest that he was an authority in the subject, but rather that he deprived them of opportunities to co-construct their understanding of knowledge.

She indicated that the class would have preferred to be taught science in interactive ways rather than relying on writing notes all the time, which would have given them an opportunity to be actively engaged in the co-construction of knowledge. To me, teachers should be knowledgeable in their subject areas so that they can encourage learners to co-construct their understanding of knowledge. Otherwise, science may not be presented as unconnected facts. Likewise, Zapholo commented:

> I remember our science teacher had a note book and every time he came to teach us he would come to class having his notebook and I remember one day we stole his notebook, and he said to us, "I won't teach you *makwedini*, where is my notebook?" And later we discovered that his notes were actually notes from a previous child he had taught. (Active interview 16/03/05)

This suggests that Zapholo's science teacher used the same notes repeatedly without doing any modifications on them to suit his learners' diverse learning needs. However, it seems such a strategy did not retard learning among some of the learners. For example, Zapholo explained that although they had a room called a laboratory with scant science apparatus, their science teacher did his level best without the science apparatus. Furthermore, despite the fact that their science teacher transmitted the science knowledge to them and wrote notes from his notebook most of the time, they still enjoyed the way he taught science. This suggests that it is possible for learning to take place if teachers prepare very well even if practical work has not been done.

Interest in science was further evidenced by the fact that Zapholo and another learner displayed their curiosity and enthusiasm by making a 'ripple tank' as a mediating learning tool (Vygoysky, 1978) so that they could see the waves. This shows that they were determined to experience science first hand. And according to Zapholo, that ripple tank was the only piece of apparatus available in their school science laboratory then. To me, this shows that given an environment conducive to learning, learners can be enthusiastic and creative in science.

According to Zion and Slezak (2005), practical work redistributes the responsibility for learning to learners in order for them to become active participants in the construction of their own understanding of scientific phenomena. However, this does not imply that practical work amounts to unguided discovery on the part of learners and passive looking on the part of the teacher. Rather, teachers are required to take an active role in guiding and scaffolding their learners.

Nonetheless, all these four science teachers believe that science would have been exciting if they had been given opportunities to do practical work themselves rather than learning it theoretically. From my own experience as a teacher educator too, for meaningful learning to take place during practical activities, this work has to be thoroughly planned and organised, with the key concepts to be developed clearly identified; otherwise, engaging learners in practical activities can be a futile exercise.

Hodson's (1990) critique of uncritical advocacy of practical work is concerned precisely with this point. He describes practical work as often being poorly thought through and presented disjoint from theory. He notes that practical work in most schools is unproductive since it is prescriptive and presented as a 'cookbook', where learners have to follow the teacher's instructions in learning the scientific facts. Such practical work thus results in very little learning taking place.

To Hodson (*ibid*), this is made worse because most teachers use practical work unthinkingly. Wilson and Stensvold (1991:351) support this view and observe "In a laboratory experience, students can do an experiment and not develop meaningful comprehension of their findings." In my view, this could also be due to the limited subject-content knowledge some teachers might have. From a South African perspective, however, even if the practical work done in schools is prescriptive, I feel it is better than no practical work at all.

I would caution readers that during 'hands-on' practical activities the emphasis should be both on understanding and development of scientific concepts. Also, the key concepts to be developed should be shown pictorially using aids such as concept maps to show how concepts link to one another. Furthermore, since teaching, learning and assessment are inextricably linked, teachers have to know how meaningful learning will be enhanced and assessed during the practical activities. This view is implied by Bodner (1986), who says that that you can teach well with little or no learning taking place. To this end, Gott and Duggan (1996) note too that practical work has a key role in the teaching of evidence provided that the type of practical work is selected carefully with a clear purpose.

Here, Nott and Wellington (1996) refer to the science knowledge that school science teachers possess as a 'black box' since those teachers all too often tend to treat science facts as unproblematic. In such circumstances, it could also be argued that probably most practical work has not contributed significantly to the expansion of learner knowledge of scientific concepts. The writers thus believe that the various approaches to practical work create tensions in the science-teaching community. Furthermore, the persistent emphasis upon the utility of and justification for practical work might conceal the diversity of actual functions of learners and teachers during practical work and therefore might hinder development of a better understanding of the role of practical work in learning *of* and *about* science.

Gott and Duggan (1996) thus propose that practical work should be selected with a clear purpose in mind; otherwise it will not be productive. Furthermore, Hodson (1990) believes that science is exciting if learners are allowed to pursue their own investigations in their own ways, rather than investigating the teacher's problem as is currently happening in most schools in South Africa. In this study, for example, Zapholo has had an opportunity to compare and contrast schools during his school days, and has learnt from this.

In contrast to his experience at Matyana Senior Secondary School, he reported that their science teacher at Healdtown Senior Secondary School did not do any practical work with them either although the science equipment was available. That is, the scope provided by the science equipment was not utilised. The teacher only did a demonstration in electricity, which most probably was his favourite topic in science.

This shows that having science equipment does not guarantee that practical work will be done; teachers themselves might lack the skills to handle the equipment (see Chapter 8). This is true for improvisation skills as well, alluded to earlier on. For instance, how are teachers who are not knowledgeable in their subject area expected to do improvisation? What will they improvise?

Zapholo's other frustration was that their science teacher used to tell them that there were four equations of motion; and he would then write those on the chalkboard without any explanation. This suggests that the chalkboard was not effectively used in the way Czerniewicz *et al.* (2003) propose. The fact that their science teacher could not explain these equations to his learners meant that he restricted their knowledge capacity instead of expanding it. The question that comes to my mind is: Was this probably the way their science teacher was taught at school, teachers' college or university?

Similarly, for Neon, the science teacher who took over from their teacher could not do any practical work with them either as he was under pressure to complete the syllabus, which resulted in them writing notes most of the time. Also, they had to focus on revising examination papers. This too shows that the focus, especially at Grade 12 level, is mainly on finishing the syllabus at the expense of learning for understanding. This pressure at Grade 12 level, I would suggest, needs to be offset by a solid grounding in the lower classes.

On a positive note, Khwezi explained that what contributed to his understanding in science was the opportunity to attend extra classes organised in the afternoons by the Grahamstown Area Distress Relief Association (GADRA) Educational Welfare. In addition to learning subject-content knowledge, during such classes, they were also equipped with computer skills. This suggests that learners need to spend time on finding more information even after school hours.

In my view, willingness on the part of Khwezi's class to attend extra lessons suggests that they were prepared to run the extra mile and take responsibility for their own learning. Most probably, their engagement in such an initiative might have encouraged their science teacher to read more and more too, so that he could be open-minded on the lines suggested by Dewey (1933) in the literature reviewed in this thesis (see Section 3.5.1).

It is recognised, however, that in order for schools to have a sound quality of education, both human and physical resources are essential. In this study, the artefacts were in the form of LTSMs which were adapted and developed as an attempt to shift from relying only on the prescribed school textbooks.

On textbooks, Leo explained that although they had enough of them at their school, they struggled to use them effectively on their own; the scientific concepts, needed to be explained by a more knowledgeable person, in this case, their science teacher. The dense scientific language in which their science textbooks were written proved to be an inhibitor rather than enabling meaningful learning, yet their science teacher never bothered to explain or simplify these difficult concepts. This experience further compounded Leo's perception that science was difficult.

Unlike Leo, however, who indicated that they found textbooks difficult to read, Neon said that at his school they had enough science textbooks and they were able to study on their own, individually and in groups. This shows that when the culture of learning is there and learners are capable of supporting one another, learning certainly can take place.

7.2.3 Relevance of science

All six science teachers said that science at their schools was presented as something that was in the textbook and in the laboratory in some schools, rather than something that exists in the learners' everyday lives: the framing of scientific problems was decontextualised and restricted within the four walls of the classroom.

According to Smit (1998), Malcolm and Smith (1998), Kasanda, Gaoseb and Lubben (2002) and Stears *et al.* (2003), linking science to the learners' everyday lives can promote deeper engagement with the content, given that the everyday experiences of learners that science education has to relate to are widely diverse. According to Smit (1998), the term 'relevance' has been used as a vehicle to drive reform and transformation in science education in South Africa so that as he observes, the reality of the developing country context has an influence on what is considered to be relevant to learners.

From my own experience as a science teacher, lack of recognition of learners' everyday knowledge might retard meaningful learning and further insights. Here, Jegede (1997:4) notes, "School science should arise from first-hand experience and project genuineness about what science really is." Furthermore, taking learners' prior everyday life experiences into consideration in teaching and learning repertoires could also enhance the dynamic and innovative interaction between learners and the teacher (see Box 6.3).

It is this space, I believe, where teaching and learning could be transformed away from a fragmented and confused regurgitation of facts towards meaningful learning. As a warning, Murphy, Beggs, Carlisle and Greenwood (2004) point out that the decontextualisation of school science is exacerbated by an over-emphasis on the content isolated from the contexts that could provide relevance and meaning.

The approaches adopted by the four science teachers' teachers in this study seem to be inconsistent with the constructivist approaches to teaching and learning whereby learners are encouraged to be actively involved in the construction of understanding of knowledge during the lessons (Bencze, 2000; Moll, 2002). Bencze (2000), however, cautions us that, under the guise of constructivist teaching, some teachers tend to engineer learners' construction of knowledge.

In this section, the six science teachers' experiences at school have been compared and contrasted. It became evident that those teachers who were taught science in interactive ways through practical work and demonstrations found the subject to be interesting even though the level and depth of conceptual understanding could not be ascertained. In contrast, however, some of those science teachers who were taught science theoretically found it boring; and some enjoyed it despite that.

I would contend that teachers ought to strive to be knowledgeable in both their subject-content knowledge and pedagogical-content knowledge as emphasised in the literature reviewed in this thesis (see Section 3.3.1). It is recognised, however, that without the provision of learning opportunities teachers will continue struggling being effective agents of change (see Section 3.4.2).

7.2.4 The science teachers' experiences of the language of learning and teaching

Zapholo reported that, although English was the medium of instruction at his school, they were taught mathematics in Afrikaans by an Afrikaans-speaking teacher who struggled to explain concepts in English. In fact, in his educational network scenario there were three languages involved: *isiXhosa* (learners' language), English (medium of instruction, which was a second language to both the science teachers and the learners) and Afrikaans (teacher's language and learners' third language). In essence, the teaching and learning was done in a cross-cultural context (Kato, 2001:53) in which language proved to be a barrier for effective learning.

In such circumstances, the learners were forced to do rote learning without any understanding. Here, Burkett *et al.* (2001) and Probyn (2004) propose that there is a need for an understanding of the role of language in a multilingual education context and this could be an area for future research. For example, Ngwenya, Leo, Nomfundo and Khwezi indicated that, although English was the medium of instruction, since they were taught science by *isiXhosa* speaking teachers they did a lot of code-switching. In contrast, Neon indicated that his school was at an advantage in that an English-speaking teacher taught them science. This, he said, helped to improve their language proficiency as well.

7.2.5 Gender issues emerging from the study

Of the six science teachers, two mentioned that they experienced gender problems, Leo indicated that when their science teacher did a demonstration he would do it alone and the girls would simply watch, but the boys could participate: he favoured boys and relegated the girls to an observing role. As a result of this, she reported, that she ended up developing a negative attitude towards science. Evidently the teacher had no connection as Law (1986) says that, assigning active roles to actors enhances learning and co-ownership.

Leo and Nomfundo both said that they found gender stereotypes very discouraging for girls pursuing science at their schools. They indicated that their male science teachers promoted the gender stereotype that science was not meant for girls (McLarren & Gaskell, 1995; Baker, 1998). To make matters worse, in some instances there were even 'put downs' and gender stereotypes by the other learners at school. Such peer pressure could have a huge negative impact on other learners. For example, from my experience as a science teacher, learners tend to laugh at other learners when they give 'wrong' answers in class or construct English sentences incorrectly, so that some learners become reluctant to take part in the lessons.

As a possible solution, I suggest that there is a need to encourage female teachers to teach science in schools (role models) so that science is not seen as a male thing. Harding (1996), Baker (1998) and Mannathoko (1999) agree, arguing that gender-inclusive environments need to be created so that girls can participate in the science classes. At present there is no indication that the main thing is for teachers to learn to drop their gender prejudices. I continue to believe that in contexts in which the science teacher's expectations are positive, girls can work positively. However, from my own experience as a learner, some female teachers tended to favour boys over girls.

As a result of their science teachers' negative attitude, particularly his insensitivity to gender issues, Leo intimated that she could describe him as a self-centred teacher. It is recognised, however, that this was the context of that time. She further indicated that girls were also scared to ask him questions when they did not understand. If learners are deprived of opportunities to ask questions, how can they be expected to make sense of what they are learning? Too often, when learners are not asking questions in class, especially in historically disadvantaged schools, is attributed to the influences of culture. Yet, in the case of Leo's science teacher, he did not make an effort to encourage them to ask questions.

Teachers should actively strive to create environments that are conducive for learners to learn, irrespective of their gender. I would suggest that equal opportunities to learn should be created for girls and boys, and gender-related issues should be one of the priorities in teachers' professional development initiatives; this is a potential area for future research.

7.2.6 Learners' peer mutual support

Zapholo, Ngwenya, Neon and Khwezi commented that what helped them when they were at school was that they mobilised one another and formed study groups as a support system. During their group discussions, those learners who were knowledgeable in science would volunteer to explain the scientific concepts. This suggests that the culture of learning and peer support was there and the learners realised that they were invaluable human resources for each other. Nespor (1994) makes the point that knowledge-constitutive activities (Lave & Wenger, 1991) can enhance learning among learners.

Lending support, Shapiro and Livingstone (2000) say that research has shown that the most successful learners are those who have a propensity to control their own effort to learn; from that we could generalise to say that learners who are willing to take personal responsibility for regulating the way in which to approach their studies are likely to succeed. Zapholo indicated that through such peer support he was able to pass physical science in Standard 10 (Grade 12), albeit with poor results.

In contrast, it seems Nomfundo and Leo did not make an effort to form study groups in order to improve their scientific knowledge. In hindsight, they would agree with Ngwenya, who believes from his own experience that when your peer explains something, you tend to understand it much better than when a teacher explains. I concur and in fact I would like to add that the advantage of such peer mutual support is that the explanations are usually given in a language that is understood by the peers. This is just one reason why it is very important for peers or colleagues to help one another.

Southwood (2000) and Spanneberg and Brown (2003) support this view believing that through peer mutual support, individuals have an opportunity to share ideas and knowledge. For learners, it seems peer mutual support does not seem to be a problem. For teachers, however, it is another matter, which is mainly why a TTCPD network (see Chapter6) was promoted in this study.

7.3 The science teachers' college educational background

This section addresses the six science teachers' professional background at the different teachers' colleges, examines the historical background, teaching approaches, planning of work, peer mutual support among student teachers, and teaching practice. This bigger picture is included to inform the reader about the variations in professional education experienced by the science teachers involved in this study. I believe that understanding of such background could be useful in conceptualising professional development initiatives for teachers.

7.3.1 Historical background

Zapholo reported that he was accepted at Lovedale Teachers' College, where he did a two-year course known as the Junior Secondary Teacher's Certificate (JSTC), specialising in mathematics and general science (what is called natural sciences today). Due to his poor matric science results, he said he was initially admitted to specialise in languages instead of science which he would have preferred. In any event, he had excelled in *isiXhosa* (mother tongue), English (second language) and Afrikaans (third language). To his surprise, when his former Healdtown Senior Secondary School principal, who apparently knew his capability in science at school level and who was now at Lovedale Teachers' College, saw him in the languages class, he instructed him to attend the science stream despite his poor science results.

Similarly, after passing Standard 10, Ngwenya, Khwezi, and Neon said that they did a teacher's course at the Cape College of Education in Fort Beaufort. Like Zapholo, Ngwenya also did the JSTC, specialising in mathematics and general science as well, a professional qualification which meant that they could teach these subjects (now called Learning Areas in the new curriculum in South Africa) to the end of Grade 9. They could be described as junior school science and mathematics teachers.

Unlike Zapholo and Ngwenya, Khwezi, Neon, Leo and Nomfundo did a three-year Senior Teachers' Diploma (STD). Khwezi and Neon did the STD at the Cape Teachers' College and specialised in mathematics and physical science. This professional qualification meant that they could both teach these subjects to the end of Grade 12.

Leo and Nomfundo, however, did a civil engineering course at Algoa Technical College in Port Elizabeth, specialising in mathematics, building science and technical drawing. They mentioned that although the entrance requirements to do the course were Grade 12 physical science and mathematics, they were accepted despite the fact that they did not meet the requirements.

It is thus evident that three out of the six teachers were accepted to do the course even though they did not qualify. In my view, it could be argued that quality was compromised at an expense of quantity (number of students registered to do the course). However, what is not clear is how such lowering of standards was compensated for to ensure that there was quality standard of education. I would contend, therefore, that there is a strong case for professional development when such teachers are in the field. Of course, this does not mean that those who qualified to do the course do not need professional development too.

Leo and Nomfundo also said that most of the students doing the civil engineering course were females although it was traditionally meant for males. They reported that the male students in their class used to look at them as being fragile especially when they were working in the workshop. Baker (1998) suggests that there is need for a climate that supports and encourages rather than isolating and discouraging women; he believes that females can perform as well if given the same opportunities as males. In the case of Leo and Nomfundo, although gender stereotypes were institutionalised at their teachers' college, they managed to make a breakthrough by doing this course.

They both reflected that their science course was only basic and one of its weaknesses was that it had no chemistry; yet in the school science syllabus, physical science is a combination of physics and chemistry. Also, they described their course as mostly physics calculations. Nonetheless, Nomfundo indicated that her strong mathematics background paid dividends. In the third year, however, they did what is called strength and materials in the place of science.

My concern is, did this course sufficiently equip Leo and Nomfundo to teach science up to Grade 12? Would it be better for them to teach technical subjects rather than traditional school subjects? Realistically, to what extent would they be able to transfer the skills they acquired from such a technical course to the school situation?

Of interest too is that Zapholo, Ngwenya, Leo and Neon all stated that they never wished to become teachers. Both Zapholo and Ngwenya wanted to be medical doctors. Leo said she had a passion for nursing. And lastly, Neon indicated that he initially wanted to do electrical engineering at a Technikon. When he could not get a place at the Technikon, his brother advised him to go to the Cape Teachers' College to do STD as a second option. Worth mentioning is that his brother was a qualified teacher himself, but was never in a classroom environment. Instead, he opted to be a businessman.

It thus emerged that four out of six teachers did not want to become teachers. However, to me, what is inspiring about these four teachers is that at least they all aspired to pursue diverse science fields rather than humanities. Nonetheless, due to the inequalities of the past education system in South Africa, having teachers pursuing the teaching profession as a second or even a third option is one of the realities.

This revelation makes one wonder how many teachers in the field have taken this profession as an alternative rather than a 'calling'. I also wonder what impact this could have on teachers' dedication and commitment. What implication does this have for teachers' professional development? Can teachers' professional development be 'a one size fit all' (Locks-Horsley *et al.* 2003)?

7.3.2 Teaching approaches

Zapholo reported that at Lovedale Teachers' College the emphasis was on the textbook method with a focus on theory; their science lecturers, in particular, read the textbook and merely explained the terms - without doing any practical work even though equipment was available. This is worrying to hear, especially at this level of education. This routine resulted in the emergent teachers lacking skills and confidence to handle science equipment.

As a result of the approaches at the teachers' college, these graduates thus believed that the only way of imparting knowledge was the way their lecturers had explained things to them: stand in front of the class and talk. The class, in turn, would listen and write down notes. Being subjected to that kind of learning for two solid years, Zapholo believes, meant that these approaches gradually got into their veins and they were, indeed, determined to emulate some of their lecturers.

Walker (1991) and Smyth (1996) recognised this pattern and note that how teachers have been socialised in the teaching profession shapes their professional knowledge: teachers who have internalised the traditional schooling system, dominated by patterns of transmission and rote learning, tend to put that into practice in their classrooms. I would caution readers, however, that we should not think of traditional approaches as all bad. Rather, while we embrace the new proposed approaches to teaching and learning, we should take what is good from the past.

In contrast to Zapholo's experiences, Ngwenya, Khwezi, Neon, Leo and Nomfundo reported that science was taught differently at their teachers' college in that the emphasis was on doing practical work. They were also given opportunities to handle apparatus during the practical work. As a result of this exposure, they found science very interesting. In addition, Neon indicated that they were also allowed to do experiments on their own. He also commented that what he found particulary helpful during practical work was that they used to have pre-experiment time when their lecturer would explain to them what they were supposed to do. In essence, the fact that they had sufficient science equipment at the college that they were exposed to proved to be a motivational factor.

Nonetheless, all these five science teachers indicated that their lecturers also transmitted knowledge at times. Khwezi commented:

> There was an emphasis on doing practical work, but also our lecturers used the 'chalk and talk' and the question-and-answer methods a lot. (Active interview 20/04/04)

From Khwezi's remark, it is evident that their lecturers used a combination of methods. However, he indicated that he found his solid high-school science foundation very helpful. It would be interesting to know to what extent their lecturers were able to promote conceptual understanding and development during these courses.

Leo and Nomfundo also pointed out that, although they had 'good' lecturers at the college, they did experience some language problems since some of their lecturers were Afrikaans speakers who struggled to explain concepts in English. Zapholo also shared such an experience. In retrospect, the fact that the students were also second and third speakers of English and Afrikaans respectively exacerbated this: language can retard meaningful learning. According to Schoultz and Hultman (2004), language is an important mediating tool for creating understanding and for being understood, a view echoed by Vygotsky (1978). Thus, scholars such as Ovando and Collier (1998), Burkett *et al.* (2001), Hendricks (2003) and Probyn (2004) emphasise that language plays a vital role during teaching and learning. This is a clear area for further research.

In contrast to the other five science teachers, Ngwenya commented that what contributed to his science subject-content knowledge while at the college was that they did some science degree courses through the University of South Africa (UNISA). However, striking the balance between his specialisation and main courses and the UNISA courses was a daunting task. The irony though, is that Ngwenya has never taught science up to Grade 12 despite the fact that he did some degree courses. Nonetheless, according to Kallery and Psillos (2001) and Sherin (2002), irrespective of what grades they teach, it is very important for teachers to strive to improve their subject-content knowledge since it affects the teachers' pedagogical-content knowledge.

In their second year, Zapholo said, they were lucky to have another science lecturer who exposed them to doing practical work. It was then that they learnt that science equipment was available at the college, locked up in a back room. As part of the course, their new lecturer also took them to the University of Fort Hare to do practical work and demonstrations. Zapholo commented that it was then that he started to enjoy science. Here, I would caution that the fact that Zapholo enjoyed science does not necessarily translate into meaningful learning. Nott and Wellington (1996:808) point out:

> Laboratories have two main functions: the creation and re-creation of scientific knowledge and scientific methods. The creation of scientific knowledge involves research and investigation, which in school science have often been a form of naïve inductivism. The re-creation of scientific knowledge is both an indoctrination into the correct procedures and a verification of the accepted canon of knowledge.

These different functions of practical work thus create tensions in the science teaching community. Hodson (1990), Gott and Duggan (1996) and Nott and Wellington (1996) also warn us that when practical work is ill-defined it might provide very little educational value for the students.

7.3.3 Planning of work

On planning of work, the six science teachers indicated that the emphasis was on a textbook. They were also required to do clearly structured lesson plans with clear objectives, an introduction, and a set of steps to be followed throughout the lesson, as well as a conclusion. As part of the introduction they were required to indicate how they were going to ascertain what the learners' prior knowledge was; and the conclusion had to link with the introduction. As far as the introduction was concerned, they had to have ready-made questions that they intended asking the learners: the question and answer method was promoted and encouraged.

Eliciting learners' prior knowledge before proceeding with the lesson is critical, in my view, since some learners come to class with many preconceived ideas. However, how to incorporate such prior knowledge into the teacher's completely pre-planned lessons is a challenge. People talk about the importance of eliciting learners' prior knowledge, yet in most cases nothing is done with that knowledge.

Roschelle (1995) and Bencze (2000) warn that learners' prior knowledge might be at odds with the material presented by the teacher. They suggest that teachers should see prior knowledge as providing flexible building blocks. What frustrated Khwezi, however, was that at the college they were not allowed to deviate from their planned lesson. They had to stick to the lesson plan, rigidly following the steps as planned. It could be argued that they were not encouraged to be reflective and reflexive as discussed in Section 3.5 in this thesis.

Yet, Zeichner and Liston (1996) note that viewing teachers as reflective practitioners assumes that they can solve problems related to their educational practices themselves (see Section 3.5.1). Thus, as far as they are concerned the notion of reflective practice needs to be part of teachers' professional development. However, Bleakley (1999) warns us that the notion of reflective practice is in danger of being adopted without rigorous interrogation, resulting in it being understood only superficially. I would add that a solid knowledge base could be useful for reflective practice.

Also, one of the criticisms that Khwezi made was that at the college they were never exposed to doing research so that they could integrate it into their teaching and learning repertoires. I, too, believe that teaching, learning, assessment and research are inextricably linked. Neglecting one of these aspects could result in an incomplete practitioner.

On practical work planning, Ngwenya indicated that they were required to do demonstrations for the learners first before they could do the practical work themselves. In essence, the demonstrations were done to guide the learners. He also said that at the college they were not given any notes and they had to make their own notes from the lecturer's summary and from their textbooks. He said that he found making his own notes useful, as it gave him the opportunity to make sense of what he had to learn. This, however, means that there should be sufficient textbooks for learners.

It seems their science lecturer endeavoured to encourage them to take responsibility for their own learning in that they were not spoon-fed with notes to memorise. I would add that, in addition to making of notes, making concept maps of the key concepts developed and where they are linked might make learning even more meaningful. It is recognised, however, that this requires thorough understanding of the concepts.

7.3.4 Peer mutual support

Zapholo, Ngwenya and Khwezi said that they were never encouraged at the college to work together with other students. Instead they were encouraged to work independently since they would be on their own after completion of the course. However, Khwezi said that a small-scale peer support was allowed when they were working in groups during practical work.

In contrast, Leo, Nomfundo and Neon reported that at the college they were encouraged to work together so that they could help one another. Leo and Nomfundo emphasised that the peer support was useful especially in the workshop. They further indicated that they were able to sustain these working relations even in the field.

This means that three out of the six science teachers were never exposed to working with other students except in their study groups. Nias (1989:13) points out that "to be a teacher is to work in a historically determined context that encourages individualism, isolation, a belief in one's own autonomy and the investment of personal resources." Hagreaves (1992) concurs that individualism, isolation and privatism make up what is called the culture of teaching in most schools: teachers in schools are separated into classes, isolated and insulated from one another.

Sadly, such isolation according to Lortie (1975) and Nias (1989) often deprives teachers of the opportunity to learn *from* and *with* one another. Nias (1989), Hargreaves (1992) and Hargreaves and Fullan (2000) feel the same, and observe that one of the characteristics of traditional teaching is its individualism to a point where the notions of professionalism and autonomy are inseparable. While I agree that it is good for teachers to be independent, I also feel that teachers should be encouraged to share ideas, expertise, frustrations and success stories. My thesis is that through engaging teachers in professional networks (see Chapter 6) could keep them from being isolated (Edwards, 2002; Loucks-Horsley *et al.*, 2003).

In this study, individualism and isolation were therefore identified as features of the culture of teaching (Lortie, 1975; Nias, 1989; Little, 1990; Hargreaves, 1992; Hargreaves & Fullan, 2000) at the college. Furthermore, the six science teachers indicated that they were not encouraged to observe and critique each other's lessons. Their lessons were observed only when their lecturers evaluated them. In my view, encouraging teachers to work together and to observe each other's lessons could contribute towards the teachers' conceptual understanding and self-confidence. However, for this to happen at the colleges and in schools, a culture of trust and mutual support needs to be engendered.

On a positive note, however, Zapholo, Ngwenya, Khwezi and Neon indicated that they formed study groups on their own; those students who were doing the same subjects used to help one another through discussions. They indicated that they all benefited and as a result they were able to grasp many aspects of science. The study groups thus proved to be a greater stimulator and contributed towards their conceptual development.

Loucks-Horsley *et al.* (2003:153) support the idea of study groups even amongst teachers. They note "study groups are collegial, collaborative groups of problem solvers who convene to mutually examine issues of teaching and learning." This, however, has its challenges. For example, regarding the study groups that K hwezi and his peers formed, he commented that females did not contribute much in the discussions.

From Khwezi's comment it is evident that gender issues proved to be a challenge: female participation was limited. Baker (1998:879) warns us, "Gender roles are a barrier rooted in culture and can prevent participation in science because of dissonance that arises from being a minority student in a majority school." When I asked him why the female students were not actively involved in their study groups, he said that possibly it was because some had low self-esteem.

7.3.5 Teaching practice

During teaching practice, Zapholo and Neon c onfirmed that they received sufficient support from the experienced teachers at the school where they were placed. It seems they both benefited from their mentor teachers: the mentoring process (Hargreaves & Fullan, 2000; Loucks-Horsley *et al.*, 2003; Patton *et al.*, 2005) was of good quality.

Loucks-Horsley *et al.* (2003:219) explain that mentoring is a "teacher-to-teacher professional development strategy that sustains long-term, ongoing professional learning embedded within the school culture." Hargreaves and Fullan (2000) and Patton *et al.* (2005) too suggest that mentoring is essential for building a re-energised professional culture of teaching and learning.

In contrast to Zapholo and Neon, the other teachers - Ngwenya, Leo, Nomfundo and Khwezi indicated that they did not get any support during teaching practice. Instead, they were left to 'sink or swim'. For example, Ngwenya reported that in his first year of practice teaching at Matyana High School, his former school, where he taught mathematics, his mentor teacher seldom came to observe him when he was teaching. If Ngwenya was on his own in the classroom, how did his mentor teacher write his progress report? How would Ngwenya know where to make improvements in his teaching? The ethical issues implied here are vital in professional development initiatives.

On a positive note, however, Ngwenya highlighted that he had much better support in his practice teaching at another school in Ginsberg in his second year. At that school, his science mentor teacher was a former student of Matyana High School. Ngwenya commended him for his wonderful classroom-based support since he used to come and observe him when he was teaching. After the lesson they would sit down and discuss how the lesson went. This, he said, helped him make improvements in his teaching and learning strategies.

Regarding his experiences during practice teaching, Khwezi said:

> During practice teaching the only form of support that I received was the feedback on my lesson plans, otherwise you were just sent to go and teach on your own by the subject teacher. And you had to do everything on your own and no teacher would be there to give you support. They simply wrote a report based on your lesson plans and there was no time set aside to discuss your strengths and weaknesses after the lesson. I would say the presence of student teachers was seen as a free time for the experienced teachers. (Active interview 20/04/04)

My own experience was much the same: when I did practice teaching, experienced teachers saw our presence at the school as free time for them. In my view, Khwezi would have been empowered by feedback on how he had implemented his lessons. He too believes that, as a student teacher, support from experienced teachers or mentors is vital for improving one's practice. Since Zapholo and Neon were exposed to quality mentorship when they were at the college, one would expect that in the field they would be in a better position to provide quality mentorship to students doing teaching practice at their schools. It seems that they did not happen as reflected in Nomfundo's comments:

> We did not get any support at all. I don't want to tell lies. It seemed as if we had come to do our own thing, you see - we really felt neglected. Even if you were teaching a lesson, no teacher would come and observe you and give you support. At that time Zapholo was teaching at Matyana Senior Secondary School and he used to lock himself up and work alone in the science laboratory. As a result I did not get an opportunity to interact with him at that time. So, I would say we were neglected and left to sink or swim. And that was the general culture of the school where we did practice teaching. We only had an opportunity to interact with Zapholo during the SEP workshops. (Follow-up active interview 14/02/05)

Seemingly the irony is that, although Zapholo was exposed to quality mentorship when he was doing teaching practice, he could not put this into practice when he was teaching. This suggests that even though a teacher might be exposed to quality mentorship, ongoing professional development is needed.

As corroborated by my own experience in the schools, all three teachers' remarks highlighted the poor mentorship and support in schools for inexperienced or novice teachers. But what are the reasons for this poor mentorship in some schools? What needs to be done to improve this situation?

From what emerged from this study, I would suggest that mentorship should be seen as part of ongoing teacher support, in particular for novice teachers (Loucks-Horsley *et al.*, 2003). Loucks-Horsley *et al.* (*ibid*:204 - 22) refer to this process, whereby an experienced teacher assists an inexperienced teacher by coaching and mentoring in order to enhance their knowledge, learning and practice through face-to-face interaction. They add that experienced as well as new teachers need opportunities for learning and growth.

To Loucks-Horsley *et al.* (*ibid*:219), mentoring is immensely important, as "teacher-to-teacher professional development as a strategy that sustains long-term, ongoing professional learning embedded within the school culture." Mentors should be teachers who are experienced and knowledgeable in their subject-content knowledge (SCK) since their primary purpose is to provide support to new teachers. Mentorship is critical too since the teachers' pedagogical-content knowledge develops in the practice. Nott and Wellington (1996) believe that PCK may help form the subject-content knowledge (SCK); the very act of teaching might provide teachers with insights into their subject.

In this section I have compared and contrasted the six science teachers' experiences at the three teachers' colleges. From the analysed data, it emerged that they were all exposed to transmissive methods. On collaboration, some of these science teachers said that they were not encouraged to work together. Instead, they were encouraged to work individually and independently. The reasoning behind this was that they would be on their own in the field. In essence, isolation and individualism (Lortie, 1975; Nias, 1989; Hargreaves, 1992) were fostered at the expense of collaboration (see Section 3.3.2). Yet there is a need to strike a balance between the two.

The literature reviewed in this thesis shows that collaboration among teachers might be beneficial in that teachers could be afforded opportunities to learn with and from one another. This is indeed critical since, according to Hargreaves and Fullan (1998) and Sherin (2002), teachers have to learn continuously in the act of teaching - to be lifelong learners (Duggan, 1996; Edwards, 2002) in order to enhance their self-development. For example, those teachers who were exposed to working together while at the colleges found that experience invaluable when they were in the field.

During teaching practice some of these science teachers mentioned that they did not get any support from the experienced science teachers at the schools where they were placed: the mentoring process (Hargreaves & Fullan, 2000; Loucks-Horsley *et al.*, 2003; Patton *et al.*, 2005) was poor and not taken seriously. Those teachers who did receive adequate support found the teaching more interesting.

7.4 Concluding remarks

In this chapter, the six science teachers' school and college educational background and experiences have been reviewed and found to be varied in many ways. In some cases, however, it became evident that there were overlaps in how teaching and learning took place at both the schools and colleges. For example, at both levels teaching and learning has been characterised by transmission and rote learning. Lack of practical work and/or demonstrations exacerbated this. Yet all these science teachers would have preferred to do practical work themselves, their assumption being that, experiencing science hands-on makes it more exciting and meaningful.

The analysed data thus revealed that these teaching approaches deprived some of these teachers of opportunities to learn science meaningfully. In this case, I believe that engaging teachers in a TTCPD network (see Chapter 6) is essential so that teachers could be afforded opportunities to learn *with* and *from* one another. The idea of sharing expertise within the schools is strongly supported by the professional development literature (Fullan, 1993; Loucks-Horsley *et al.*, 2003).

Considering sharing of expertise as a central tenet in this study, our professional development network was designed to address a number of identified school-based needs such as opportunities to discuss curriculum in an ongoing manner with each other and with other professionally knowledgeable colleagues in the field of science.

The next chapter foregrounds the teachers' practice of teaching and professional development and support within their different school contexts. This was seen as fundamental in the context of this study since the culture of a school contributes to the learning of teachers. Without a supportive culture the professional learning of teachers might not survive. With this in mind, this study contends that there is a need for the creation of learning communities of practice in schools. The notion of a community of practice helps to describe how teachers' learning occurs in collaborative school-based communities. In the light of this, an examination of the teachers' practice of teaching and professional development and support is essential.

Chapter 8

Practices of teaching and professional support: Data analysis and findings

> Classrooms are not limpid, tranquil ponds, cut off from the river of social, cultural, and political life. They are contested spaces – whirlpools containing the contradictory crosscurrents of struggles for material superiority and ideological legitimacy that exist in the world outside. Becoming alert to the oppressive dimensions of our practice (many of which reflect an unquestioned acceptance of values, norms, and practices defined for us by others) is often the first step in working more democratically and cooperatively with students and colleagues.
>
> (Brookfield, 1995:9)

8.1 Introduction

In this chapter, the focus is on the six science teachers' practice of teaching and professional support within their school environments, which Brookfield (1995) believes are contested spaces with many contradictions. This was seen as fundamental in the context of this study since, according to Loucks-Horsley *et al.* (2003), the culture of a school contributes to the learning of both teachers and learners. Without a supportive culture, they argue, the professional learning of teachers might not survive.

Bearing this in mind, this study contends that there is a need for the creation of learning communities of practice (Lave & Wenger, 1991; Patton *et al.*, 2005) in schools. The notion of a community of practice as proposed by Lave and Wenger (1991) helps to describe how teachers' learning occurs in collaborative school-based communities. In the light of this, I examine the six science teachers' practice of teaching (see Section 8.2) and professional development and support (see Section 8.3). Some concluding remarks are provided to consolidate the ideas in this chapter. To investigate these aspects, which I believe are critical in the context of a study concerned with a professional development network of teachers, the following questions were explored:

Does the way science was taught at the teachers' colleges have an influence on the science teachers'

- perspectives, assumptions and beliefs?
- practice of teaching?

Does professional development and support influence the science teachers'

- practice of teaching?
- school-based and collegial support?

8.2 Practice of teaching: Experiences, perspectives, assumptions and beliefs

This section explores the six science teachers' practice of teaching in terms of their teaching experiences, perspectives, assumptions and beliefs, classroom challenges and constraints, and finally their innovations in teaching and learning. The intention here is to provide professional developers and educators with some insights as to what form of professional development initiatives could be appropriate and productive for teachers.

8.2.1 The six science teachers' teaching experiences

Zapholo indicated that he started teaching in 1976 at Matyana Senior Secondary School. Although he was not qualified to teach Grades 10 - 12, he was asked to teach science to these classes. Given the drastic shortage of qualified teachers in South Africa, in particular, science and mathematics, it is not unusual for teachers to be asked to teach where they are not qualified. This reality has serious implications for quality teaching and learning especially if teachers do not regard themselves as lifelong learners.

Not surprisingly, to Zapholo this proved to be a great challenge as previously at the teachers' college very little science-content knowledge for Grades 10-12 had been covered. The emphasis had been on Grade 8 - 9, which were the grades he was qualified to teach. However, he indicated that he was very keen to teach Grade 12.

In the process, he was compelled to depend on his teaching methods, which were understandably characterised by transmission of knowledge to learners. He also had to adapt the textbook method learnt at the teachers' college; and knowledge-building (Latour, 1986; Law, 1999; Edwards, 2002) was compromised. As a result, he encountered problems of not knowing *why* and *how* certain scientific concepts were developed. This was exacerbated by the fact that he did not know how the experiments were performed and what apparatus was required. He commented:

> You see, because at the teachers' college there was little time given to practical work, most teachers including myself found it difficult to cope with experimental work, handling of science apparatus, and making of conclusions from experiments. (Follow-up active interview 23/05/05)

In an effort to familiarise himself with the science experiments, he used to work in isolation in the science laboratory. Yet Gomart and Hennion (1999) are in favour of collective human endeavours rather than individual efforts, which in my opinion is the preferred option for learning. Zapholo realised that to strengthen his subject-content knowledge, he had to read science textbooks. He did so, and it helped. I would recommend that teachers need to be textbook literate.

Ngwenya started teaching in 1983 at a primary school, although he was qualified to teach Grades 8 and 9. He said that he was pleasantly surprised at the primary school to discover that all the theories that they had learnt at the teachers' college were not applicable in the real school situation because the learners they read about in textbooks were totally different from those he encountered at his school. He had to adapt to the real situation.

Furthermore, since he was assigned to teach young children, he believed that they should see, where possible, the things he was going to be teaching them. For example, if he were going to teach them about a pigeon, he would bring one to the classroom so that they could see the different parts he was going to talk about. As a result, he thinks his learners found general science interesting. However, I would argue that finding science interesting does not necessarily mean that learning has taken place. Here, Nespor

(1994) notes that in order to understand how an activity is connected to learning and knowledge, we have to understand the classroom interactions first.

From Ngwenya's comments it seems that m useum artefacts would have been useful resources to use. However, he unfortunately did not make use of these resources. Roschelle (1995) reminds us that museums provide learners with the opportunities to experience objects directly while at the same time learning socially in small groups; museum artefacts provide opportunities for a shift from individuals to a collective (see Section 4.2.2).

However, Roschelle's (*ibid*) criticism is that the museum exhibits are static and the assumption is that a good presentation will make underlying concepts obvious. I concur with Roschelle, and suggest that a museum visit needs to be carefully planned. Unfortunately, in my experience, some teachers tend to take their learners to the museum when they have not planned anything to do at their schools, resulting in non-alignment between what is taught at school and at the museum.

In his second year of teaching, Ngwenya was offered a teaching post at Matyana Senior Secondary School (his former school), where he was assigned to teach mathematics instead of general science. He indicated that one of the things that frustrated him at Matyana was the number of learners in the class. One of the classes he taught in 1984 had 104 learners, and it was very difficult for him to teach such a number. The individual attention talked about at the teachers' college seemed to be a myth. He commented:

> I remember there was no space to move around and it was difficult to give individual attention that was talked about at the teachers' college. As a result I used to just write notes on the chalkboard and simply explain those notes. Then I would ask my learners to read those notes for tests or examinations. (Active interview 4/05/04)

In this case, the contextual circumstances forced him to rely on giving notes to his learners, and thus he was the only source of knowledge: his teaching approaches could be categorised as being teacher-centred rather than learner-centred. Also, he pointed out that one of his weaknesses was not making sufficient efforts to encourage his learners to find out information on their own or to ask questions.

According to O'Sullivan (2004), teacher-centred approaches are characterised by teacher dominance over passive learners. Such approaches might lead to rote learning and stifling of critical and creative thinking. However, my experience as a learner and a teacher has shown me that even though this style might be labelled teacher-centred, learning does occur where teachers are capable of problematising and mobilising their teaching repertoires and where learners take their education seriously. Thus, I would argue that it is dangerous to generalise and deduce that teacher-centred approaches are bad or good. Rather, we should appreciate the time and context in which the different teaching and learning approaches take place.

Khwezi, Neon, Leo and Nomfundo, all started teaching in 1991. Khwezi taught at Phandulwazi Senior Secondary School and Neon at Pioneer Senior Secondary School, where he had been a student. Like Ngwenya, they initially both taught mathematics since there were enough science teachers at their schools. Neon taught general science for two years and later in 1993 he was assigned to teach mathematics. This suggests that the three science teachers' learning spaces to develop and grow in science were limited.

Furthermore, in the case of the three science teachers who predominantly taught mathematics in their teaching careers, what needs to be asked is: If a teacher has specialised in say two subjects and has been teaching one subject for a number of years, how could such a teacher's knowledge base be kept 'fresh' while that person is not teaching the other specialisation subject? For example, when the physical science teacher left Khwezi's school in the middle of 2001, he was assigned to teach physical science in Grade 12 for the first time. Coincidentally, this was the year when he joined our network, something which afforded him an opportunity to be part of a community of practitioners as proposed by Lave and Wenger (1991).

Reflecting on his past experiences of teaching general science, Neon indicated that he used to encourage his learners to work in groups. He indicated, however, that he found it challenging to determine whether all learners in the various groups were learning or not. From my own experience as a teacher and a professional developer, this is one of the main focuses of group work.

Leo and Nomfundo taught at Mfundweni Senior Secondary School. Their school operated from three different primary schools, on the *platoon system*. They indicated that they were unfortunate to start their teaching careers at such a school, which was like a reformatory since they used to get learners who could not be accommodated at other schools or had dropped out of other schools. On a positive note, however, they considered their school's organisation and contextual factors to be a challenge rather than a problem, and were prepared to face them.

Initially, they both taught general science in Standard 6 and 7 (Grades 8 and 9). Based on their expertise and as an attempt to mobilise (Callon 1986) them in the teaching and learning of science, Leo was assigned to teach the physical science section; whereas Nomfundo taught the biology section of general science. This suited these two science teachers' strengths and weaknesses. Furthermore, such a division of labour (Hardman 2005) was useful in compensating for the lack of opportunities for professional development.

Leo's memory reflects that although she had completed the teachers' course, she was still not feeling confident enough to teach the entire general science. This is further evidenced by the fact that she was happy with the arrangement of splitting the general science into physical science and biology sections and she was much more comfortable with the physical science section. This reminds us that teachers might have their own particular reasons for the preferences they show in certain sections of the subjects that they teach. In my view, if these preferences are not considered, this could have a negative impact on teaching and learning.

Like Zapholo, both Nomfundo and Leo were later asked to teach grades they were not qualified to teach. Leo was asked to teach physical science at Grade 10 level although she felt that she did not have much understanding of subject-content knowledge at that level, and had not done chemistry at the teachers' college. The question that comes to mind is: Since Leo had said in her own words that she did not have much understanding of science, how did she then improve her science-content knowledge in order to cope with a Grade 10 class?

Nomfundo was asked to teach biology at Grade 12 level although her experience was limited to her own schooling experience where she had gone no further than Grade 12 herself. She thus commented:

> When I was asked to teach biology, I told my HoD that I did not major in it, but she said that I should use my method skills, which I did, and I was delighted because my Standard 10 learners passed with exemptions and biology was one of the subjects which my learners passed very well. (Active interview 3/08/04)

What is revealed by these teachers' experiences i s that in certain schools there is a tendency to rely on teachers' pedagogical-content knowledge when subject allocation is done. It could be argued that this could indicate the limited human resources in some schools. As far as I am concerned, however, the fact that a teacher has done a method course in one subject does not necessarily guarantee that that teacher could teach any other subject. In my view, this is problematic as teaching a certain grade with limited knowledge of the subject-matter content could force one to resort to relying only on superficial textbook knowledge. I also believe that ideally the teachers' subject-knowledge base should always be greater than that of their learners, which is apparently a luxury in some of the historically disadvantaged schools in South Africa.

Leo and Nomfundo further indicated that a barrier for effective teaching at their school was the fact that they had no science equipment. Hence, they had to teach science theoretically, the way they themselves had been taught at school. They were only able to do certain practical activities on electricity using the electricity kits they obtained from the Science Education Project.

From the actor-network theory perspective (see Section 4.2.2), it seems in this school context that there was a deficiency of both human and physical resources. Had science equipment been available, I am curious to know, would the two science teachers have been able to use such equipment? In my experience as a science subject adviser, it was usual to find science equipment in some schools packed into boxes because several teachers could not use it. In such circumstances, the scope provided by the physical artefacts was wasted. For example, Zapholo said that at their school they have enough biology apparatus; yet the biology teacher does not use the equipment. This confirms that there is a need for development of teacher competences and skills.

These are some of the realities of the historically disadvantaged schools in South Africa. Some of the science teachers' shortcomings revealed in this study have been addressed in studies that examined the link between teachers' subject-content knowledge and pedagogical-content knowledge (Shulman, 1986; Sanders & Morris, 2000; Kallery & Psillos, 2001; Sherin, 2002; Schoultz & Hultman, 2004). Such studies have shown that teachers' subject-content knowledge influences aspects of their pedagogical-content knowledge. Furthermore, Murphy *et al.* (2004) agree that insufficient subject-content knowledge could result in teachers' lack of confidence, which might lead to science being taught in uninteresting ways.

In this study, all six science teachers believe that inadequate subject-content knowledge could have a negative impact on one's teaching ability. Zapholo commented:

> I strongly believe that no matter how efficient a teacher is in his or her teaching methods, inadequate content knowledge in the subject would be a challenge and would weaken his or her teaching ability. (Active interview 16/03/05)

I concur with Zapholo and Sherin (2002) too supports this view. Without being a devil's advocate, I have some pertinent questions to pose. Were teachers' colleges able to equip teachers sufficiently with subject-content knowledge and practical work skills? If most teachers in the field are regarded as unqualified or underqualified, as is the case in many schools in South Africa, how could these gaps in subject-content knowledge and practical work skills be compensated for?

In this study, the questions above indeed point to the need for teachers' professional development (Hargreaves & Dawe, 1990; Southwood, 2000; Spanneberg & Brown, 2003). In the literature reviewed in support for this study, Schäfer (1999), Southwood (2000) and Spanneberg and Brown (2003) believe that teachers' professional development should be an ongoing process throughout the teachers' career. I too support this view, believing as do Hargreaves and Fullan (1998) that teachers have to do a lot of learning on the job.

During tests and examinations, which were based on the work given by the teachers, learners were required to regurgitate or reproduce what they had been taught. Here, Zapholo explained that if a student obtained 80 per cent, he would be satisfied that he had done something; test marks to him were invariably an indication that learning had taken place. Ngwenya concurring with Zapholo commented:

> During tests or examinations, if a learner mentioned something that was not in the notes, I would mark him/her wrong because he or she did not give me what I taught them. You see, whereas the learner might be right [laughing]. In short, what I wanted from my learners was for them to give me back what I taught them. So, I would say the emphasis was on writing notes and the learners would be required to reproduce those notes as they are. (Active interviews 4/05/04)

From Ngwenya's comment it seems evident that the questions asked were closed in nature: his learners had to demonstrate how much they had rote-learned. In such circumstances, their creativity might be restricted. There seems to be no contradiction here, since the way you teach will invariably determine how you phrase questions. However, all the teachers felt that what was good about tests or examinations was that they were individual activities.

Khwezi indicated that he personally feels that it would be interesting if learners could do examinations in practical work as well. However, with a drastic shortage of science equipment in most historically disadvantaged schools, he recognised that this would be difficult. In addition, the lack of teachers' practical work skills could also be a potential barrier. It is for these reasons that in this study, a teachers' transformative and continuous professional development network (see Chapter 6) has been adopted to mobilise both the science teachers' subject-content knowledge and pedagogical-content knowledge.

In this section, the six science teachers' practice of teaching has been emphasised and explored. It has emerged that allocating subjects to teachers who are not qualified to teach the subjects proved to be a challenge as teachers lacked subject-content knowledge as well as practical work skills. Likewise, it became evident that it is dangerous to assume that if teachers have pedagogical-content knowledge they can teach subjects they have not specialised in. It is thus suggested that for effective teaching and learning to take place, both teachers' subject-content knowledge and pedagogical-content knowledge need to be enhanced.

8.2.2 Teachers' experiences, perspectives, assumptions and beliefs

All six science teachers highlighted the fact that they were the only source of knowledge in their science classrooms. For example, based on his determination to be a professional, Zapholo willingly faced the challenge of teaching Grade 10 - 12 despite the fact that he was not qualified to teach these grades. This challenge profoundly influenced his assumptions and beliefs about teaching and learning as he had to rely on reading the textbook in order to transmit information to his students.

It is evident that he relied on the prescribed textbook as the sole source of subject-matter knowledge, which he then imparted to his students, relying on transmissive approaches to teaching and learning. Zapholo even confessed that he also kept his former learners' exercise books, in particular those who had written his notes very well, so that he could use them in future classes. He commented that he had witnessed this strategy during his own years at school (see Chapter 7). Walker (1991) and Smyth (1996) note that a teacher's knowledge might be shaped by that person's schooling system.

Some questions are: To what extent was Zapholo able to understand the contents of the textbook he was reading? How creatively could he transmit such knowledge to his

Some questions are: To what extent was Zapholo able to understand the contents of the textbook he was reading? How creatively could he transmit such knowledge to his learners? From my own experience as a learner, however, the adoption of transmissive approaches does not necessarily mean that no learning takes place especially for those learners who take learning seriously.

Unfortunately for Zapholo, the fact that he had to read and try to understand the textbooks resulted in him working in isolation (Lortie, 1975; Nias, 1989; Hargreaves, 1992; Hargreaves & Fullan, 2000). Yet, according to Senge (1990), learning starts with a dialogue whereby actors suspend their assumptions and co-engage in a genuine collective-thinking process.

In Zapholo's case, such learning spaces were not there and so he used to work alone in the afternoons in the science laboratory, reading textbooks and trying to figure out how things worked. To further strengthen his science-content knowledge he went so far as to get assistance from Rhodes University, which shows how determined he was.

Zapholo's statement on working in isolation confirms what Leo and Nomfundo's experience were when they did practice teaching at Matyana Senior Secondary School (see Chapter 7). This suggests that teachers might have embedded reasons why they do things the way they do them. To unearth these can be a complex matter, but it might be useful for professional developers to find out the teachers' background, experiences and needs rather than simply imposing strategies such as collaboration on them. It is for these reasons that I value finding out teachers' educational background in this study (see Chapter 7).

Ideally, though, it might have been useful if Zapholo could have done such construction of understanding of knowledge in partnership with a colleague in order to expand his capacity to create the results he wanted to achieve (Senge 1990). It is recognised that his school context did not encourage networking, but opportunity was there by virtue of other people being present. Instead, working in isolation was the norm. Nias (1989:15) observes that isolation not only makes teaching private but also lonely.

In this study, although Zapholo felt isolated and lonely, he wanted the isolation for the space it gave him to address the gaps in his subject-content knowledge. I would argue that we need to work towards self-initiative along with responsibility for networking. I believe that when teachers are pro-active and responsible, ownership in networks would increase. This is what we endeavoured to achieve in this study.

Regarding his past assumptions about the teaching and learning of science, Khwezi's belief was that most things should come from him, and his learners should simply receive the information. Although he was qualified to teach Grades 10 - 12, he also relied on simply transmitting knowledge to his students. Furthermore, as a result of his past beliefs, he indicated that he mostly used question-and-answer methods, moving step by step to check if his learners understood or not. In the process, however, he deprived them of opportunities to discuss and co-construct knowledge. Acknowledging the shortcomings in his past beliefs about teaching and learning, Khwezi commented:

> I think my past beliefs about teaching and learning had many weak points because I did not give my learners any opportunities to explain how they knew about the subject matter. I also recognise now that learners have to be given an opportunity to discover things on their own so that they can understand knowledge better. (Follow-up active interview 1/02/05)

It seems that Khwezi realised the disadvantages of relying purely on transmitting knowledge to learners during the teaching and learning process. However, explaining and consolidating concepts should not be equated with transmission of knowledge to learners. And before teachers are able to effectively engage their learners in class, I would argue, those teachers need to be clear in their subject knowledge as well as their pedagogical-content knowledge (Shulman, 1986).

When I asked Neon what his past assumptions and beliefs about teaching and learning were, he intimately commented:

> I believed that most of information should come from me only rather than to come from the learners as well. I believed that I was responsible for doing my work thoroughly... I also tried to ask questions to find out if learners understood or not and I would explain to them anything that was not clear. (Follow-up active interview 1/02/05)

From his statement, Neon seems to be conflating transmissive approaches with a teacher's responsibility. Furthermore, he explained that he only relied on the practical work that was in the textbook and in particular that prescribed in the syllabus. The system of teaching was the one where the teacher was required to stand in front of the class and 'preach', spoon-feeding the learners. The disadvantage with this, Neon observed, was that some learners did not study the work that was given to them. It could be argued that his learners did not find the work challenging and stimulating.

Leo, too, believed that she had to work very hard as a teacher in order for her learners to pass. As a result, she used to follow the textbook rigidly. This suggests that her focus was on the end product rather than the process. While I agree that the ultimate objective of teaching should result in learners progressing from one grade to another, equally important should be learning for understanding. But, what skills and competences do teachers need to have in order to be able to teach for understanding? Furthermore, how can teachers teach for understanding if they are teaching subjects they are not confident in? These questions suggest that there is a constant need to engage teachers in professional development networks (see Chapter 6).

Like Ngwenya, Leo acknowledged that in the past curriculum she believed that as the teacher she was supposed to give all the information to the class without the learners participating; this deprived learners of opportunities to interact and co-construct knowledge in their classrooms. As a result little transformative learning took place. From my own experience as a science teacher, learners found it difficult to apply knowledge in their everyday lives. Nomfundo commented:

> It was the child first. I used to believe that one has to prepare so that you can be able to give the information to your learners. And that it was very important that you were fully prepared before you could go to class. Otherwise you would appear stupid if you did not prepare well, you see, because there were learners that were challenging. What you would find was that in each and every class there would always be a learner who was challenging, and I liked that because it encouraged me to work hard and read more. (Active interview 7/04/04)

This comment reveals that Nomfundo recognised the importance of thorough preparation. In my opinion, preparation and time management are skills that need to be developed among teachers. It is recognised, however, that the quality of preparation depends on the teacher's knowledge base as this is essential in knowledge capacity-building (Latour, 1986; Law, 1999; Edwards, 2002).

In this section, the six science teachers' past perspectives, assumptions and beliefs about teaching and learning have been explored. In summary, this study revealed that the science teachers' perception of their role was that of transmitters of information while their learners were seen as receivers of that information. Learners were framed as empty pots to be filled with knowledge from the teacher; and were thus deprived of opportunities to co-construct knowledge through discussions in class; their teachers were the only source of knowledge. This situation was further compounded by the fact that opportunities for networking were minimal at these schools.

8.2.3 Classroom experiences

Language

One of the challenges that these science teachers highlighted was that of language. As a result, code-switching, the practice of teaching in both English and *isiXhosa*, was used. Our network actors had also used code-switching in their efforts to promote conceptual development in their learners even though English is the official medium of instruction at their schools. At the same time, these actors cautioned that lessons should not be mainly in isiXhosa since examinations are in English.

Zapholo indicated that he once did a mini-research on this strategy: he gave one group of learners a test written in *isiXhosa* and another group a test written in English. To his surprise, he noted that the learners who wrote his test in *isiXhosa* did not do better than those who wrote in English. He commented:

> Although the question of language is a key issue, I believe that for a child to know a second language, he or she must know his or her own language. And they must read; our

> learners don't want to read and write. I think we teachers lack ideas of how to encourage our learners to read and write. I think we lack the ideas and skills because these skills were lacking from our teachers' colleges where we ourselves were actually trained. (Follow-up active interview 10/10/04)

These are some of the complexities that exist and confront science teachers in their classrooms. Yet Edwards (2002) reiterates that it is through mediation that transformative learning processes could be enhanced.

Literacy

The six science teachers highlighted the importance of reading and writing. They were experiencing problems with learners who had passed Grade 7 from the feeder schools. They commented that it seemed that these learners were merely promoted to the next grade because of age and they struggle to read and write.

In an attempt to solve this problem, Nomfundo said that they were encouraging other teachers in their school to work together. She indicated that they were taking advantage of the fact that Leo was teaching English in 2004, which gave them an opportunity to mobilise literacy and the teaching and learning of science at their school.

I agree with these science teachers that learners need to be equipped with reading and writing skills. However, Zapholo realised that teachers themselves seemed to lack these skills. In addition to the need to pay attention to reading and writing, he also emphasised the need to simplify the scientific language, which with its density might retard meaningful learning. Here again, networking is seen as a useful strategy to work together, as according to Nespor (1994), knowledge and learning are products of social activity rather than of isolated minds (see Chapter 6).

Learner participation

The six science teachers mentioned another frustration they had faced in the past - that of their learners not asking questions during their lessons. When Neon asked his learners why they were reluctant to ask questions their response indicated that they were concerned about the perceptions of other learners who were laughing at them, saying that they were asking simple things: they feared being ridiculed by their peers. Some learners even reported that some teachers shouted at them when they asked questions during their lessons. When I asked him what the reason could be for some teachers not wanting their learners to ask questions during their lessons, he responded:

> I'm not sure about what I'm going to say, but I think that some teachers do not want to be asked something they do not know, they are scared to say they do not know the answer to the question. Instead of saying, today I don't have an answer and I will come back tomorrow with it. Or to redirect the question to the other learners in class because it is possible that one of the learners might know the answer. As a teacher you need to be confident and not pretend that you know everything. (Active interview 6/04/04)

Neon's comment expressed some fellow-feeling for teachers not wanting to appear ignorant of their subjects. I think that he is correct in saying that teachers need to be confident in the subjects they teach. Lack of confidence may result in teachers asking superficial questions in class rather than thought-provoking ones, thus avoiding learners' questions or not encouraging them to ask questions or engage with the subject matter.

Furthermore, learners might also be reticent about asking questions in class because of the lack of sufficient time and space to do so. The science teachers suggested that a possible reason for this is that the syllabus is too long and thus dwelling on a specific topic would be time-consuming. Under these circumstances, time is saved at the expense of learners' conceptual development. It is for these reasons that Edwards and Clarke (2002) propose that there is a need to create learning opportunities for which teachers are enrolled as lifelong learners (see Section 4.2.2).

While I agree with Neon that teachers should admit to not having all the answers to learners' questions, they cannot do so all the time. A teacher should be able to guide and support learners towards a good answer and that requires a knowledgeable teacher (both in subject-content knowledge and pedagogical-content knowledge). Unfortunately, in an effort to maintain a sense of authority, some teachers who may feel threatened by their learners tend to discourage the asking of questions as Neon pointed out.

Research too shows that there is a positive correlation between levels of confidence about teaching the subject and understanding it in the context of science (Kallery & Psillos, 2001). These authors postulate that teachers' knowledge of subject-matter content influences the nature of the questions they ask their classes. Like Neon, Zapholo felt that he needed to encourage his learners more in asking questions in class. When I asked him what he thought the reasons were why his learners did not ask questions in class, he suggested:

> Sometimes I wouldn't understand why. But, I think sometimes it is the way they have been subjected to in the primary schools. I'm made to believe that at primary school teachers tell them to always keep quiet, its time to rest. And also, this notion of us teachers, having inherited this method of standing in front there, doing the talking alone, can suppress the thinking of the learners. (Active interview 16/03/04)

Zapholo's comment points towards teaching and learning strategies that at times suppressing the learners' questions. He also contended that, as a second language speaker of English, he was influenced by this fact in the types of question he asked in class; they were not always relevant to what he wanted to find out from his learners. Phrasing of questions could therefore suppress the way his learners responded. This is as a vicious cycle which needs attention in many science classrooms.

The science teachers in this study thus recognised a need to encourage 'learner talk' in science classrooms. The current perception is that classes are being dominated by 'teacher talk'. Yet I feel there is a need to strike a balance between the two. I believe that 'learner talk' could be enhanced by teachers co-engaging and learning to talk science with their colleagues (see Chapter 6). In my experience, a potential barrier to learner engagement in 'learner talk' may be the tendency of some teachers to place strong emphasis on giving the 'right' answers in class, resulting in learners fearing giving 'wrong' answers.

In an attempt to encourage his learners' active involvement in class, Zapholo explained, he adopted a strategy of engaging learners in interactive practical activities and discussions during his lessons. And Hodson (1990) maintains that laboratory skills should be seen as a means for further learning. Similarly, Ngwenya said that when he was teaching general science in 1983 he was faced with a drastic shortage of science equipment for practical activities at his school; and he used to borrow science equipment from Zapholo, his former science teacher, so that his learners could experience science at first hand. He had to risk embarrassment to seek help from other science teachers. This suggests that the scope given by LTSMs as well as access to human resources and different perspectives cannot be underestimated.

Collaboration and networking

The sharing of resources between Zapholo and Ngwenya, mentioned above, I see as an opportunity where they could have worked together and supported one another. They would thus become part of a collegial and cohesive professional network as proposed by Loucks-Horsley *et al.* (2003) in the literature reviewed in this thesis.

What would have made such a working relationship unique too would be the collaboration between a primary school science teacher and a senior secondary school teacher, something that is generally not happening in schools. Instead, there is a tendency for teachers to blame one another: when learners do not know their work, senior secondary school teachers tend to deflect blame onto primary school teachers. This suggests that there is a need for teachers to communicate, network and interact within and across schools rather than blaming one another. That was the contention of this study.

For instance, Nomfundo stated that collaborating with Leo, who was with her at the teacher's college, made teaching at her school enjoyable because they are supporting each other a lot. Although the literature on collaboration reviewed in this thesis (see Section 3.3.2) is portrayed as panacea, obviously teachers have to know, understand and trust one another for meaningful collaboration to take place.

In this section, the classroom challenges and constraints experienced by the six science teachers have been discussed. It emerged that although language barriers were a prominent feature of the historically disadvantaged schools these were not insurmountable if teachers could be provided with skills to cope with them. Here, the teachers emphasised the need to promote both reading and writing skills among learners in order to enhance meaningful learning in the science classrooms.

8.2.4 Teachers' innovations in teaching and learning

In time it became evident to Zapholo that his teaching and learning methods were not based on learners learning things themselves. Instead, learners depended solely on his knowledge, the only source. Ngwenya, who was Zapholo's former learner at Matyana Senior Secondary School, confirmed this (see Chapter 7). According to Brownlee (2003), in such circumstances learners believe that knowledge is transmitted from an authority and learning is believed to be taking place through passively receiving such knowledge.

I would however argue that teachers do have to strive to be authorities and specialists in their subject areas. For this, teachers have to raise their own understanding. For example, Zapholo attempted to improve his teaching in his science classes by reading textbooks. He commented:

> During those days, I've been reading a textbook, a textbook which was even prescribed to me I felt that it gave lots of nice definitions and explained certain terms. I would use that type of a textbook because it actually alleviated the job of making definitions or making conclusions about certain principles in science. (Active interview 16/03/04)

Zapholo acknowledged that he depended solely on the knowledge from the prescribed textbook. However, in his attempts to improve his teaching and learning, he became more mindful of the need to do practical work with his learners. On getting science equipment for his school he commented:

> You know what I did, I just took the physical science textbook written by Godden and Nieser, and the other textbook written by Pienaar and Walters, and I just wrote down every piece of equipment that I saw there because in those days there was a requisition form and I just ordered everything although I did not know how to use some of the equipment. When I received the equipment, I went to Prof Helm at the Physics Department to ask how those apparatus were used. (Active interview 16/03/05)

Zapholo's statement raises many issues. Firstly, while Zapholo used two textbooks as a source of information, the question arises of how well he used those textbooks. It is within this context that I regard development and adaptation of resources as critical in science classrooms. Similarly, I feel that there is a need for teachers to be equipped with skills to evaluate their learning and teaching support materials such as textbooks, which I see as important mediating tools during teaching and learning processes.

Secondly, Zapholo mentioned that in those days, unlike today, teachers had to requisition science equipment. But the biggest challenge for him was that he did not even know how to use such equipment. The irony here is: How are science teachers expected to order and use equipment when they have never been exposed to using it?

At the time of the interview, Zapholo indicated that he did not know when he had last received science equipment at his school. This is very distressing; there is a need to promote science in schools and practical work is a main component for enhancing conceptual development amongst students, as both human and physical resources are needed for this. In an effort toward self-empowerment, Zapholo taught himself science. He learnt how to do experiments, studied science books and consulted with university lecturers from Rhodes University.

Khwezi and Neon indicated that to improve their conceptual development in science they networked with their former science teachers, who also helped them with some science equipment. Through such co-engagement, learning spaces were created. Nespor (1994) believes that by participating in networks teachers can gain more knowledge about their subjects.

Zapholo started to realise that his learners had changed; his teaching in the same old ways created problems for them. He also became bored teaching the same Grade 10 to 12 work over and over again, and this stimulated him to revisit his teaching and learning strategies. He acknowledged his shortcomings in science subject-content knowledge, pedagogical-content knowledge, and manipulation of skills (Sanders & Morris, 2000).

Leo and Nomfundo also reported a change in their approaches to teaching and learning: they no longer stand in front of the class talking alone. Leo tried to avoid having her learners perceive her as 'the know it all' (see Chapter 7), as her own science teacher had portrayed himself when she was at school. She does not put herself on a pedestal now, pretending that she has all the answers. Furthermore, they both encourage their learners to share ideas and to discuss in groups, and to show respect for each other's views (Law, 1999). As a result, they say, their learners communicate freely with them and they also ask questions, albeit on a small scale.

This suggests that, by and large, the science teachers involved in this study were thinking about their teaching, which I consider a bold step and an indication of a mind shift towards being reflective practitioners (see Section 3.5.1). Zeichner and Liston (1996) posit that reflective teachers think about how they frame and solve educational problems. In actor-network theory language this is referred to as problematisation (Callon, 1986). I believe that for such reflections to be of value, teachers ought to be familiar with their subject content.

Teachers also need to be exposed to a variety of teaching and learning repertoires to help them to think about how their learners learn best. Loucks-Horsley *et al.* (2003) emphasise that professional development for teachers should be concerned with the improvement of learners' learning and understanding. Within this context, we make sense of Zapholo exploring some strategies on how to focus on learning rather than on teaching as he had been doing in the past. He commented:

> As I realised that the same type of notes did not necessarily make any meaningful learning to another group of learners, I then tried to look for more textbooks, read more textbooks to see how various textbooks explain certain concepts. Ultimately, I developed a way of writing my own notes or handouts. (Active interviews 16/03/04)

I would argue that Zapholo had to see himself as a lifelong learner before he could encourage his learners to learn with understanding. According to Duggan (1996), lifelong learning encompasses both formal and informal learning. Dillon *et al.* (2000)

add that professional development should be geared towards developing skills and competences that teachers require to become lifelong learners.

Zapholo indeed demonstrated this through reading a variety of textbooks and writing his own notes in order to suit the needs of his diverse learners, recognising that the way things are expressed can influence how they learn. Dison and Pinto (1999) and Czerniewicz *et al.* (2000) observe too that LTSMs should be an integral part of curriculum development. Thus, "the progressive view of teachers freeing themselves from 'old traditional textbook-centred teaching methods' and instead creating their own LTSMs from 'almost anything around them' echoes through the curriculum documents" (Czerniewicz *et al.*, 2000:iii). Also, as they say one has to be mindful of language usage when writing the LTSMs, as learners use language to construct their understanding of knowledge. This suggests that teachers need to be equipped with language skills in order to encourage such skills amongst their learners; and they are likely to need support for this.

Another concern brought by the six science teachers was a perception amongst their learners that science was something that happened only in the laboratory, rather than something which is happening in their everyday lives. They recognised this inability to link science to everyday life as something that they themselves had inherited from the way science had been taught at school as well as at the teachers' colleges.

In an attempt to address this challenge, Zapholo felt the need to link what he was teaching to the learners' everyday lives (Stears *et al.*, 2003). For this, he regarded learners' prior knowledge as basic for the teaching and learning process. Roschelle (1995) notes that recognition of learners' prior knowledge requires careful consideration of assumptions about knowledge, experience and learning; from my own experience as a teacher educator, I have noted that some teachers struggle to incorporate their learners' prior knowledge into teaching and learning.

It emerged from this study that the science teachers all embraced the need for the development of activity-based LTSMs in enhancing learning among their learners. They felt that this mode of teaching should not be limited to practical activities but should be used in group work too so that learners could share the scarce resources; but group work should also be used to encourage learners to co-construct understanding of scientific concepts. Likewise, they suggested that there was a need to strike a balance between group work and individual work to cater for the different learning needs of learners.

In this section, the six science teachers' practice of teaching has been discussed. It emerged from the analysed data that their assumptions about teaching and learning were influenced by the way they were taught at the teachers' colleges. They thus transmitted information from the textbook to their passive learners, who were subsequently required to regurgitate it during tests and examinations. On reflection, they also felt that they deprived their learners of opportunities to co-construct knowledge and to ask questions or explain concepts. Furthermore, a failure to link science to learners' everyday lives was cited as one of their weaknesses.

I would also suggest that the learning of well-founded scientific concepts should not be underemphasised. In spite of the traditional approaches to teaching and learning, from my own experience as a learner and a teacher, those teachers who were committed and showed interest in the education of their learners made an indelible contribution. Similarly, those learners who put a lot of effort into their work passed very well.

8.3 Professional development and support: Experiences, perspectives, assumptions and beliefs

This section explores the six science teachers' perspectives and assumptions as well as experiences on professional development to consider the Department of Education and its perceived responsibility, opportunities for personal development and growth, and support systems in collegial and school-based situations. These aspects were discussed in the TTCPD network (see Chapter 9) as a preliminary, which in my view is critical before teachers can be effective agents of change.

8.3.1 The department and its perceived responsibilities

On professional development and support, Zapholo and Ngwenya reported that in the past the Department of Education used to engage teachers in in-service training courses in science and mathematics for the whole week. Such courses used to be held in Mamelodi and later at Soshanguve, in Pretoria. Their focus was on subject-content knowledge, and practical work in the case of physical science.

The last course Zapholo attended was a departmental Alfa course which focused on upgrading teachers on their Standard 10 work. Evidently, the DoE realised that they had to empower teachers in content knowledge. To ensure that teachers were authorities in their subjects I would suggest that it would have been useful to do work beyond the Standard 10 (Grade 12) level.

Both Zapholo and Ngwenya found such courses informative and refreshing in that their subject-content knowledge was enhanced. In addition to the courses being informative, the opportunity to interact with various teachers from other schools in the different regions was also inspiring. Unfortunately, they did not use these opportunities to network with their colleagues after the courses in order to sustain their working relations (see Chapter 7) and hence missed out on becoming an established community of practitioners (Lave & Wenger, 1991; Nespor, 1994).

A problem experienced after such courses was the lack of appropriate science equipment at their school, which meant that they could not do the experiments that were taught during those courses, with their learners. Locks-Horsley *et al.* (2003) suggest that professional development initiatives should focus on the improvement in learners' learning – this was clearly not the case after the courses.

Furthermore, there were no follow-up school visits to provide support to teachers at their schools, which Spanneberg and Brown (2003) say are essential. Instead, inspectors (now called education development officers (EDOs)) used to visit to check how teachers were progressing, placing emphasis on completion of the syllabus and not on support. The inspectors came to their schools simply to check their files and the learners' books to find out how much work they had done. It could be argued that the focus of such visits was on the end product rather than on the implementation process.

When I asked Ngwenya how he had experienced visits by the inspectors, he said:

> In those days, those visits were very threatening - but helpful, because as a teacher you knew that you were not supposed to relax because any time the inspectors could come and visit the school [laughing] and check how far you were. Because when you teach you are supposed to finish the syllabus of that particular standard you are teaching so that the next teacher can build on what your learners have done. (Follow-up active interview 7/10/04)

In contrast to Ngwenya's remark emphasised here on the importance of completing the syllabus he added that the teachers' organisations have since abolished the visits by inspectors and that it is now the responsibility of the HoDs to monitor progress in their departments. Teachers' progress was, however, seldom monitored at his school. Furthermore, the completion of the syllabus is being affected by teachers' boycotts, especially in some historically disadvantaged schools. The irony is that they have to do continuous assessment even where there is no continuous teaching and learning.

Clearly there is need for appropriate bureaucratic monitoring systems in schools; and this could be an area for future research. Edwards (2002:354) echoed the need, noting that not much attention has been paid to governmentality in schools even though quality in education is often discussed.

Unlike Zapholo and Ngwenya, the teachers Leo, Nomfundo, Khwezi and Neon, who all started teaching in 1991, said that they had never been exposed to any form of INSET run by the department to enhance their subject-content knowledge. They believe that INSET courses could make them better teachers if they could be organised into genuine learning spaces (Nespor, 1994), where self-initiative, pro-activity and responsibility are encouraged among teachers.

At the time of this study, all six science teachers reported that there was not much support from the department to ensure that teachers were developing in their field, except for the once-off outcomes-based education workshops. With no other programme, the once-off workshops had proved ineffective; and these workshops had no follow-up support to monitor the implementation process either.

Furthermore, the lack of support by their district office was exacerbated by the fact that there was no science subject adviser to support them in the schools; their last one had been in 2000 – this lapse weakened the network between the district office and the schools.

I maintain that for change to be effective, teacher support and professional development is vital. According to Pollard and Tann (1993) and Southwood (2000), for teachers to be effective agents of change, opportunities for professional development should be available to support an ongoing process. Leo reiterated that for change to be effective in the classrooms, it must start with the teachers, as key actors (see Section 4.2.2) in the education system. Hence in this study, the importance of the TTCPD network is emphasised, whereby teachers are encouraged to work together in non-threatening environments (see Chapter 6). Zapholo stressed:

> Regarding teachers' professional development in this new system, teachers need to have regular workshops so that they are not left behind in this transformation as far as teaching of science and mathematics is concerned. (Active interview 16/03/05)

Clearly Zapholo sees the need for the professional development of teachers. I would add that it would be imperative even if there was no transformation in curriculum. In my experience as a teacher educator, matters in South Africa have been complicated by the fact that some teachers had not yet mastered the old curriculum. So, introducing the one to these teachers has been an additional burden for them. It is for this reason that I propose that networking amongst teachers is crucial, so that they can learn from one another.

Furthermore, relying on teachers to help their colleagues without a formal structure in place can be a futile exercise. For example, when I asked Zapholo, who is involved in helping the district office with continuous assessment (CASS), if he is able to run workshops at his school, he responded:

> I'm very sorry here, it is quite true, you know. I've been involved with the CASS implementation for the past three years, and I've never had a chance of sitting down in my school, in my department, and call teachers together and explain to them how to go about doing CASS because we are all busy trying other things like, culture of going to the classroom, culture of teaching, culture of learning, culture of being early to school, redeployment. (Follow-up active interview 10/10/04)

Zapholo's comment directs attention to a problem of prioritising at his school, which has resulted in some human resources not being used optimally. He also recognised that contextual factors can retard progress and hamper opportunities for school-based support. In the case of his school, these factors are used as a scapegoat.

This also suggests that the cascading model, a process in which some teachers are required to attend workshops and thereafter have to run such workshops for those teachers who did not attend, has to be carefully monitored. For example, Neon complained that whenever teachers from his school had been to a workshop, they simply reported back what the department wanted rather than showing evidence of having been exposed to a collective learning environment. He further commented:

> It seems the most important thing is what the government needs, that is, what they want you to do. The government wants us to do this and that, but we are not told how to do it. (Active interview 6/04/04)

This suggests a mismatch between policy formulation and implementation in certain schools. As a result, the implementation process is neglected, which in turn affects transformation. Similarly, when I asked Nomfundo whether she had been afforded the opportunity to share knowledge with other teachers at her school, she responded:

> It is not easy at all, but Leo and I do try and share knowledge. We feel we acquire a lot of knowledge from our research network, but there is no platform to share it. Its like when

> you've been to a workshop, you are not given any opportunity to run a workshop in your school. That frustrates a lot, you see. (Follow-up active interview 14/02/05)

Despite the fact that some teachers are trying to empower themselves, they find it difficult to share knowledge with their colleagues. I would suggest that schools should be encouraged to set up forums where teachers can discuss educational issues with the view to improving their practice. Senge (1990) reminds us that people have to continually learn how to learn together.

Spanneberg and Brown (2003) and Pomuti *et al.* (2003), too, believe that teachers could benefit from school-based support from peers. They note that one of the potential values for teachers of being engaged in school-based support is that they can learn from one another in a relaxed and non-threatening environment. Another potential spin-off, in addition to the opportunity to share knowledge with each other, is that teachers might learn to believe in themselves. However, it is recognised that trust should be developed first.

It emerged from this study that all six science teachers saw the need for ongoing teachers' professional support to ensure quality of teaching and learning in their schools. However, they recognised that schools ought to be pro-active and accountable to ensure sustainability of school-based support as it was evident that in some schools contextual factors proved to be inhibitors.

8.3.2 Opportunities for personal development and growth

Ngwenya completed an upgrade course in woodwork in 1987 in an attempt to improve his qualifications, but he never had an opportunity to teach woodwork because this subject was not offered at his school. In light of this, he expressed the opinion that it would have been more useful if he had done an upgrade course in mathematics or science so that his content knowledge in these school subjects could improve.

Khwezi indicated that he tried to improve his science-content knowledge through reading different science textbooks. Kallery and Psillos (2001) support the idea that teachers need to be knowledgeable in their subjects since this influences the way they present that content to their learners.

The six science teachers in this study indicated that they all used to attend the science workshops organised by the Science Education Project during the 1990s. The teachers found those workshops invaluable for giving them an opportunity to interact with science teachers from other schools and enabling them to share expertise, ideas and content knowledge. They had therefore been exposed to a learning community of practice (Nespor, 1994). Khwezi had the following to say about the SEP workshops:

> The SEP workshops promoted practical activities, which are seldom done in schools due to the lack of science equipment as well as lack of these skills on the part of some science teachers. Also, those workshops helped novice teachers to be confident when dealing with practical work. It is very embarrassing when a teacher cannot perform a practical activity. (Follow-up active interview 1/02/05)

The teachers indicated that they were also all involved in the Khula Project and the Micro-Chem Kit Project coordinated by the science subject adviser in collaboration with the Rhodes University Education and the Chemistry Departments respectively. Their schools were subsequently supplied with some micro-scale science kits and worksheets for hands-on practical activities with their learners. The science subject adviser in the district was then required to do follow-up support.

The Khula Project provided computers to enhance the teaching and learning of science and mathematics in these teachers' schools, and they all commented that these experiences had been empowering. According to Goduka (2005), a relational worldview does not consist of separate elements, but of relationships among humans, and between human and physical artefacts. These science teachers therefore felt that it is important for the Department of Education to provide support for teachers so that teachers could be effective agents of change.

Little (1992), Southwood (2000) and Spanneberg and Brown (20003) support this view, and they observe that teacher support for quality teaching and learning in schools is imperative. Smyth (1996) concurs that teaching should generate a genuine collaborative and sharing community in which teachers can learn from one another.

In addition to being involved in the projects mentioned above, Zapholo indicated that what was helpful in strengthening his chemistry and physics content knowledge was doing some degree courses through the University of Port Elizabeth, now called Nelson Mandela Metropolitan University. It was then that he realised that science was interesting as this was his first experience of handling science apparatus in a real laboratory. From this experience, he recommended that a teacher teaching at Grade 12 level should strive to do science at university level.

His research skills were further enhanced when he did the MEd course in Science Education at Rhodes University. Similarly, the other science teachers involved in this study did an ACE Science course through Rhodes University and later some did the BEd (INSET) and BEd (Honours) courses. Nomfundo and Leo added that they were also involved in the Environmental Education and Sustainability Unit at Rhodes University to further empower themselves. As a result they managed to encourage another teacher at their school to register for the ACE Environmental Education course. All the science teachers in this study indicated that studying at tertiary level enabled them to keep abreast of the transformation of the curriculum in South Africa.

It emerged that the six science teachers felt empowered by the exposure to the activities organised by the NGOs in the district. Through being involved in such initiatives, they were afforded opportunities to interact and share knowledge with other practitioners. Furthermore, they enhanced their knowledge by studying at various tertiary institutions. This suggests that for teachers to be effective agents of change in their classrooms, they ought to engage in lifelong learning.

8.3.3 Collegial and school-based support

All six science teachers in this study reported that teachers at their schools were not used to working together. They confirmed that there was a culture of working as individuals instead, a notion which teachers inherited at their colleges, where they were encouraged to work independently. Yet, there is the need to create spaces for teachers to network and collaborate so that they can share their expertise. Ngwenya commented:

> At my school there are still problems. We are not used to working together. Teachers still prefer to work individually. It is your baby that if you have a certain problem in your learning area or subject area you should consult with your colleagues on an individual basis. Otherwise, the school has nothing to offer. There is no school-based support. (Active interview 4/05/04)

It is evident from Ngwenya's comment that the collaborative work structures that existed were weak and not mutual and reciprocal. Yet knowledge-building is taken to be a joint exercise within a network (Edwards, 2002). Hargreaves and Fullan (1998) believe that through strong collaborative work cultures teachers become part of a collegial and cohesive professional development. However, Goodnough (2003:515) warns us that "the guarantee for collaboration cannot be given simply because individuals work together voluntarily on shared tasks." It should be recognised, however, that the science teachers in the current study were teaching different grades, something that in my view could have an impact on the level of collaboration and sharing of knowledge. Similarly, power relations in terms of their positions at their school could have an effect.

Similarly, Khwezi indicated that at his school there were no opportunities to discuss certain topics that they teach with other teachers; as a result he had at times felt isolated and had to find his own ways to solve problems. He used to go to his former science teacher, who is also in the research network, who would willingly explain the problem. So, his former teacher was very helpful and supportive.

When I asked Khwezi if he was able to encourage other teachers at his school to work together, he replied:

> In my school we have never worked together in the past, but now have started to work together this year. And we have had two meetings so far. In science I've been asked to take a leading role and in other subjects there are other teachers who have been appointed to be in charge (Active interview 7/02/05)

Actor-network theory facilitates the assigning of roles in networks in order to enhance the learning process. However, this demands commitment on the part of teachers. Khwezi divulged that there was no form of support from the HoD and the school principal, except to be told that they should honour their classes. Nomfundo and Leo indicated that their school principal was also not supportive. Leo offered the following example:

> I remember one time I went with learners from my school to an 'Active Week'. During the 'Active Week', learners from different schools were trained as HIV/AIDS counsellors and were equipped with counselling skills so that they could be able to help those learners affected by the HIV/AIDS at their schools... This should have been launched at our school, but there is no support and these learners are now feeling demotivated. (Active interview 7/04/04)

Nomfundo and Leo felt that their school principal lacked both managerial and leadership skills. They further reported that other school principals attend health-promoting workshops where they share their health-related school problems and their success stories in this regard. Yet their school principal does not attend these, and simply keeps the information in his files in his office; this lack of dissemination of information at their school hampers the school's development.

In contrast, Neon said that his school principal and HoD were very supportive and that the teachers were willing to work together. When I asked Neon if he gets an opportunity to share information with the other teachers, he said that they do so on an individual basis. He said that since most teachers at his school were studying, they were prepared to share knowledge with and support one another. He added that in the past two years of teaching science together with his colleague, who is also in our network, they have become accustomed to sharing and tackling certain science topics together. After the lesson they would sit down and discuss how the learners responded and how they could improve their lessons.

Neon further commented that they would share what kind of questions would be appropriate to ask during the lesson and went so far as to set common examination papers. He said that the activities in the research network had encouraged them to reflect on their lessons. It could be argued that Neon and his colleague did what Dewey (1933) suggested: they have become reflective practitioners (see Section 3.5.1). Such teachers look back over what has been done with the view to modifying future actions, and they can both pose and solve problems. In this study, the science teachers endeavoured to solve teaching problems together. Neon thus felt such attempts to work together broke down working in isolation.

Lortie (1975) and Nias (1989) note that isolation is the most widespread characteristic of teaching. In most cases teachers prefer to work individually because they feel protected from inspection and intrusion. In such a culture, teachers are separated and insulated into classes, depriving themselves of an opportunity to learn from one another. Here, Hargreaves and Fullan (2000) argue that the terms professional and autonomy seem to be inseparable for teachers. The disadvantage of working individually is that teachers are deprived of the opportunity to learn from one another; and hence, professional autonomy might inhibit innovation. Zapholo explained that in the past he used to work in isolation in the science laboratory:

> I would be found in the laboratory for most of my free time, during teaching time and in the afternoons. The reason why I was working alone was because I wanted to familiarise myself with the science-content knowledge, science equipment, solving science problems I had given as homework or class test. And I broke that isolation by making contact with Rhodes University. (Active interview 16/03/05)

In the case of Zapholo, it seems that professional autonomy stimulated innovation as he tried to make use of his free time to familiarise himself with his science work. It should thus be borne in mind that learning starts with an individual. From my own experience, I know that in some schools teachers are not motivated to do their school work. Zapholo's comment also implies that when science teachers are not confident in their science-content knowledge and practical work skills they may prefer to work in isolation since they may not be confident enough to share their limited knowledge with their colleagues.

Zapholo said that although the teachers do talk about the importance of collaboration in their staff meetings, they do not have a formalised working structure to implement such collegial support. It is for these reasons that ANT proposes that teachers in a network should strive to formulate problems together (see Section 4.2.2). However, Ngwenya said he and Zapholo are trying to help one another in their natural sciences department, albeit on an informal individual basis. For instance, they sit down together and discuss what topics to teach and how to teach them. He added that the geography teacher at their school helps him with the theme of 'Earth and Beyond' in the natural sciences curriculum since it has a lot of geography content knowledge.

Ngwenya also seemed appreciative of what was happening at the former Model C schools where his children are currently schooling. He noticed that at these schools the entire school engages in a common topic or theme at the same time. He is optimistic that if they could do that at the historically disadvantaged schools as well, things might improve and that possibly learners might not migrate to the former Model C schools, which are at present believed to be more functional.

On dysfunctionality of schools, I believe that if teachers could work as a team, get more parents involved in the education of their children, and encourage learners to put more effort into their studies, things would improve. Furthermore, if the department is sincere about the quality of education in the schools, they should organise teacher support. Gayford (2001) and others support this view.

Southwood (2000) emphasises that in these collegial processes there should be respect, trust and appreciation of individual's practical knowledge so that teachers develop their common purpose as a community (Hargreaves & Dawe, 1990). Zeichner and Liston (1996) particularly stress the element of trust. A compelling argument here is that professional development should occur throughout teachers' careers (Schäfer, 1999). Sadly, however, such professional development in most South African schools is minimal at the moment.

Leo felt that there was a big gap between the old curriculum and the new curriculum and that teachers needed professional development to refresh their minds. Like Zapholo, Leo commented:

> You know that you have been doing something in the same way for many years and now all of a sudden you have to change the approach. In the past you used to be a teacher who just sits there and instruct the learners, but now you know that you should not just give your learners some activities, but rather you should play your role as a facilitator. Initially, I thought that to be a facilitator meant just to give your learners some work to do on their own, and say they must do a certain activity. They must know things themselves. But as the time went by, you know that you are still a teacher, you must still explain things to your learners and they must understand what they are supposed to do. At the same time as they are busy working you should be part and parcel of the lesson. (Active interview 7/04/04)

Leo's clarification of what it means to be a facilitator is telling. This suggests that the transformation of curriculum is a challenge for teachers. To make matters worse, some school principals lack understanding of the new curriculum and are thus unable to give support to teachers. In this situation, Khwezi feels that professional staff development would not only help individual teachers but also help the entire school to be functional.

Nomfundo commented that when she talks about the importance of collaboration amongst teachers at her school, they seem to make an excuse about the timetable. But in her view, what counts most are the learners. When I asked her why some teachers are not willing to work collaboratively with others, she commented:

> Firstly, the other teachers who were teaching science in our school were not qualified to teach it, they were just asked to teach it to make up the required number of teaching periods. As a result they were not interested to teach science, you see. (Follow-up active interview 14/02/05)

From my own experience as a science subject adviser and teacher educator, this is prevalent in some historically disadvantaged schools, where you will find that science is taught by unqualified or underqualified teachers. In some secondary schools such teachers are usually asked to teach the lower grades where a solid foundation in science is needed. The problem with that arrangement is that, you would find that the learners' content knowledge was poor since teachers themselves were not knowledgeable in the subject.

Khwezi also acknowledged that there were serious gaps in teachers' practical work skills and subject-content knowledge, a view supported by Sanders and Morris (2000). Such gaps might affect the quality of learning among learners. Where teachers' subject-content knowledge is limited, teachers tend to believe that they should be transmitting more information than they do. Yet Schoultz and Hultman (2004:30) believe that "experimental-material with 'hands-on' kits and activity books is not self-sufficient material. It requires a teacher who is active, knowledgeable and sensitive and who will lead the student on the path to new knowledge."

Neon indicated that he would like network actors to deal with the problems of assessment again since he still grappled with this. He commented:

> With me, something that I'm very interested in is assessment. I feel I'm not sufficiently clear in it. I would like us to do it again in our network. Another thing is that I did not attend any OBE workshops because when these are run, the district office says that they want only one teacher per school, whilst we have five teachers teaching one learning area. (Active interview 6/04/04)

Spanneberg and Brown (2003) propose that teachers should form clusters so that they could support one another rather than working individually.

In this section, the six science teachers' professional development and support experiences have been compared and contrasted. It emerged that only two science teachers were formally exposed to in-service training courses organised by the department which focused on subject-content knowledge. Although in the professional development literature reviewed in this thesis (see Section 3.3.3), Gilbert (1994) refers to the kind of teacher 'training' that these two teachers received as 'technicist' and as a deficit model, the teachers reported that they found these courses worthwhile and informative since they enhanced their very limited subject-content knowledge.

However, what frustrated them upon completion of their courses was that when they went back to their schools they did not have the science equipment used in these courses and so were unable to implement the knowledge and skills they had learnt. In my view, equipping teachers with competences and skills that they are unable to apply is an extremely frustrating one. This is all the more serious in terms of the paradigm shift in professional development Loucks-Horsley *et al.* (2003) propose from transmission of knowledge to experiential and problem-focused learning.

It also emerged that in the departmental courses in the past, there was none of the follow-up support given suggested by Spanneberg and Brown (2003). Instead, teachers used to be visited by inspectors, who focused on their planning files and the learners' books to check how much work, as prescribed in the work programme, was covered. As a teacher, I also found that teachers were not required to deviate from the department's work programmes.

Although the visits by the inspectors were threatening, teachers were forced to 'pull up their socks'; unlike today, whereby many teachers seem to do what they like and seem not to be accountable to anyone. It would seem that for some schools to be functional, improved working relations with the district office and commitment on the part of teachers is needed.

The six science teachers pointed towards the usefulness of interaction with other science teachers during the SEP workshops which had been run by an NGO in the past. They said that those workshops promoted interactive practical activities even though they were prescriptive and this helped towards the creativity and innovation that was needed on the part of science teachers. The teachers also reported that they were all involved in the Khula Project and the micro-scale science kit project coordinated by the Rhodes University Education and Chemistry departments respectively.

Through being involved in such projects they felt that they were afforded opportunities to be engaged in professional development (Southwood, 2000; Spanneberg and Brown, 2003). Their appreciation suggests that all the teachers would benefit all the time from empowerment programmes. They could be helped still more by school environments designed to be more conducive to learning.

Presently, the six science teachers do not get any form of professional support from the department except for OBE workshops that are run for teachers, which are once off. The teachers believe that there is a need for ongoing workshops for their capacity-building. They even suggested that such OBE workshops should not cover a lot of work in one time and that teachers should be accredited for attending them. On a positive note, however, some teachers are improving their qualifications through studying at various tertiary institutions, which helps them to cope with the transformation in the curriculum.

All six teachers said that collegial support was essential but that at present they had no opportunities to discuss subject-related topics with their colleagues. They felt that this was exacerbated by the fact that there was no form of school-based support where teachers could discuss with colleagues. Instead, teachers have to fend for themselves or help one another on an individual basis. Lacking collegial support and teamwork, teachers are thus pulling in different directions as they tend to work individually, which do not accord with the advocated principles of the new curriculum.

Loucks-Horsley *et al.* (2003) suggest that teachers should function as part of a learning community. This is far from the case at present. For instance, in this study it emerged that in some schools even if teachers have been to a workshop, they would be unable to run similar workshops for other teachers.

Poor management and leadership skills were also highlighted as among the potential barriers to teacher support, affecting dissemination of information in some schools. For example, three science teachers in this study said that they seldom have departmental meetings at their schools. This suggests that the coordination of activities and communication within these schools is likely to be poor. From my own experience as a teacher, I believe that it is necessary to have synergy of school activities for a school to function properly. This could also help to strengthen collaboration and team work among teachers.

According to Richardson and Anders (1994), collaboration among teachers is likely to help them to transform their classwork and reflect more deeply. For Loucks-Horsley *et al.* (2003), in collaborative processes "teachers become co-learners and co-creators of learning communities." In such circumstances, understanding and experience become mutually constitutive (Lave & Wenger, 1991).

8.4 Concluding remarks

This chapter reviewed the practice of teaching and professional development and support experiences of the six science teachers in this study. The analysed data revealed that their practice of teaching was heavily influenced by their past experiences at the teachers' colleges, which they found themselves putting it into practice. They thus felt that ongoing professional development and support for teachers was essential for change to be meaningful and effective, and to ensure quality education.

The next chapter examines the benefits of the teachers' transformative and continuous professional development network on their conceptualisation of science, and the curriculum, and subsequently the transformation of their practice. One function of this collaborative network was to develop and implement learning and teaching support materials with a view to improve teaching and learning of science. The idea of networking is at the heart of this thesis. The support of learning spaces for teachers is an essential element in quality education.

Chapter 9

The TTCPD network:
Data analysis and findings

> The process of collaborating with other teachers and curriculum experts enriches the professional development opportunities. Through analysis of curriculum and discussion, teachers build their own knowledge of the content, curriculum organisation and design, and content-specific pedagogy. They begin to identify content that they do not understand and plan together to address such gaps. They return to their classrooms with new views. Also, by collaborating with others, teachers become less isolated in their individual classrooms and develop a broader perspective of science and mathematics education.
>
> (Loucks-Horsley *et al.*, 2003:122)

9.1 Introduction

In this study, the influence of the science teachers' transformative and continuous professional development network on their practice was examined. One function of this collaborative network, which Loucks-Horsley *et al.* (2003) believe enriches professional development opportunities was to develop and implement learning and teaching support materials. The LTSMs were to expand the science teachers' capacity to create the results they desired in their classrooms (Senge, 1990).

This chapter thus explores the six science teachers' perspectives on their involvement in the network. The idea of networking is at the heart of this thesis on the provision of learning spaces for teachers as an essential element in quality education. As an attempt to pull key issues and ideas together, some concluding remarks are provided.

To address these aforementioned aspects, the following questions were posed:

Does engaging science teachers in a TTCPD network

- influence their subject-content knowledge, pedagogical-content knowledge, perspectives and assumptions about their practice?

- enhance collaboration and collegial support amongst them?
- enhance individual and collaborative reflections on their practice?

These questions were useful in framing the interviews and some answers to them have been interwoven throughout this chapter.

9.2 TTCPD network: Implications for professional development

In this section, the six science teachers' experiences and perspectives of being involved in the TTCPD network are discussed, as are their perspectives of engaging in individual and collaborative reflections.

9.2.1 Teachers' perspectives on their involvement in the network

Zapholo explained that before he became an actor in our research network he had what he metaphorically refers to as 'the classroom and me' (Active interview 16/03/05). He believed that if he were teaching, allowing someone else to come into his classroom would harm the teaching process; his science classroom belonged to him and nobody else could interfere while he was teaching. Nomfundo and Leo confirmed that Zapholo used to work alone in the science laboratory (see Chapter 8). Although they would have loved to interact with him, they struggled to find space in the timetable for this.

As Lortie (1975) describes, Zapholo was separated and insulated from other teachers at his school. I would contend that his school context possibly did not provide opportunities for teachers to network. Although the proponents of actor-network theory (see Section 4.2.2) advise that teachers should secure spaces for networking and collaborating whereby they become part of a learning community (Senge, 1990), I would caution that we should not lose sight of the situations in which teachers are working.

Nias (1989:13 - 6), too, observes that to be a teacher is "to work in a historically determined context that encourages individualism, isolation, a belief in one's own autonomy and the investment in personal resources" emphasising "the uniqueness of an individual, the specificity of context and the primacy of the person." However, although such isolation might protect teachers from intruders, it unfortunately deprives them of the opportunity to learn from one another. Furthermore, while a belief in one's autonomy and personal investment is necessary, I believe that such autonomy could be enhanced if there are opportunities to interact with other practitioners.

Hargreaves and Fullan (1998) and Nias (1989) argue that isolation and individualism might inhibit collaboration, depriving teachers of opportunities to develop shared professional knowledge. However, what could add value to what is proposed by these writers would be to explore and explain the factors that might lead to such isolation and individualism. From my own experience as a school teacher and a teacher educator, if you have no knowledge to offer, you will tend to shy away from your colleagues.

This suggests that the relational worldview that Goduka (2005) alludes to in Section 4.2.2, in which people receive and give to each other requires opportunities for capacity-building to be effective. Similarly, co-learning as proposed by Senge (1990) is a skill on its own that needs to be learnt. In view of this, before we blame teachers for being reluctant to collaborate with others, I suggest that we need to determine the underlying issues that might contribute to such reluctance. Likewise, we should be careful not to fall into the trap of making collaboration a slogan and hence generalise how teachers should be functioning.

In contrast to his previous private style, after joining our research network, Zapholo said that he felt that it was quite good to allow your colleagues to come into your classroom while you were teaching. He went so far as to suggest that one's colleague could assist by co-teaching or that they could observe you and how you do things. It is recognised, however, that for a genuine learning community (Senge, 1990) to be created among teachers, they have to learn to work together first.

Furthermore, through his involvement in our network, Zapholo said that he was afforded an opportunity to pilot and discuss his teaching and learning unit of work, something he had never done before in his teaching career. In the past, he said, if he had planned a lesson he would be satisfied with it as the information was taken from the prescribed textbook. He indicated that he found the input and suggestions from network actors invaluable. As a result, he was able to modify certain sections in his unit of work to suit his learners' needs. In short, his unit of work was enhanced by his sharing the materials with his peers; it could be argued that this is one of the benefits of networking. Development of LTSMs was central in this study.

Czerniewicz *et al.* (2000) emphasise that the development and adaptation of LTSMs that are relevant to the learners' different contexts should be the focus in curriculum development. Yet they feel that insufficient account was taken of resources and capacity when policy on the new curriculum was formulated in South Africa. It is for these reasons that I contend that a TTCPD network was essential for the capacity-building (see Chapter 6) of the science teachers involved in this study.

In addition, being exposed to the different perspectives of the other science teachers in the network, Zapholo found that presenting his work to his peers enhanced both his presentation skills and confidence. He thus urged that teachers should not to be afraid to talk to their colleagues about their schoolwork. It is recognised, however, that it takes a brave teacher to disclose that they do not understand certain topics that they are teaching.

From Zapholo's report we can deduce that he now sees the need for collegial support among teachers. In the literature reviewed in this thesis (see Section 3.3.2), Zeichner and Liston (1996), Hargreaves and Fullan (1998), Southwood (2000) and Spanneberg and Brown (2003) all support the idea of collegial support through networking among teachers. It is acknowledged, however, that this requires trust and openness to be established among the community of practitioners (Locks-Horsley *et al.*, 2003). In this study, trust was developed and fostered through showing respect for the teachers' views during the workshops (see Chapter 6), as proposed by Law (1986).

Through collegial support, Zapholo believes, teachers could learn how to accommodate both intradisciplinary and interdisciplinary integration in the subjects they teach. It is of course recognised that this requires teachers to be authorities in their subjects. For example, in this study Zapholo claimed that one of his strengths was the ability to develop LTSMs using 'easy-to-get' resources. He also aspired to be a lifelong learner (Czerniewicz *et al.*, 2000; Edwards, 2002) through improving his science-content knowledge by doing some degree courses.

Furthermore, he has been teaching Grades 8 to 12 science classes for many years and thus was familiar with the subject content; although, like Brookfield (1995), who notes that experience should not be equated with expertise, Zapholo also felt that teaching a certain grade for many years would not necessarily guarantee that a teacher would be more knowledgeable in the subject.

Reflecting on some network actors, he believes that some still lacked confidence in developing their LTSMs although they have been teaching science for quite some time. He ascribed this to the fact that some of them were not comfortable with certain topics in science. For example, Leo and Nomfundo indicated that they did not do chemistry when they were doing the teachers' course (see Chapter 7). Sherin (2002) and Murphy *et al.* (2004) believe that insufficient subject-content knowledge, lack of experience in science practical investigation, and lack of resources can have an impact on teachers' confidence. Lack of confidence in turn may contribute to science being taught in uninteresting ways.

To me the link between conceptual understanding in science and self-confidence is clear. Kallery and Psillos (2001:166) warn us that teachers' subject-content knowledge affects teachers' pedagogical-content knowledge. However, I would like to caution that confidence does not necessarily equate to being knowledgeable in the subject that you teach.

One of the positive outcomes of network actors working together was that Zapholo kept a helpful watch as Khwezi designed a learning programme unit for the entire year. The LPU was subsequently discussed, modified and shared with all the network actors. This was another indication of the transformative learning taking place in the network. In this study, it could be argued that both Zapholo a nd Khwezi assumed the roles of principal actors (Law, 1986). I regard this as evidence of their development and growth in the TTCPD network.

Furthermore, Zapholo noticed that his colleague Ngwenya had started teaching the topic of *electricity* after there had been a network workshop on the subject. In the past Ngwenya had started with the biology section, which Zapholo thought he could be more comfortable with. To him this was evidence of the impact of the TTCPD network on his colleague's development. I would contend that the availability of LTSMs (Czerniewicz *et al.* 2000) proved stimulating. This suggests that, for capacity-building we need both human and physical resources as proposed in ANT (see Section 4.2.2).

Likewise, Ngwenya's willingness to do co-teaching and participatory observation (see Section 5.4.1) in the afternoon could be viewed as evidence of his commitment to collaborate with his colleague. It could thus be argued that co-teaching (Murphy *et al.*, 2004) and participatory observation do play a vital role in enhancing co-engagement (Goduka 2005) and hence confidence amongst teachers. Although Ngwenya was active in helping learners during the practical activities, he felt that he was not yet ready for collaborative teaching where he could be in the driving seat. This suggests that professional development is a process that takes place over time; and my observation was that actors develop at different paces.

Regarding his engagement and participation in the network, Zapholo commented:

> I feel that my science subject-content knowledge has rendered me invaluable in our research network. In most cases my teaching experience and my subject-content knowledge has helped me to explain things to my colleagues in the network better than I would have done three years ago. Also, my teaching and learning approaches have improved; as a result, I am changing all my old worksheets and my old notes to suit my present style of teaching and learning. (Follow-up active interview 10/10/04)

Zapholo's perception that his teaching experience and subject-content knowledge had rendered him invaluable in the team was confirmed by both Leo and Nomfundo. For optimal participation of all network actors, however, Zapholo suggested that there was a need for more practical activities; presentation of lessons, with key concepts to be developed clearly identified; and visits to each other's schools to support one another.

Nomfundo concurred that interschool class visits to do co-teaching and participatory observation could add value to our experiences in the network. She felt that this could give actors an opportunity to learn and reflect from each other to a greater extent and subsequently would allow suggestions on how improvements in teaching and learning could be made. Her thinking confirms Mezirow's (1991) and Cranton and King's (2003) assertions that knowledge about teaching is communicative and emancipatory rather than instrumental. Furthermore, questioning and reflecting on what teachers do, and how, is critical.

Senge (1990) and McNiff (2002) support the idea of having practitioners learning together, and both experienced and inexperienced practitioners need such opportunities. For example, although Zapholo is an experienced science teacher in this study, through being involved in the network he was afforded an opportunity to improve his teaching and learning strategies. This suggests that, no matter how experienced a teacher is, learning has no boundaries (Brookfield, 1995). Zapholo commented:

> The knowledge and experiences I have acquired from being a member of the network has been invaluable. I have become a much stronger and much more improved science educator with a new confidence and eagerness to share my experiences of the physical world we inhabit. (Active interview 16/03/05)

I believe that Zapholo's willingness to share knowledge with colleagues was enabled by the learning spaces provided by the network. This is in line with Nespor's (1994) assertion that knowledge and learning are products of socio-cultural activities. Similarly, Ngwenya also felt that being a member of our research network had impacted positively on how he now taught science.

When I asked him what had influenced him to change his teaching and learning strategies, he replied:

> What has helped me is that there is a group of science teachers I'm working with and we meet at the Education Department, Rhodes University. In our network we have workshops to improve our conceptual understanding in science and clear our misconceptions, and discuss ways of improving our teaching and learning approaches. Furthermore, we are supporting one another because we come with our problems and share our teaching experiences of the lessons we've taught in our schools. (Active interview 4/05/04)

Ngwenya said that being involved in the research network allowed him to clear up some of the misconceptions he had in science as well as affording him the opportunity to find out from other colleagues how they approached certain science topics. This, he said, enabled him to have a better understanding of the various science topics and enhanced his teaching and learning skills. He added:

> In the past I used to plan on my own. But now I take some ideas from the team to enrich my lesson plans. That is, I now have a variety of sources of information rather than relying only on the textbook as I did in the past. Planning and discussing with colleagues also helps to answer some of the learners' challenging questions. I feel when you are a teacher if you are clear and knowledgeable in your subject-content knowledge, you won't experience many problems in class. (Active interview 12/05/05)

Ngwenya's comment declares that he has shifted from relying solely on the prescribed textbook to using a variety of resources to obtain information. He went on to say that, ever since he had tried some of the approaches he had learnt from the network, in his opinion his learners enjoyed science more. However, he expressed a need to have similar initiatives in their schools in other subjects or learning areas, such as mathematics, and not only in science. In his opinion, mathematics is one of the problematic subjects for teachers and learners alike; hence, his proposal is that mathematics teachers should try and support one another as well.

Kallery and Psillos (2001) note, teachers who are not knowledgeable in their subject-content would embed their misconceptions in the lesson plans, thus passing these on to their learners. Thus they suggest that "issues that relate to what sort of knowledge teachers might need in order to become effective practitioners, what teachers know and how their knowledge informs the classroom practices are central questions to those concerned with teacher education and continuing professional development" (*ibid*:166).

Nespor (1994) suggests that in order to understand how an activity is connected to learning and knowledge we have to understand the interactions within a network. For example, regarding improvements which Ngwenya believed needed to be made in the network, he said:

> What I've noticed in the network is that it is very rare to find that the entire network members are present in our workshops. You find that other people have other commitments on our workshop days. Another weakness on my part, which I have in the network, is that sometimes I do not attend our workshops, as result I find that I'm left behind. Otherwise it is very useful to be part of the network. (Active Interview 4/05/04)

Clearly time, space and prioritising proved challenging for some network actors. Also, the fact that Ngwenya was left behind when he did not attend our workshops suggests that although he and another actor were from the same school, they seldom met to share what was discussed; this contradicts ANT's perspective that sharing of knowledge by practitioners is essential to expand their capacity.

As a solution, Ngwenya suggested that dates could be set aside for the entire year so that network actors could commit themselves and plan around those dates. He acknowledged that there were always unforeseen circumstances, but his comment shows that teachers have to commit themselves when they engage in professional development initiatives. According to Babikwa (2004), actors need to develop an inner-self motivation.

It should be emphasised, however, that actors must gain from initiatives. For example, Leo commented:

> When I first joined our research network in 2001, initially I was reluctant thinking that it was a waste of time. But as the time went by, through attending our workshops, I obtained useful information and I thus felt motivated because each and every time I found that I was enriched and improving in my science content knowledge and conceptual understanding. (Active interview 1/02/05)

It is evident from Leo's comment that subject-content knowledge and conceptual understanding are important. She also said that she found being a member of the network very useful as she had had a problem with designing her teaching and learning units of work as well as learning programme units. She indicated that in the past she had relied on preparing short-term lessons rather than planning over a long period of time.

After engagement in our TTCPD network, she feels confident in preparing for her classes; and when preparing activities for her unit of work, she referred to what had been done in the network. Capacity-building is evidently needed for the development and evaluation of LTSMs (Czerniewicz *et al.*, 2000). Edwards (2002) emphasises that knowledge-capacity-building is essential for teachers to be effective in their classrooms.

Like Ngwenya, Leo said that being in the network had encouraged her to find additional information from various sources when planning her units of work, rather than relying only on the textbook as she had done in the past. She commented:

> Initially, I always believed that a prescribed textbook was sufficient, but now I do some comparison to ensure that I have the correct information. For instance, I also make use of mind maps and concept maps, something I was not familiar with in the past. (Active interview 7/04/04)

This suggests that she recognised the need to be textbook-literate through comparing and contrasting information from different textbooks. She added that she felt that she had acquired scientific knowledge and many skills from the network that render her more effective in enhancing learning. As a result, she thought that her learners understood concepts much better when she used the concept map strategy rather than just getting them to read notes.

Leo, Nomfundo, Ngwenya, Khwezi and Neon all concurred that in 2002 when they registered for the ACE science course at the Rhodes University Education Department the importance of being members of the network became more pronounced. Furthermore, they indicated that being network actors also motivated them to do the BEd (INSET) and the BEd (honours) courses, something which further contributed to their empowerment. Leo and Nomfundo were involved in the Environmental Education unit as well.

Leo indicated that as a result of being involved in the research network she felt confident to the point that she was able to teach up to Grade 12. However, I feel that this might be an over-ambitious aspiration for a teacher who did science only up to Grade 11 and did not do chemistry at the teachers' college. It may be useful for her to do some science degree courses as Zapholo did, to improve her content knowledge.

Like Ngwenya and Nomfundo, Leo added that the science demonstrations conducted in the network were particularly helpful in clarifying some of her misconceptions. I too believe that it is vital for teachers' misconceptions to be cleared; and all the more so, taking into account the point in Osborne and Simon (1996), that a teacher with limited science knowledge may not be aware of learners' misconceptions. In either case, the teacher would find it difficult to provide clear explanations for the learners; subject-matter content-knowledge is important for the adaptation of the materials to "students' abilities, prior knowledge and preconceptions" (Kallery & Psillos, 2001:167).

This shows that how strong the relationship can be between subject-content knowledge and confidence, and indicates that teachers' ongoing professional development is indispensable. Ongoing professional development should target teachers' subject-content knowledge, pedagogical-content knowledge and other skills. Leo's comment supports this assertion:

> Sometimes demonstrations would be made in the network and this contributed to our development. I feel this has developed me a lot because I have gained confidence to teach both the natural sciences and the physical science. This has been useful too since my background to teaching was the old one from the teachers' college, that is, 'chalk and talk'. That is, I used to read the textbook only and teach all that information as it is to my learners. But now, through being involved in our research network, I started to grow and then I was exposed to finding more information rather than only relying on the textbook. (Active interview 1/02/05)

Here, Leo highlighted the importance of demonstrations and modeling, acknowledged the impact of how she was taught at the teachers' college. Walker (1991) and Smyth (1996) in the literature reviewed in this study observe that teachers' professional knowledge is shaped by how they have been socialised in the teaching profession. They say that teachers who have been socialised into transmission and rote learning will tend to put that in their practice. However, I would caution readers against labelling all teaching from the past as transmissive: teachers still needed to explain and clarify scientific concepts or information for their learners. In my opinion, consolidation of concepts is not necessarily transmission of knowledge. It emerged that Leo felt empowered by this process of consolidation of key concepts, echoing Nespor (1994) who says that knowledge-constitutive activities can provide opportunities for capacity-building among teachers.

Leo indicated that she had felt that there was a ceiling over her head as a result of the grades she had taught in the past. She commented:

> But I'm still worried that I have been teaching lower grades with a focus on OBE for a long time. I feel the level at which I was teaching in the past has deprived me of opportunities to participate fully in our network. I tended to have a limit in terms of science-content knowledge. I think if I was given an opportunity to teach senior classes in the past I could have gained more knowledge and that could have enhanced my level of participation. (Active interview 1/02/05)

From Leo's experience, it is evident that teaching in the lower grades without getting any form of professional development and growth could result in a teacher becoming unnerved by subject-content knowledge. As a matter of fact, since she has been assigned to teach Grade 12 in 2005, she felt that the assistance she had received from the network actors has been very empowering.

Nomfundo also said that ever since becoming a member of our research network she had felt much more confident; however, she felt that there was a lot more she could do to improve her teaching and learning in science, that learning is an ongoing process. She commented:

> The practical activities, which were conducted in the network, were an eye-opener. Also, the learning programme unit that he discussed and shared with us, I'm using it and I find it very helpful. And the skills I have acquired from the network I'm trying very hard to implement in my school. (Active interview 7/04/04)

Clearly, Nomfundo benefited from the activity-based approaches adopted in the network. What Leo found particularly helpful was that in the network there are two teachers from the same school. Unlike Zapholo and Ngwenya, Nomfundo and Leo shared ideas and helped one another often in their school environment and as a result she found working collaboratively with her colleague very empowering; as Pomuti *et al.* (2003) state, teachers are likely to benefit from ongoing school-based collegial support.

Leo also saw a need for the network to have regular workshops in order to cover enough science topics. She said that network should have a chance to prepare and present lessons and then to discuss the lessons so that, through being involved in the research network, individual actors, as proposed by Spanneberg and Brown (2003), could learn to believe in themselves and show willingness to take responsibility for their learning.

It emerged that Leo and Nomfundo were still grappling with designing LPUs; yet this is critical for long-term planning. It is recognised, however, that long-term planning hinges on the amount of subject-knowledge a teacher has. Here, I would argue that it is very important for a teacher to understand beforehand which concepts will be developed during any lesson. In fact, I would suggest that teachers should strive to move beyond this and consider how the key concepts link in order to promote conceptual understanding.

On the teaching strategies that Nomfundo learnt from the network's activities, she reported that through implementing these she found that her learners were cooperative and she thinks that they enjoyed science: her classroom as an actor-network has been transformed - in the past she felt that her learners had a negative attitude towards science, and evidently the way she taught science did not excite them. According to Schoultz and Hultman (2004), it is important for teachers to create contexts, which give learners motivation and desire to learn.

From my own experience as a teacher educator, this ability is lacking in some schools because many teachers are asked to teach subjects they have not specialised in. For example, in this study Khwezi reported that the discontinuation of Afrikaans as a school subject in his school had resulted in some teachers being asked to teach natural sciences instead.

Khwezi said that he found being involved in our research network and the discussions very useful and inspiring. He expressed the feeling that his practice was gradually improving since he was able to bring his problems to the network and to share ideas and experiences about the teaching and learning of science at his school. He was particularly excited that, once he began implementing these ideas at his school, his learners seemed enthusiastic about science – as Nomfundo had also found. Furthermore, as a result of his involvement in the network, his first group of matric learners did very well in their end-of-year examinations in 2001.

He therefore felt that through his involvement in the network he was getting opportunities to grow and develop professionally, something which was lacking with the department. According to Robinson (1999), lack of professional development and growth can impact negatively on the teachers' effectiveness in their classrooms. It is within this context that this study attempted to create a community of learning for the senior secondary school science teachers.

All the science teachers involved in this study reported that they were benefiting from being involved in the research network, as it served as an opportunity for their professional development and growth. Ngwenya, Zapholo, Leo and Nomfundo indicated that it was also advantageous to have the support of colleagues from their schools rather than being on their own. Leo and Nomfundo said their advantage was that they had been together at the teachers' college, something which could have contributed to their ability to collaborate. They felt that this served to facilitate ongoing collegial interaction at their school. Furthermore, Nomfundo felt that collaboration enables her to meet the demands of her learners and her collaboration with Leo had helped to improve their conceptual development and their self-confidence. Similarly, Ngwenya commented:

> It is a great advantage that there are two of us from the same school in the network because whenever I encounter a problem, I immediately go to my colleague to ask for help. But my colleague is so busy. However, he does sometimes make a chance for us to discuss science related issues. (Active interview 4/05/04)

Ngwenya approached his colleague for assistance but this was not reciprocal. From his comment it is also clear that time and space can inhibit effective collegial support within schools. When I asked Khwezi how he felt about the fact that there was no other science teacher from his school in the research network, he responded that he was not feeling it that much, but realised that it would have been useful if there was a colleague from his school too so that they could plan together. But he said that he was happy with the support he is getting from the network actors.

Khwezi also said that he had learnt, among other things, how to develop inquiry-based LTSMs; design science teaching and learning units; and design learning programme units; as well as, how to do rubrics for assessment purposes for different skills. The advantage with LPUs is that they facilitate planning for the whole year so that you can see a bigger picture. He added that he was feeling much more comfortable with the outcomes and the skills to be developed during his lessons.

Another aspect which he had found useful from the network is the idea of mobilisation and incorporation of learners' prior knowledge during teaching and learning. He said that in the past he used to explain everything to the learners himself, but now he also gave them an opportunity to share their ideas and to be actively involved in the construction of understanding of the knowledge. Roschelle (1995) cautions that neglect of prior knowledge could result in learners learning something opposed to the teachers' intentions for learning and he also warns that prior knowledge could be at odds with what is taught, resulting in little learning taking place.

Khwezi further indicated that he had learnt from the network the skill and importance of linking what you teach to the everyday lives of learners, making science more relevant for them. Smit (1998:26) cautions that the term 'relevance' in school science has been used to drive the transformation in science education, yet it might mean different things to different people. Furthermore, I would argue that relevance could be influenced by people's context in which they are living.

On his participation in the network, Khwezi said:

> One of my strengths, I think, is that I'm committed and I've shown this through attending the network's workshops regularly. I'm always attending and I'm also happy with my level of participation [laughing]. However, I feel that this needs to be extended to other teachers, provided of course they are prepared to be committed. (Active interview 20/04/04)

Emphasising the importance of commitment and attending workshops regularly, Khwezi stressed unlike Leo - that he was happy with his level of participation in the network. Another experience he said would remain indelibly in his mind was presenting at the Research Methods and Interpretation courses organised by the Education Department. This suggests that professional support and empowerment of teachers can take place in many ways. In light of his experiences in the network, Khwezi emphasised that it is important for teachers to collaborate so that they can complement each other's weaknesses, and share knowledge and ideas in order to improve their teaching, learning and assessment strategies. He further commented:

> I see participatory action research as a potential vehicle for change and improvement in the classroom. I also think that PAR is about an attempt, which is made in collaboration with colleagues to understand and improve the teaching practice. (Follow-up active interview 1/02/05)

It is clear here that Khwezi sees the need for teachers to work together as Spanneberg and Brown (2003) observe that such self-supporting communities of practice might result in teachers seeing themselves as self-sufficient human resources.

Leo still needed some support in research on her practice and in presenting work at conferences. She felt that engaging in research could contribute to the improvement of her teaching and learning. This agrees with Majara and Raubenheimer (1997), who posit that becoming a teacher researcher is characterised by being involved in reflection and deliberation about classroom practice. Furthermore, through research, teachers could further grow professionally and become effective change agents (see Section 3.4.2).

In this study, all six science teachers were dealing with learners from poor socio-economic backgrounds. Thus, by making science relevant to their lives, they noticed that they were able to apply science knowledge in their homes that they learnt in the classroom. In the past, however, Khwezi confessed, he had presented science in isolation rather than within the context of real life (Baker, 1998) since he had no one to discuss the scientific knowledge with.

Neon reported that through his involvement in the research network he was able to resolve issues he was grappling with in the new curriculum. He commented:

> In the network some of my misconceptions such as 'the force of gravity' have been cleared. When I was at school I was told about the force of gravity and this is how this is written in some textbooks as well. I feel that being exposed in this network is an empowering experience for me; as a result the idea of allowing learners to brainstorm, which I learnt from the network, is very helpful. Initially, I thought brainstorming was intended just to while away time so that you could hear the learners' ideas, and not taking seriously the things they have mentioned during the process. Also, I never bothered to link what is taught at school with my learners' everyday life experiences. It was only my information that I regarded as important. (Active interview 6/04/04)

Neon realised that teachers ought to see themselves as human resources who are responsible for clearing up misconceptions through networking with their peers. Kallery and Psillos (2001) note that misconceptions can be present in the language of teaching and this can cause learners' misconceptions to remain.

Furthermore, Neon pointed out that it is helpful to have a colleague from his school involved in the network so that they can help one another. However, he pointed out that he was the one who always shares the information from the network, as his colleague was absent from the network's workshops most of the time since he was actively involved in the activities of the teacher's union. He added that he normally advised his colleague on how to get information and on how to deal with certain aspects of the work more quickly and easily. Neon further mentioned that sometimes they would do co-teaching and helped one another and in the process they had not experienced any problems with learners comparing their teaching abilities. In his view this could be a potential problem during the process of co-teaching.

Neon suggested the following items that needed to be improved in the network:

> In our workshops we need to keep focused and do our reflections on our experiences in our classrooms for the first hour, and then focus only on one aspect, for example, assessment. Assessment is the major problem I'm still grappling with. After we had discussed assessment in our network, I started to realise the different assessment strategies and how to apply them. (Active Interview 6/04/04)

While I agree with Neon that assessment is critical, from my own experience if you teach a subject you are not comfortable with you are likely to struggle with the assessment. On the development of LTSMs, Neon commented that he felt much more comfortable as far as science-content knowledge was concerned and he was happy with his level of participation in the network. However, he indicated that there was a need to spend more time on science content, and proposed that we run our workshops more regularly in order to be able to tackle more science topics. Such dedication is to be applauded but surely this was not feasible or sustainable since network actors have other commitments at their schools.

This section addressed how the six science teachers saw their involvement in the TTCPD network. From the analysed data it emerged that the teachers benefited in many ways. It became evident that knowledge-building was best constructed in collaboration with colleagues and that this enabled teachers to see themselves as co-learners who have to be lifelong learners.

9.2.2 Engagement in individual and collaborative reflections

All six science teachers confessed that they had not bothered to reflect on their lessons before becoming involved in the network as they had never been exposed to doing so at the teachers' colleges. Engaging in reflections was something new to them. Yet, for Hargreaves and Dawe (1990:229), "reflective practice brings together the principles of practicality, collegiality, and reflection as a basis for professional development."

To show how practitioners enhance their practice while they are constantly engaged in it, Schön (1983, 1987) uses the term 'knowing-in-action'. Schön believes that such 'knowing-in-action' is converted into 'knowledge-in-action'. What Schön does not explain explicitly, though, is what contributes to the quality of such 'knowing-in-action' and 'knowledge-in-action'.

For example, instead of engaging in reflection, Leo said that she used to complain to other teachers about her learners not being serious in their studies. To say the least, this is common practice amongst most teachers. Yet, according to Cranton and King (2003), critical self-reflection on teaching can be a starting point for continuing, self-directed professional development.

The actors reported that through the research network they had learned to reflect on their lessons and found this process very useful in informing their practice. That is, as proposed by Schön (1983, 1987), they were afforded opportunities to engage in both the 'reflection-in-action' as well as 'reflection-on-action'. Based on their experiences, they recommended that after a lesson it would be wise to sit down and ponder what went right and what went wrong. It was recognised that a sound knowledge base on the part of teachers would enhance reflections.

Neon cautioned that the danger of not engaging in reflection was that one might carry on teaching in the same manner as before, assuming that what was done was the right thing; whereas, upon reflection, one might realise that there was a need to make improvements here and there. Bodner (1986) agrees and points out that it is common practice for some teachers to teach well with little learning taking place. This suggests that courses on teachers' professional development should encourage teachers to engage in reflections. I would argue that such reflections could be enhanced further through collaborative development of LTSMs as we endeavoured in this study.

All six science teachers indicated that doing and writing reflections was helpful in that after the lesson one was able to see where improvements to lessons could be made and they thus recognised that it was important to put things in writing. Leo said that what she found very useful in enhancing engagement in reflections was the fact that the network actors were afforded opportunities to share their teaching experiences at their schools. Furthermore, different ways to approach lessons were discussed. Zapholo indicated that he also saw reflection as a stepping-stone towards doing research on his own practice; teachers ought to see themselves as researchers (Majara & Raubenheimer, 1997).

To Stenhouse (1978), becoming a teacher researcher requires a shift from the traditional approach to teaching to a teaching repertoire that includes reflection and deliberation about classroom practice so that through research, teachers could grow professionally and become effective change agents (see Section 3.4.2). Research could also enable teachers to question their perspectives, underlying assumptions and beliefs (see Section 3.4.3).

Here, Majara and Raubenheimer (1997:511) note that "becoming a researcher also needs an ability to be reflective and critical of oneself, of others around you, of activities engaged in and their outcomes." In essence, research capacity-building could be on the agendas on teachers' professional development. From my experience as a teacher educator, however, it is recognised that not all teachers are researchers.

Zapholo, Ngwenya, Nomfundo, Leo and Neon agreed that what they found very useful was doing co-teaching and thereafter collaboratively reflecting on how the lesson went and how to make improvements. Pollard and Tann (1993) and Richardson and Anders (1994) support the view that when teachers engage in reflection collaboratively, reflection might be enhanced as they are more likely to share and support one another in reciprocal ways. In my opinion, teachers need to strive to improve their conceptual development while they reflect. Liston and Zeichner (1990) add that it is the collaborative character of reflective teaching that gives it its power.

For example, Leo commented that she found it helpful to work with Nomfundo at their school and most of the time they tried to find time and space to talk about teaching and learning. She emphasised that, for her, working together indeed contributed a lot to their being reflective practitioners. They added that this sharing also helped to clarify their conceptual understanding (Costa & Kallick, 2000). As a result, when they went to their classes after their discussions, they felt much more confident.

In the light of this, Nomfundo proposed that there was a need for network actors to do interschool class visits to give support to each other and to further enhance their level of critical reflection. Spanneberg and Brown (2003) support the idea of school-based support and this is fundamental in their professional development model.

It is evident that co-planning and co-teaching encouraged the actors to be co-learners, which may further enhance opportunities to engage in collaborative reflection. However, I would like to suggest that the teachers need to take this a step further and consider analysing their learners' work (Loughran & Gunstone, 1997; Loucks-Horsley *et al.*, 2003) as well. As Zeichner and Liston (1987) explain that by doing so they would become creators of educational knowledge including knowledge of how their learners learn and this is an area for future research.

Pollard and Tann (1993) observe that the value of engaging in reflection could be enhanced when carried out in association with other colleagues, as opportunities to learn *with* and *from* each another are increased (Loughran & Gunstone, 1997) – which is why networking has been advocated in this study. Furthermore, co-teaching and collaborative reflections were seen as useful strategies to enhance such networking.

For example, Zapholo, reflecting and commenting on his lesson when we did co-teaching and participatory observation, felt that at the beginning he did a lot of talking, depriving his learners of reading skills and ability to understand instructions. He also indicated that as the lesson progressed he became anxious when the practical activities were not working well in other groups. He said:

> As a result, I think at some stage I became very anxious and my mood and voice changed, you know. I said read instructions, and I spoke of a jersey and other materials, yet learners were only rubbing with one material at a time. I realised that the learners were not getting the results that I expected. And in groups where the results were actually observable, I never went to find out how they did it. In the groups where the learners were struggling I just went and said; "rub hard, do it this way", and not asking them to

> explain why the activity was not working. (Video discussions: Zapholo's reflections, 11 September 2003)

From Zapholo's comments it emerged that teachers may deprive their learners of opportunities to co-construct understanding of knowledge. Zapholo further acknowledged that his lesson was a combination of traditional and constructivist approaches as he had to explain concepts to his learners while at the same time encouraging them to discover things on their own. Here, despite the transformation in curriculum, there is a need to strike a balance between these two teaching and learning strategies.

Ngwenya confirmed this, explaining that in some groups Zapholo did the activity for his learners, instead of scaffolding them in the right direction. This suggests that teachers may need to be equipped with skills on how to scaffold their learners. Furthermore, he thought that Zapholo could have asked his learners to explain why the activity was not working. Zapholo justified his approach in terms of the time constraints, explaining that he had not wanted other groups to be left behind. It could be argued that not enough provision was made to accommodate differences in the pace at which learners learn and that he wanted to cover too much work. It could be argued that teaching for understanding and meaningful learning is a complex process.

Zapholo cautioned us that, although group work was encouraged during activities, one should be careful to note whether learning is in fact taking place. The fact that learners were potentially equipped with observation skills does not equate to their learning something, as some learners have a tendency to 'watch' without being actively involved. Learners should therefore be given opportunities to explain their observations, preferably in writing and verbally. Ngwenya also expressed an opinion on group work:

> And I think there have been misconceptions about group work. Actually in most cases some teachers would simply put their learners in a group because there is a shortage of apparatus and not because they should be given opportunities to learn from each other. Yet, to me, I think the purpose of group work should be to encourage learners to help one another. Furthermore, here are the learners doing a practical activity in a group, how do you as a teacher know that there is learning taking place? I think what was fascinating about our LTSMs on electricity is that learners had to make predictions individually

> before they were required to discuss as a group, which means that individual construction of knowledge was catered for. (Video discussion: Ngwenya's reflections, 11 September, 2003).

An advantage of group work according to Zapholo was that it gave learners who were generally quieter in class an opportunity to participate in discussions even if they gave 'incorrect' input. Furthermore, learners were able to communicate with their peers in their familiar mother tongue.

Having discussed the advantages of group work, Zapholo agreed with Ngwenya that there should also be provision for individual work. Furthermore, his own criticism of his lesson was that he neglected the fact that he was teaching learners who were second-language speakers of English – he therefore spoke too fast, thinking that they understood. He felt that he could have revisited how he talked from time to time and scaffolded learners during his lesson. He also said that learners tended to want to imitate what their teacher demonstrated during practical activities at the expense of their own creativity and innovation.

Zapholo did feel that his learners had enjoyed being assisted by his two colleagues, Ngwenya and me. He explained that at times learners tended to pay more attention when a new person presented items to the class as they "become tired of your own voice". Zapholo further explained that in his lesson he had tried to implement OBE and focused on conceptual development. He said he had also tried to present his lesson in an interactive way paying much attention to the active involvement of his learners. Given all the challenges experienced during teaching and learning, he felt that professional development of teachers was critical.

> Teachers need to be empowered, number one, about group work control; number two, teachers need to be empowered on writing worksheets and developing teaching and learning support materials; number three, teachers need to develop their subject-content knowledge. That will actually automatically help them to know the basic concepts of the various lessons. Number four, I think we need to engage in co-teaching since there comes a time when your own learners become tired of your own voice. We need to try and do things differently all the time. (Video discussion: Zapholo's reflections, 11 September 2003)

On the limited resources in schools, Zapholo reiterated that teachers needed to be equipped with improvisation skills. However, it is recognised that if teachers are not knowledgeable in their subject, they will find it difficult to improvise. On collaboration, Zapholo suggested that there should be a mechanism in each school whereby teachers teaching the same subject frequently meet to discuss their subject-related problems. However, he warned that teachers should not be coerced into doing so. Furthermore, this does not mean that teachers should collaborate all the time as they will ultimately be on their own.

Nonetheless, Zapholo had found the reflections on his lesson, received from two network actors very empowering. Furthermore, he was inspired by the critical and positive feedback he received. As a result, he felt that he had thrown away the 'classroom and me' syndrome, realising the benefits of collaboration with his colleagues over not working in isolation (Lortie, 1975; Nias, 1989).

This realisation was offset by the understanding that his individual efforts were still insecure. Furthermore, he expressed delight at being complimented by his colleagues on the use of the chalkboard to consolidate key concepts, which Czerniewicz *et al.* (2000) brings to our attention as a valuable yet under-utilised resource. At the time, I wrote the following comment in my research journal:

> As the learners were busy doing practical activities, what inspired me was how Zapholo consolidated key concepts on the chalkboard as the lesson progressed. I have a feeling that the notion of 'chalk and talk' has stigmatised the use of the chalkboard for some teachers, yet in my view it is a useful resource. I also liked the idea that learners were encouraged to do some estimation (integration with mathematics); as a result some learners experienced some problems in giving the appropriate estimations. (Research journal 28/08/03)

Zapholo had been surprised that his learners were pleased to have other teachers who also helped them during the lesson. They had subsequently commented to him that they enjoyed receiving immediate assistance when they needed help, rather than waiting for their teacher while he was still busy with other groups in class. This suggests that it can frustrate learners not to get assistance when they want it. This is indeed a revelation as far as group work is concerned.

Group work has become a slogan in the new curriculum in South Africa; however Zapholo's reflection raises questions regarding learners' diverse learning experiences during group work. I would suggest that if teachers want to do co-teaching they should plan the lesson or activities together so that they could become co-learners in the process, as we did in this study.

Ngwenya also remarked that he felt that co-teaching and participatory observation were useful in that it was difficult to take in all that was happening in class when one was alone with the learners. Having a colleague observe, however, provided the added advantage that the other teacher could make suggestions about possible improvements. Furthermore, through engaging in collaborative reflections opportunities to learn about one's strengths and weaknesses are created.

I believe that recognising one's weaknesses is strength in itself. For example, one of the suggestions that Zapholo took with good spirit was that he tended to want to do too much work during his lesson. As a result, he did not sufficiently encourage his learners to ask questions or when they did ask questions he did not redirect the questions back to the other learners so that they could attempt to answer them. He also confessed that one of his weaknesses was that he liked to explain things rather than giving his learners more time to talk in class: he needs to encourage more 'learner talk' in his classroom. It is recognised however, that language could be a barrier. For example, in my journal entry I made the following comment:

> It was nice watching how the learners interacted in the various groups and how they attempted to discuss in English. Some of them really spoke good English and this suggests that language as a barrier is not an insurmountable problem in our science classrooms. But in some groups there were interesting results and Zapholo was quick to realise the effect of the humid air we were all breathing and he opened the windows. I so wish that he had given this problem to his learners to solve instead of telling them how to solve it. Also, what I missed during this lesson were questions raised by the learners in their various group. I strongly feel that teachers need to encourage their learners to ask

questions rather than only encouraging them to answer the questions posed by them. (Research journal 28/08/03).

Like Nomfundo, Neon believed that through co-teaching, participatory observation and collaboration, reflections could be enhanced. His comment above shows that he sees the value of obtaining feedback from his colleagues. Cranton and King (2003) note that ideas and evidence from others help us to consider our own views with a new mindset.

This section has explored the six science teachers' experiences of engaging in individual and collaborative reflections on their practice. It emerged that co-teaching was seen as a potential strategy to enhance reflections. However, it was recognised that teachers' practical knowledge and their knowledge base played an important role in the process of engaging in critical reflection.

9.3 Concluding remarks

This chapter explored the six science teachers' experiences of the TTCPD network. In this study, the actors had several practical reasons for establishing a collaborative relationship among them within and across their schools. Our primary goal was to enhance the teaching and learning of science. This we did through collaboratively developing and implementing science LTSMs with a view to improving the quality of teaching and learning.

The six science teachers described working together on collaborative development of LTSMs as an invaluable experience. The process allowed some of the science teachers' misconceptions to be cleared up through engagement in the network, and as a result they felt much more comfortable in their science-content knowledge and subsequently in their conceptual understanding.

They commented that through their involvement in the network they had learnt how to encourage their learners to 'brainstorm' and discuss during their lessons. Exposure to elicitation, mobilisation and incorporation of learners' prior knowledge was also commended. Furthermore, making science relevant to the learners' everyday lives was seen as inspiring for teachers and learners alike and this was identified as an area in which they needed more improvement.

Designing the learning programme units was also very helpful in that planning was done for the entire year rather than snapshot-disjointed lessons. They felt that this helped to create a bigger picture which in turn afforded an opportunity to find a wide range of information from various resources. They recognised that this required them to be textbook-literate and knowledgeable in their subject-content. Thus, teaching of senior grades was seen as an advantage in terms of such subject-content knowledge. In contrast, teaching lower grades resulted in some actors not participating as much as they would have liked.

Furthermore, learning about different assessment strategies and construction of rubrics in the network was experienced as very useful and empowering; the teachers all found mind maps and concept maps of use in linking key concepts to be further developed; and sharing ideas with network actors was particularly effective in terms of understanding how learners learn. These science teachers also felt that they were now able to handle some questions asked by their learners. They commented that this was important since the new curriculum in South Africa puts a lot of emphasis on the learners' learning and understanding. The group process highlighted the need to encourage learners to ask questions during teaching and learning; though it was recognised that language could be a barrier to effective learning.

Reflecting on their practice was experienced as helpful in that the teachers were able to think about what went well during their lessons and what aspects needed improvement. The teachers believed that as a result of engaging in collaborative reflection they had been afforded opportunities to learn about their strengths and weaknesses. Furthermore, reflecting on their practice of teaching was seen as a stepping-stone towards researching their own practice. This aspect of professional development was not something they had previously been exposed to. Being given the opportunity to co-present their work at the Research Methods and Interpretation courses and at conferences further boosted some network actors' confidence. This strategy for professional development is a potential area for future research.

The next chapter presents conclusions, limitations and recommendations. My reflections are in the form of my experiences of the research design process, and the research strengths, limitations and difficulties encountered in the study. I also critically reflect on the methodology, content of the study as well as the extent to which the research goals and questions have been satisfied. It is recognised, however, that this study also raised many other questions that were not answered because they lay beyond the brief of this study. Lessons learnt and their implications have also been explored. Finally, some tentative recommendations are provided.

Chapter 10

Reflections

> For those embarking on the reform voyage, there is much preparation work needed before embarkation. The route and final destination will need to be planned. If all the different vessels are to arrive safely at port, then the lead ship will need to understand the capabilities of the different craft on voyage, as well as the skills and enthusiasms of the captains and their crew. Much will have to happen during the journey itself to keep the flotilla together, but whilst there may be treacherous waters ahead, there are also some land-marks to guide the way.
>
> (Riley, 2000:35)

10.1 Introduction

The research presented in this thesis is underpinned by socially critical-emancipatory principles and located within a qualitative framework. Its focus is on the science teachers' transformative and continuous professional development network as discussed in Chapters 6 and 9. Central to this study is the development of both participatory and emancipatory approaches to teacher professional development, premised on mutual and collaborative support as argued by Southwood (2000), in which the actors' capabilities and skills are essential as suggested in the epigraph.

In this study, teachers have been afforded opportunities to bring and discuss problems, and share ideas, insights and issues, success stories, failures and challenges on their learning and teaching of science. Aspects of their stories are thus woven into the different chapters since it is my belief that teachers' *voices* are essential. Contradictions are regarded as precipitating development and learning experiences rather than being barriers. Most importantly, despite the teachers' diverse practical and professional knowledge as reflected in Chapter 8, they are recognised and acknowledged as people who are pro-active and capable of taking responsibility for their *own* professional development.

In this chapter, my reflections are in the form of: my experiences of the research design process, and the research strengths, limitations and difficulties encountered in the study. I also critically reflect on the methodology, content of the study as well as the extent to which the research goals and questions have been satisfied. It is recognised, however, that this study also raised many other questions that were not answered because they lay beyond the brief of this study. Weaving throughout these aspects are my critical comments and impressions. Lessons learnt and their implications have also been explored. Finally, some tentative recommendations are provided.

10.2 Reflections on the research design process

> Our experiences, no matter how difficult at times, are our lessons. We are to observe the lessons and hopefully grow stronger. But there is one critical point that some of us miss, that, our experiences are not only for us, but are also for those who cross our path.
>
> (Ngcoza, 1998:22)

In this section of the thesis, I provide my critical reflections on the research design process particularly on the methodology and content of the study.

10.2.1 Methodology of the study

During this research project, I found myself entangled in what Wardekker (2000:260 - 1) and Kemmis and McTaggart (2000:573) call "paradigm wars"[22]. In this study, I would contend that paradigm wars refers to the perceived intersection area between the socially critical–emancipatory orientation and interpretivist paradigm, where this research initially seemed to be located in. This space may further be referred to as what

[22] To Wardekker (2000:261), "paradigm wars" are sometimes equated with a controversy between quantitative and qualitative methods. Furthermore, he notes that the difference between paradigms is not based on how research is done nor on what is researched, but on why it is done. It reflects two different views of how the results of research may contribute to better human (cultural) practices, on two views of the relation between knowing and acting, two views of learning in which research results are the inputs of the learning process. To Patton (1990:14), "qualitative and quantitative methods involve differing strengths and weaknesses; they constitute alternative, but not mutually exclusive, strategies for research."

Wardekker (2000:271) calls a "zone of actual development" of the actors, where the collaborative professional development was situated.

I initially saw this positioning of this study as a potential cause of tension that could inhibit or delay progress. This tension was exacerbated by the inclusive discussions during the Research Methodology and Interpretation courses held at the Education Department, Rhodes University. The participants had divergent views on the paradigm on which this study was framed. Some suggested that this study was better situated to an interpretivist paradigm, whereas some suggested that a critical theory paradigm would be more appropriate. It could be argued that these participants viewed these two paradigms as opposed.

The clash of paradigms proved confusing and at times a challenge for me. At that time, I must admit, I had neither anticipated the length of time it would take nor the amount of intellectual endeavour entailed in resolving this tension. The interpretivist paradigm comes into play since implicit in it, is understanding, development and change. Yet a PAR approach was an enabling framework to improve the science teachers' practice demanded emancipation as outlined in the critical theory.

Nonetheless, when I discussed this issue with my supervisors (who played a dual role throughout, as supervisors and critical friends); they cautiously suggested that paradigms are not necessarily disjointed and oppositional but could be overlapping and coherent. Maggs-Rapport (2000:224), too, contends that through a more multi-method approach, researchers may come closer to understanding both their own interpretations of the research phenomena and the experiences of research participants. While I applauded these suggestions, I felt that I needed firmer ground to stand on.

In this study, within the socially critical - emancipatory orientation, a participatory action research approach was adopted (see Sections 5.3.2). Robinson (2002) notes that

PAR approaches are based on the principle that the actors own the knowledge generated and gained through the research process. She further believes that, through reflecting on their practice, actors could be afforded opportunities to modify their practice in an ongoing way. It is recognised that for this to take place support systems are necessary.

Similarly, Babikwa (2004), comments that PAR requires research education and action. In this study, the action taken was in the form of collaborative development and the implementation of learning and teaching support materials with the view to improving the teaching and learning of science. Also, the actors were seen as co-learners and co-researchers (see Chapter 6). Central to this initiative was fostering and sustaining quality science education in four historically disadvantaged secondary schools. I would argue that there was significant evidence that education and action as dimensions of PAR were achieved in this study.

David (2002) observes that if PAR approaches are adopted, actors ought to be involved in the formulation and conduct of research. He also says that active participation of all those in the process and the link between research and improvement of practice are fundamental to PAR (Robison 2002), and that was the contention of this study.

In contrast to David's (2002) view, however, I realised that there was still room for improvement of the 'research dimension' in this study in the sense that the actors' development was at different levels. Some actors did not see themselves as researchers, but rather were interested in improving their science-content knowledge and pedagogical-content knowledge in order to cope with the demands of the new curriculum in South Africa. This reality had a bearing on some actors' involvement in research activities.

It should also be borne in mind that in this study both the science teachers and I had limited knowledge and understanding of PAR approaches: we embarked on this study not knowing what its outcomes would be. Despite that, our collective inspiration was a feeling that there was a need for us to work collaboratively together and this, indeed, had some implications for the evolution of the PAR process.

10.2.2 Content of the study

Through this study an attempt was made to mobilise science teachers from four different secondary schools that differed in their physical resources to form a network so that they could learn *with* and *from* each other. On reflection, this was indeed a great challenge for the science teachers and for me since all of us had been socialised in traditional approaches (see Chapters 7 and 8), which fostered independence and individualism at the expense of collaboration (see Section 3.3.2).

I am proud to argue that this study is informative and could be used as a starting point by professional developers. In my presentation I have thus tried to take into consideration the different audiences I expect to benefit from this study, in particular, curriculum and policy developers, professional developers, education authorities, teachers and school managers. My extensive use of the actors' voices and direct quotations was part of my intention to help readers of this thesis have a broad understanding of a study whose attempt was to promote collaborative approaches to teachers' professional development.

10.3 Perceived strengths, limitations and difficulties in this study

> To write is to stir the self as reader. Therefore, the human science researcher is not just a writer, someone who writes up the research report. Rather, the researcher is an author who writes from the midst of life experience where meanings resonate and reverberate with reflective being.
>
> (Van Manen, 2002:238)

This section explores reflections on the strengths, limitations and difficulties of this study. I would suggest that these issues should be understood with, particularly in the context of the need for change and transformation in education in South Africa.

10.3.1 Strengths of this study

The findings in this study document some significant changes in teachers' content knowledge, pedagogical-content knowledge, perspectives, and assumptions pertaining to their practice as a result of being involved in the TTCPD network. The assumptions were identified through active interviews in which the actors had to tell their stories freely. I am also convinced that structured interviews would not have been suitable for this study with an emancipatory focus.

I would argue that the following were strenghts of the study:

- Unlike most professional development studies, what was unique about this study was that it was not part of any educational programme or course, often characterised by technocratic structures, methods and strategies which encourage dependency among actors (Babikwa, 2003). In this study, although it was explained to the science teachers involved that this was part of my PhD research, they participated willingly and voluntarily as they embraced the need for professional development.
- One of the pertinent questions often asked in a study of this nature is: What would the actors get out of such a study? In an attempt to address this question, all the teachers involved in this study were encouraged to engage in educational studies in order to improve their qualifications. Some of these teachers did an ACE science course and subsequently studied BEd (INSET) and BEd (Honours) courses, which they completed. One teacher did an MEd course and managed to complete it within two years. His study fed into our research project. This suggests that the actors experienced significant personal an d professional transformations which were important for their careers as science teachers.
- In the context of South Africa, with reform-based teaching practice, collaboration is considered a vital component. However, how to foster such collaboration among teachers remains a challenge. Nevertheless, the findings of this study suggest that creating opportunities for teachers to collaborate

with other colleagues enhanced their level of empowerment in that they became co-learners and co-constructors of science knowledge (see Chapter 6). Keedy (1999) notes that teachers are the best resource for professional development as they collaboratively engage in improving their practice. This is in line with the basic tenets of socially critical - emancipatory orientation (see Section 4.2.1).

- The fact that all the network actors' mother tongue was *isiXhosa*, encouraged us to discuss freely during our workshops. It could be argued that the language barriers were eliminated to some degree. Nonetheless, for purposes of the thesis, discussions were tape-recorded and transcribed into English.
- The findings of this study further demonstrate that collaboratively developing LTSMs enhanced both the science teachers' content-knowledge and pedagogical-content knowledge. Teachers were pleased that their misconceptions were cleared up in non-threatening environments. This is critical since teachers need to become learners of science themselves. When teachers are afforded learning opportunities, such experiences might result in positive learning experiences for their learners in the long run as well.
- The findings of this study indicate that there is a need for teachers to reflect on their practice. Reflectivity and reflexivity (see Sections 3.5.1 and 3.5.2 respectively) create opportunities for teachers to think and act on their practice.
- Actors in this study experienced major personal and professional transformations which were important landmarks in their careers. For example, becoming co-learners and co-constructors of knowledge as reflected in Chapter 6 of this thesis was useful in establishing reciprocity (see Section 3.3.2) among the actors, not necessarily in the form of knowledge-sharing only, but also in listening and engaging in discussions.
- Decision-making processes increased, during which the views of other actors were respected. To a large extent, one could argue that actors deepened their level of empowerment. Nevertheless, findings reveal that there were still times when the more influential actors dominated the quiet ones. It thus

remains a challenge to manage participatory methods without perpetuating power differences.

10.3.2 Limitations and difficulties in this study

Given the teachers' work commitments, engaging them in a professional development and growth initiative can be quite a daunting undertaking. Like any other study on professional development, this one had its limitations and difficulties, which should be seen as lessons to be learnt. I identify the following:

- When I started this study I was a science subject adviser, and selecting just a few teachers to work with on a professional development initiative caused some tensions in the schools in that other teachers felt excluded. Such tensions were exacerbated by the fact that the schools involved in the network were sponsored with micro-scale science kits. This was, however, corrected by ensuring that all the other historically disadvantaged schools received these physical resources too.
- I believe we all have strengths and weaknesses. One of the weaknesses in this study was the difficulty of not having a structured plan to follow. Instead, we relied on issues to emerge from the study - which is in line with emancipatory research. Thus, I would argue that it would have been more useful if we had paid particular attention to the process that would lead to the desired outcomes.
- When I started this study, I had limited knowledge of the theoretical framework that could underpin such work. I envisaged a study that would take into consideration the centrality of the teachers in their own professional development. This assumption was based on the fact that I was dealing with experienced teachers I had been working with in various projects in the past. However, my limited knowledge of the dynamics of such a study with an emancipatory intent proved to be an inhibitor.

- Given the fact that co-engagement in this study varied, I fell into the trap of interacting with some actors more than others, in particular the male actors. This imbalance was due to the fact that I was able to visit male actors, even at their homes, when I wanted us to discuss issues pertaining to our research activities. In my view, this would have been difficult to do with the female actors (gender realities) as I did not want to create tensions in their families. As a result, at one stage I felt that I could have done an in-depth ethnographic study with one school in this study.
- The fact that the science teachers in this study were encouraged to further their studies at Rhodes University where I am teaching was both a strength (see Section 10.3.1) and a limitation. It was a limitation in that it is possible that teachers could have made statements about what was happening in their practice to satisfy me. Thus, reliance on data which the science teachers chose to share could be problematic.
- In reality, the fact that some of the actors at the same school continued to help one another on an individual basis rather than reciprocally could be seen as a limitation in this study as it contradicted the spirit and goals of participatory methods. Although some science teachers were engaged in this study, they could not transcend their school cultures of working individually.
- I feel it would have been useful if I had encouraged network actors to keep the portfolios (and not individual portfolios) at their schools to document evidence of their development and growth through being involved in the TTCPD network. Also, as part of their portfolios teachers could have kept an analysis of their learners' work rather than just reflecting on their teaching experiences; some of the reflections were superficial at times.
- Time, space, work commitments, and family and community commitments proved to be inhibitors for most teachers in this study. This resulted in our programmes now and again being interrupted and at times momentum was lost.
- During the active interviews, the fact that *isiXhosa* was used, was both an advantage and a disadvantage. It was a disadvantage since I had to transcribe

the interviews into English (which is my second language), and in the process some data may have been distorted or skewed, despite my efforts. Nonetheless, validation of data was ensured through member checks (see Section 5.4.3) although the critical analysis of members varied in rigour.

- Striking a balance between doing research *with* and *on* teachers proved a challenge as I discovered that not all teachers in our network were equally interested in doing research. Some were more concerned with improving their science-content knowledge and pedagogical-content knowledge in order to cope with the demands of the new curriculum in South Africa.
- Limited knowledge and experience of engaging in formal collaborative approaches on my part and on the part of the teachers involved in the study proved to be an inhibitor in the use of participatory approaches. Similarly, the level of active participation was also limited by some of the teachers' limited science-content knowledge as well as their experience of teaching science only in the lower grades for many years. These realities proved to be contradictory to the ideals of PAR approaches, which emphasise collective action. This suggests that it is not a foregone conclusion that participatory approaches can ensure equal participation by all actors.
- Furthermore, within the schools, contextual factors such as lack of collaboration among the teachers, a poor culture of teaching and learning, and governmentality militated against the use of participatory methods. The issues of governmentality and the poor culture of teaching and learning could be interesting aspects for future research.
- It is acknowledged that the analysis presented in this study raises issues such as gender, language and governmentality, but does not explore them in detail. To do so was beyond the scope of this study except that I feel that the participation of the female teachers in this study could have been given more attention. For instance, of the six science teachers, only two male teachers were involved in presenting material at the Research Methods and Interpretation courses and conferences. I see this as a limitation in this study. The nature of the study, however, was not to impose things on actors; rather

actors were at liberty to develop professionally, socially and personally at their own pace. I believe that this is line with the socially critical - emancipatory orientation.

In sum, although I encountered a number of *cul de sacs* in this study as reflected in the limitations and difficulties mentioned above, I consistently felt that there was no turning back. In the process of *changing gears* in this journey, a metaphor intended to illuminate changes in development in our network, I was determined not to resort to the reverse gear.

10.4 Reflections: research goals and questions

This study had two main goals (see Section 1.4). To achieve these, I realised that I needed information on the teachers' science educational background and their practice of teaching (see Chapters 7 and 8 respectively) as baseline data. I believe I was able to elicit valuable material on these aspects, which served to guide our actions in the network. However, before such data could be generated, it was essential that a good rapport be established with the actors.

Three questions (one primary and two secondary) were interrogated in this study. The primary question pertains to the influences of the TTCPD network on the science teachers' subject-content knowledge and pedagogical-content knowledge, collaboration and collegial support, individual and collaborative reflections and subsequently on the practice of teaching. The secondary questions deal with the science teachers' educational background, how it influenced teachers' SCK, PCK, assumptions about teaching and learning and ultimately their practice of teaching; and the benefits of professional development and support on the teachers' practice and how it ultimately influenced school-based and collegial support. Although these questions have been presented separately, it is evident throughout the work that they are interlinked.

Rapport and collegial support in the network was established through our workshops (see Chapter 6), which proved to be a determining factor in the choice and use of active

Rapport and collegial support in the network was established through our workshops (see Chapter 6), which proved to be a determining factor in the choice and use of active interviews. These were used to further generate in-depth quality data. The conversational nature of this data-generating technique proved to be invaluable in encouraging the science teachers to share information freely on their science educational background, practice of teaching and about their involvement in the TTCPD network. In the context of a study with an emancipatory intent, this was essential and in line with the view that knowledge is socially located and constructed (Babikwa, 2003).

The intended outcome here was to encourage the science teachers to use their past science educational background (both school and professional) as a lens for examining their past and current underlying assumptions about the teaching and learning of science. I believe that introspection, which is a central aspect of reflection, is vital for inner self-motivation. Their present practices, however, had to be understood within the time and contexts of their diverse schools.

In response to the goals of this study, I developed a conceptual framework through a review of literature on professional development, reflective and reflexive practice (see Sections 3.5.1 and 3.5.2). The use of participatory methods was relevant to the transformative nature of this study. Participation is preferred especially where social transformation and emancipation constitute the goal of learning. In this study, co-learning (as reflected in Chapter 6) was fostered as a strategy to empower actors, who were also seen as partners in the process. The study could be described as reciprocal partnership (McNiff, 2002).

The data revealed that the TTCPD network was essential for effective and meaningful change to take place. However, the co-engagement of teachers through a participatory action research approach to facilitate and enhance transformative learning proved to be a slow and challenging process. These findings suggest that empowerment is a process and Babikwa (2003) suggests that we need to look at empowerment horizontally (practical needs addressed) and vertically (more strategic goals pursued). His contention is that hortizontal and vertical forms of empowerment are inextricably linked and complement one another.

10.5 Lessons learnt, and implications

In this study, I learnt that it is extremely difficult to do research *with* teachers rather than *on* them, through integrating PAR approaches into an initiative that aims to achieve a short-term goal of a PhD study. My expectations and the actors' expectations were at times not on the same wavelength or as congruent as I would have liked. It could be argued that the fact that I had divided attention, with one eye on the PhD thesis and the other on the social dynamics of the network, proved to be a challenge.

This implies that if PAR is to achieve its emancipatory goals, which was the contention of this thesis, sufficient time and space must be dedicated to it. Yet, in this study it was difficult at times to adhere to the schedule, and that militated against the recursive and reflexive nature of PAR as proposed in the literature (see Figures 6.1 and 6.3). Despite that we were committed to the belief that the empowerment of all actors was a major goal of the entire process and we tried to achieve this in various ways, albeit slow and inconsistent or contradictory in some cases. Nonetheless, opportunities for empowerment were enormous.

As an example, some teachers demonstrated their empowerment and growth through taking control of the process, and emerged as key actors willingly taking the leading roles. It is here that I found the actor-network theory (see Section 4.2.2) relevant. In view of these documented changes among the teachers, I can confidently say that the PAR process led to our empowerment, albeit, understandably, at different levels. I would contend that a lesson from this experience is that diversity is a fact of life that cannot be overlooked. This implies that professional developers should develop positive strategies for addressing diversities of participants, focusing on their contexts and needs, a point made by Babikwa (2003) in his study.

What we also learnt was that the PAR process is slow and long-term. Central to it is a need for co-ownership and shared power over the research (Robinson, 2002), but this demands a high level of commitment on the part of actors. The power dynamics in this study proved to be a complex experience as some actors were keen but not confident enough to take leadership positions. I found this experience very frustrating at times.

Furthermore, although the actors were intended to be in charge of the research process, the fact that I was the initiator made some actors initially see me as the controller. Likewise, the fact that my research knowledge base was stronger than the others resulted in them expecting me to take a leading role in this aspect. However, the fact that the actors were knowledgeable and had current experience in science classrooms proved to be a balancing force; some of them demonstrated much contemporary expertise in this area.

As a result of co-participation in the study, the actors developed the capacity to challenge some of their underlying assumptions about their practice. They also saw the need to confront their contextual factors, which had proved to be an inhibitor in many ways. It became evident that the actors saw the need to shift from being isolated to being active agents of change (see Section 3.4.2). This implies that professional developers, in particular, should strive to create environments that are conducive to co-learning for teachers (see Chapter 6).

Participation by some actors, however, was initially restricted by the limited science-content knowledge that they possessed, which was further confined by the grades that they teach. In contrast, the positive change in attitude towards self-reliance among some actors was another remarkable outcome of PAR engagement. For example, one of the actors developed a learning programme unit for the entire year, which was subsequently adapted by all network actors.

This study revealed that the professional development of actors is a process rather than an event. Trust and mutual respect among actors were also seen as essential ingredients. This implies that professional developers need to provide opportunities for ongoing professional development of teachers whereby teachers' needs and aspirations are foregrounded. It also became evident in this study that abilities for actors to be able to reflect critically on their practice hinged on the knowledge that they possessed. This implies that there is a need for a rigorous interrogation of what is really entailed by reflective practice; I see this as a potential area for future research.

As a final note, it is my contention that while engaging teachers in a TTCPD network is essential; it should be done with caution. The lessons learnt from limitations and difficulties in this study show that practitioners are heterogeneous rather than homogenous, a view emphasised in ANT (see Section 4.2.2). This implies that, while it sounds wise to encourage teachers to collaborate, there is a need for professional developers to pay attention to their individual needs. It is my contention too that, in studies which claim to be emancipatory in intent, the focus should be on empowering teachers to take responsibility for their *own* empowerment.

10.6 Recommendations

The study focused on the influence of the TTCPD network (see Chapter 6) with a view to improving the six science teachers' practice. The results have illuminated the fact that the role and importance of the TTCPD network cannot be overstated.

Arising from this study, I thus offer the following recommendations for consideration by policy and curriculum developers, professional developers, and education authorities and, last but not least, teachers and school managers.

10.6.1 Policy and curriculum developers

- Policy and curriculum developers should ensure that the policy documents are available and accessible; provision of support to ensure that the practitioners are able to interact and put these requirements into practice is essential.
- Since this study has revealed that there seems to be a lack of alignment between policy formulation and implementation, there is a need for continuous research

and evaluation of programmes to ensure that there is alignment between these aspects.

- This study has also revealed that 'training' of practitioners in most cases is not seen as a process of development or empowerment. Instead, practitioners are simply required to acquire knowledge and skills in order to implement the new curriculum; that is, technicist approaches are used under the guise of emancipation. McNiff (2002) refers to this as a delivery model which has very little focus on learning. This is exacerbated by the fact that some facilitators have very limited knowledge of the theoretical, philosophical and practical implications of the new curriculum in South Africa. This has resulted in differing and distorted interpretations of the OBE philosophy and its approaches.

10.6.2 Professional developers

- Professional developers need to encourage and create learning communities of practice (Lave & Wenger, 1991; Patton *et al.*, 2005) so that teachers can support one another in enabling and non-threatening environments. This is invaluable: through learning communities of practice, teachers could be afforded opportunities to discuss and share ideas, knowledge, skills, success stories and frustrations with their colleagues.
- Encourage collaborative strategies of mutual support as integral practices of professional experiences throughout the teachers' careers, as proposed by Southwood (2000). This is essential; as Hargreaves and Dawe (1990) point out, teachers have to learn on the job continually. Duggan (1996) and Edwards (2002) agree that teachers have to see themselves as lifelong learners.
- Acknowledge the knowledge and power teachers have in supporting one another as professionals. The centrality of teachers in the implementation of professional development initiatives is essential.
- Recognise the need to see development as empowerment rather than 'training' in a technicist sense. According to Babikwa (2004), techinicist 'training' structures and strategies create dependent practitioners. Gilbert (1994) warns us of the

deficit models of professional development, which assume that teachers have limited knowledge and skills. This implies that professional developers need to tap into the teachers' knowledge bases. To this end, Loucks-Horsley *et al.* (2003) propose a paradigm shift in professional development initiatives from transmission of knowledge to experiential and problem-based learning.

- Professional developers should ensure that teachers are knowledgeable in their subjects. They should not only master the limited concepts stipulated in the 'syllabus', but should know more.
- There is also a need to equip teachers with research skills so that they can evaluate and do research on their own practice.
- In any reform endeavours, in my view, professional developers should support teachers in understanding the demands of their new role in bringing about effective change in their classrooms and cater for the capacity-building for teachers that this implies. Invariably, there is also a need to consider teachers' school contexts in promoting teacher change. Here, Hargreaves and Fullan (1998) and Loucks-Horsley *et al.* (2003) note that professional development and growth for teachers should not be a 'one size fits all', but should be tailored to the teachers' diverse needs and the diverse socio-economic and political contexts. Hargreaves and Fullan (1998), Loucks-Horsley *et al.* (2003) and Goodnough (2003) all support this view.
- Acknowledge and encourage both individual and collaborative reflection as a vital component of teacher development. Through engaging practitioners in collaborative reflection as evidenced in this study (see Chapters 6 and 9), teachers could be afforded opportunities to learn from each other in reciprocal ways. Learning could further be fostered through discussing how learners learn.

10.6.3 District office education authorities

- Restore governmentality in schools by giving ongoing support to the school principals and HoDs. It should be acknowledged that the success of any school hinges on the quality of leadership and management styles.

- Facilitate and create environments in the schools whereby teachers are afforded opportunities to share knowledge, ideas, experiences, success stories and challenges on their practice. This could be done through workshops, shared planning or co-planning, inter-class visitation and co-teaching in order to get ongoing feedback.
- Encourage school-based curriculum development and support. It emerged from this study that the department needs to offer continuous teachers' professional development workshops that are tailored to the teachers' needs, as the *once-off* OBE workshops have proved to be a futile exercise. It has also been argued that the 'technicist' belief that learning can be cascaded (Babikwa, 2004) was flawed as the facilitators of the OBE workshops were not sufficiently knowledgeable themselves. This suggests that there is a need for education authorities to be exposed to quality professional development as well.
- As proposed by Spanneberg and Brown (2003), visits and follow-ups to the schools should be offered to give support to teachers in their school contexts. This implies that there is a need for knowledgeable subject advisers at district offices who are visible and always available to give support to teachers.
- The vital role of language in South African schools raises serious concerns about the culture of teaching and learning. There is a need for teachers to be equipped with second-language skills in order to meet the demands of the new curriculum. This could be an area for future research.
- There is a need to strengthen partnerships between the schools, university and DoE to ensure that professional development initiatives are effective.

10.6.4 Teachers and school managers

- Teachers themselves should strive to create learning opportunities within their schools and learn to work together collaboratively and on an ongoing basis (Senge 1990). Teachers (whether experienced or inexperienced, as it emerged from this study) need opportunities to work collaboratively.

- According to Loucks-Horsley *et al.* (2003), effective professional development can only happen if teachers work with their colleagues towards a common goal rather than in isolation. This also suggests that teachers should take a central role in bringing about improvements in their practice.
- There is a need to encourage collaborative working cultures that support ongoing professional development and growth in schools so that transformative learning (Brookfield, 1995; Cranton, 1996; Babikwa, 2003) can be enhanced among teachers. As highlighted by Brookfield (1995) and Cranton (1996), at the heart of transformative learning teachers are being afforded opportunities to question critically and reflect on what they do, whether what they do works or not; and why they believe what they do is important. In this study, through working collaboratively on a common goal of improving teaching and learning of science, teachers were capacitated and ultimately saw themselves as lifelong learners (Duggan, 1996; Edwards, 2002; Cranton and King, 2003).
- Teachers, HoDs and principals in schools need to be involved in ongoing professional development and growth. My contention is that it is vital to encourage a school-based approach and collegial support amongst these stakeholders. This could serve to empower the school managers (HoDs and principals) to engage with the implementation process in a mutual and collegial spirit rather than being authoritative or taking a back seat.
- Infrastructure within schools needs to be set up to encourage and support collaboration. For example, planning teams and teacher networks should be formed. Teachers need to be encouraged to form clusters or networks, whereby they could learn *with* and *from* one another.

In my view, this study provides a useful model for teachers who wish to work together without necessarily using the assistance of an external expert. It is recognised that for teachers to develop school-based collaborative work cultures as Richardson and Anders (1994) proposed, the tensions between policy development and implementation need to be resolved. Furthermore, the teachers' commitment is essential.

10.7 Concluding remarks

It became evident from this study that the science teachers saw the need for change and thus demonstrated change in their practice as a result of being involved in the TTCPD network. On reflection, their interrogation and questioning of underlying assumptions about their teaching and learning proved to be a catalyst in many ways.

This study has also demonstrated that some theories are not mutually exclusive but may complement one another. In my initial conceptualisation, I had hoped to employ the socially critical - emancipatory orientation as a lens to interpret the data generated. Later, however, I learnt that I needed to understand the in-depth dynamics underpinning a study of this nature. As a result, I embarked on an additional theory called actor-network theory to analyse the methodological and epistemological basic of this study. Understanding educational phenomena is a complex undertaking, I found, particularly as the empowerment of teachers is a process rather than an event and has its own logistics.

Unlike many professional development studies, a driving force behind this study was not a programme leading to a certain formal qualification. Instead, the science teachers participated voluntarily because they saw the need to improve their conceptual understanding and subsequently their ability to learn and teach science in more interactive and innovative ways. I consider this to be a major breakthrough and as such the uniqueness and strength of this study.

Evidence from this study shows that as the science teachers interacted with colleagues, they expanded their science-content knowledge, pedagogical-content knowledge, knowledge on how learners learn, and so on. Furthermore, their collegial interactions were enhanced, albeit at different levels. However, there is a need to recognise and respect the complex interactions between individuals and their contexts. For instance, it became evident in this study that school contexts were potential barriers that can impinge on teachers' collegiality.

This was exacerbated by the fact that some teachers were not used to working collaboratively. Thus, on the assumption that teachers are vital in any reform process, there is a need for the development of school-based collaborative approaches to teacher development; for this, creation of space and time for teachers' *voices* is essential.

In this study, efforts to implement collaborative approaches as recorded in literature were directly influenced by the different schools' contextual factors. The school situations pose many challenges to curriculum, policy and professional developers to develop programmes that cater for such varied contexts.

My analysis of the schools' contexts and dynamics has established that relationships with the department affect governmentality in some schools in many and sometimes destructive ways. The study illustrated that the department at times frustrated its own policies by failing to honour its own commitments. Also, it seems that during OBE workshops, emancipatory educational methods are not adhered to and the ideals of democracy are just given lip service.

With regard to the TTCPD network, this study has established that four major factors that militate against the attainment of this goal need to be taken into account:

- teachers' science educational background;
- teachers' limited science-content knowledge and pedagogical-content knowledge;
- lack of skills and lack of confidence to question underlying assumptions on their practice; and
- the lack of synergy and the prevalent tensions between policy formulation and policy implementation, which impacts negatively on development in schools.

This study has thus demonstrated that teachers' science educational background does indeed influence their underlying assumptions about teaching and learning. It became evident that the way they themselves were taught tended to dominate their practice. Consequently, evidence from this study revealed that ongoing teachers' professional development that fosters growth in teachers' science-content knowledge is needed, along with practical work skills, pedagogical-content knowledge, development, evaluation and the adaptation and implementation of learning and teaching support materials.

Through engaging teachers collaboratively in participatory methods it is possible to generate some remarkable results regardless of the many contextual problems. It is therefore a challenge for the department and the government to create learning environments that will nurture school-based and collegial support that promote use of emancipatory professional development initiatives among teachers instead of focusing on deficit models (Gilbert, 1994), which this study has revealed as detrimental.

I now understand that collaboration as a slogan is a slippery concept, which professional developers need to interrogate rigorously in order to understand it more critically. My suggestion is that researchers, professional developers and teacher educators spend time developing initiatives in school-based learning and problem-solving processes. This might prove a worthwhile exercise. Ongoing collaboration and emancipatory efforts would counter the shortsighted assumption that once-off workshops develop and empower teachers.

Although it was the contention of this study that teachers should strive to take responsibility and leading roles in their professional development, it became evident that for teachers to take such responsibility they needed to be adequately prepared and committed. There was a need for the creation of learning environments where teachers' school contexts were taken into consideration. Likewise, I believe that when teachers are exposed to conducive learning environments they will be willing to learn *with* and *from* each other. With this in mind, it is important that in such learning communities of practice, teachers should be regarded as key players who are capable and responsible for their own professional development and growth.

Reflection, both individual and collaborative, emerged as fundamental in this professional development network. Engaging in reflection allows teachers to examine their thinking, actions and decisions during their practice. According to Zeichner and Liston (1996), viewing teachers as reflective practitioners assumes that they can both pose and solve problems that are related to their practice. Through being exposed to the reflective processes, teachers thus are empowered to voice critically their assumptions about their practice.

On reflection, the ebb and flow (Loughran & Gunstone, 1997) characterising this research *journey* has been both frustrating and fascinating in many ways. Nonetheless, such frustrations and fascinations were reflective of the complexity of teachers' professional development.

> This journey reminds me of my early childhood years. My late mother once told me that when I was five years I was taken to the doctor. Bear in mind that in those days transport was scarce. When we could not get transport I humbly suggested in *isiXhosa* that "*nazi iinyawo, nantsi indlela*", which means, "here are the feet, and here is the road." This could be interpreted to mean that finding solutions to problems was closer to my heart and the solution in that case was engaging in the journey.
>
> In this study, although I have opted to use an 'incomplete metamorphosis' metaphor to describe this journey, I have found it to be very long and exhausting. It has been characterised by moments of frustration and jubilation. At times of frustration, when days were dark, friends few and goal posts moved, I felt like changing into reverse gear. Such thoughts were compounded by the fact that my own humble beloved parents and many other people who have been very inspirational in my life, who should have witnessed my destination, had taken eternal life.
>
> It seemed the wrath of the ancestors had turned their tides against me and I do not know how many times I have visited my parents' graves for their support. Nonetheless, when I lost my two beloved kids before my son, Nkosiphendule, little did I know that I was prepared for the challenges of life such as this research journey. That itself is a cause for jubilation. Likewise, I've been inspired by the commitment on the part of the co-participants in this journey. And what will remain indelibly in my mind will be the amount of collegiality and support from my critical friends. (Research journal 28 August 2007)

Epilogue

> The relentless scrutiny of failure has many unfortunate and distorting results. First, we begin to get a view of our social world that magnifies what is wrong and neglects evidence of promise and potential. Second, this focus on failure can often lead to a kind of cynicism and inaction. If things are really this bad and there is no hope for change, then why try to do anything about it? Third, the documentation of pathology often bleeds into a blaming of the victim. Rather than a complicated analysis of the coexistence of strengths and vulnerables (usually evident in any person, institution, or society), the locus of blame tends to rest on the shoulders of those most victimised and least powerful in defining their identity or shaping their fate. Fourth, the focus on pathology seems to encourage facile inquiry. It is, after all, much easier to identify a disease and count its victims than it is to characterise and document health.
>
> (Lawrence-Lightfoot & Davis, 1997, cited in Peters, Gregoire & Hittleman, 2004:5)

In this quote, Lawrence-Lightfoot and Davis (1997) alert us to the dangers of focusing on the 'wrong' things that practitioners do, implying that the positive aspects are more re-energising. This suggests that we need to shift from the rhetoric of criticism towards an exploration of practitioners' potentials.

In writing this thesis I have attempted to represent a collective experience, designing it in a way that allows space for all *voices* involved to be heard. But here, on behalf of the project network I would like to claim the last word. I have opted to draft this epilogue in *isiXhosa* (which is my mother tongue) first, and then translate it into English (my second language). I see this as an act of emancipation in line with the socially critical-emancipatory orientation discussed in this thesis (see Section 4.2.1). I have also asserted a certain degree of self-empowerment in language by using metaphors, a terrain I feel I am still a novice in.

As a starting point, the use of the metaphor *journey* in the thesis title is intended to capture our network experiences. It also implies that learning is a process even though the destination might not be known. Like many other journeys, ours has had its ups and downs. Despite tensions and contradictions, we were motivated by the thinking that success does not consist of never failing, but of rising against the odds whenever we fail, an appropriate view in a study concerned with collaborative professional development.

To further reflect the developmental cycles in this study, I have chosen to use the *changing gear* metaphor. Throughout this journey we had to change from one gear to another, and it became evident to all of us in the network that professional development goes at different speeds and needs to build up over a long period of time. We capitalised on the neutral gear to organise our thoughts to inform our actions. Through moving forwards and backwards we were able to discover the tensions, inconsistencies, contradictions and even 'blind spots'. Our reflexive process meant continually situating and framing the research process; it was slow and took a long time for us to engage in higher gears which would have accelerated growth. It became more evident to us that change occurs at its pace and that commitment is essential.

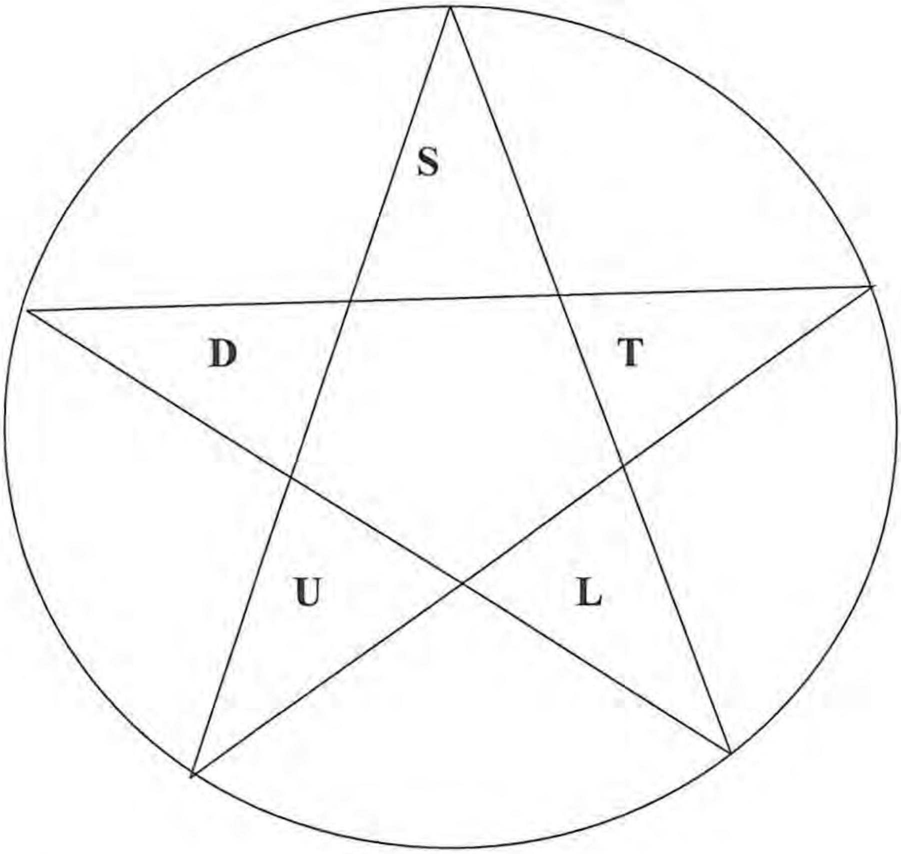
I have used the metaphor of *metamorphosis* to describe the transformative orientation of this research journey: the collaborative development of learning and teaching support materials was used to sustain this transformation. Centrally, we co-constructed scientific knowledge, something which contributed to our personal, social and professional growth. In the process, we had to question and abandon some of our underlying perspectives, assumptions and beliefs about the teaching and learning of science that had, by and large, been shaped by our past educational background. Furthermore, as the network matured, trust and mutual negotiation were enhanced. To highlight the fact that we have not yet reached our destination, I have referred to this thesis as an *incomplete metamorphosis*, something which suggests that professional development is an ongoing and lifelong process.

This thinking is in line with the notion of teachers having to learn throughout their careers. Ownership of learning should reside with them. In hindsight, even though I have opted to refer to this study as an incomplete metamorphosis, it does not imply that its life span has been shortened. Instead, this shows that professional development which claims to be empowering and emancipatory is a complex process rather than a brief event.

I view this study as a step of a journey towards a future where practitioners create their own opportunities, take responsibility for their *own* professional development, and develop their *own* networks. This is captured by the *journey of hope* metaphor. As we found, the journey is enriched by travelling together. Supervisors and critical friends play vital roles. Actors were afforded opportunities to engage in doing research, something which many had never been exposed to doing formally. Exposure to co-presenting and interacting with other actors and academics proved to be a wonderful learning experience for some actors in this study.

We found that professional development is a dynamic, multifaceted phenomenon. It became more evident that we needed to support one another through professional networks. Such ideal network of hope is represented in the dynamic diagram below, a diagram co-constructed in dialogue with critical friends (including my supervisors and the actors involved in this study).

Central to this multifaceted phenomenon is collaboration and transformative learning. It is recognised, however, that this does set up personal and power dynamics – over time if fundamental ideas such as respect for the individual, the knowledge and experience actors bring with them to the network are nurtured – they could support a more dynamic and mutually beneficial future for practitioner professional development.



Key: **S - Schools**
D - Department of Education
U - University
T - Teachers
L - Learners

On a final note, this has been a very challenging and empowering experience for all of us as co-learners and co-researchers in the network. We have learnt many things and our own knowledge has been transformed in many ways. We see this study as a seed for future professional development networks. Ideally, these professional networks could involve a range of different actors such as university researchers, subject advisers, teachers as well as others in a collaborative approach to professional development.

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APPENDIX A

INQUIRY-BASED PRACTICAL ACTIVITIES ON ELECTROSTATICS

ACTIVITY 1

PURPOSE: To investigate what happens when one insulator rubs another insulator and the objects are brought near each other.

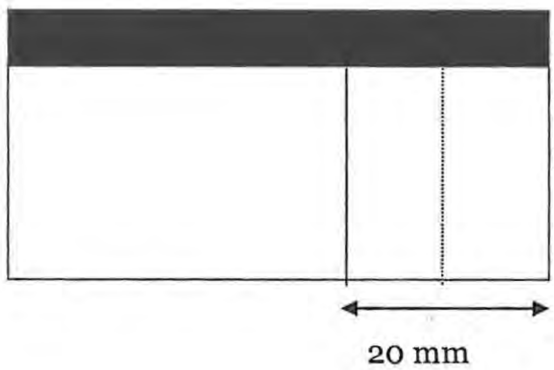
RESOURCES:

For this activity you will need

- A firm plastic (transparency).
- A hard plastic ruler.
- A pair of scissors.

WHAT TO DO:

Cut a 20 mm strip from the transparency from its breadth as shown below.



Now cut this strip in the middle (10mm) But DO NOT cut the shaded part.

1. PREDICT what will happen when you rub the strips with the inside of your jacket, your jersey, your tie, the outside of your jacket, or your hair etc.

   PREDICTION --

   EXPLAIN YOUR PREDICTION---

Now rub the plastic strips using any of the above-mentioned objects. Rub about 3 times.

WHAT DO YOU OBSERVE? --

EXPLAIN YOUR OBSERVATION: --

PREDICT what will happen if you bring the plastic ruler or your finger close to the rubbed plastic strips

PREDICTION ---

EXPLAIN YOUR PREDICTION---

----

2. Now RUB the plastic ruler using any of the above-mentioned objects. RUB about 3 times. Bring the rubbed ruler close to ONE of the strips.

   WHAT DO YOU OBSERVE? --

   EXPLAIN YOUR OBSERVATION--

   ----

3. Let us go back to the LIGHTNING STORM picture. What charges did we see in the picture?

   ----

4. Do you think that the SAME CHARGES are found in other matter? --------------

   EXPLAIN YOUR ANSWER---

   ----

5. **CHALLENGES**:

What charge do the plastic strips have after being rubbed using the different types of the above-mentioned objects? EXPLAIN-----------------------------------

----

What charge do the objects have after being used to rub the plastic strips?

EXPLAIN ---

EXPLAIN how a CHARGED object and a NEUTRAL object attract each other?

----

6. Let us look at the **TRIBOELECTRIC SERIES** below.

Scientists have ranked materials in the order of their ability to hold or give up electrons. This ranking is called the tribo-electric series

Your hands
Glass
Your hair
Nylon
Wool
Fur
Silk
Paper
Cotton
Hard rubber
Polyester
Polyvinylchloride plastic

NOTE: The one higher up in the list should give up electrons and become positively charged.

CONSOLIDATION:

8. Can you write a SUMMARY of your INVESTIGATION? Begin this way:

When PLASTIC is rubbed with FINGERS or SILK, the plastic gets a

-------------------------------------- charge.

When PLASTIC is rubbed with a JERSEY or HAIR , the plastic gets a

-------------------------------------- charge.

Charges of the SAME KIND--

Charges of DIFFERENT KINDS---

A CHARGED object can ------------------------------a NEUTRAL object.

9. From the SUMMARY of your INVESTIGATION we can NOTE that:

Note: There is a FORCE between CHARGES.

There is also a FORCE between CHARGES and NEUTRAL objects.

FORCE BETWEEN CHARGES.

ACTIVITY 2.

PURPOSE: 2 (a) To investigate the effect on the amount of FORCE when the amount of CHARGE is increased (what happens to the force when we increase the charges)?

2 (b) To investigate what a CHANGE in the DISTANCE between A CHARGED object does on the FORCE.

RESOURCES:

For this activity you will need

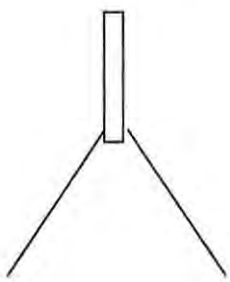
Two plastic strips.

A ruler.

WHAT TO DO:

Rub the two strips at the same time TWICE with silk or your fingers.

ESTIMATE the distance between the bottom ends of the strips--------------



Repeat the rubbing of the strips **THREE TIMES** and then **FOUR TIMES**, record your estimations each time in the table below.

NUMBER OF RUBBINGS	AMOUNT OF CHARGE (small, big or bigger)	WHAT HAPPENS TO THE FORCE

When you increase the number of rubbings what are you doing to the amount of charge?

What can you say about the SIZE OF THE FORCE when the amount of CHARGE CHANGES?

EXPLAIN YOUR ANSWER CLEARLY---

Now for the next investigation -RUB ONLY ONE strip THREE TIMES to give it a charge. RUB a plastic ruler to give it a charge. Slowly bring the ruler to the strip. Start from a distance of about 120mm from the strip and record your estimations each time.

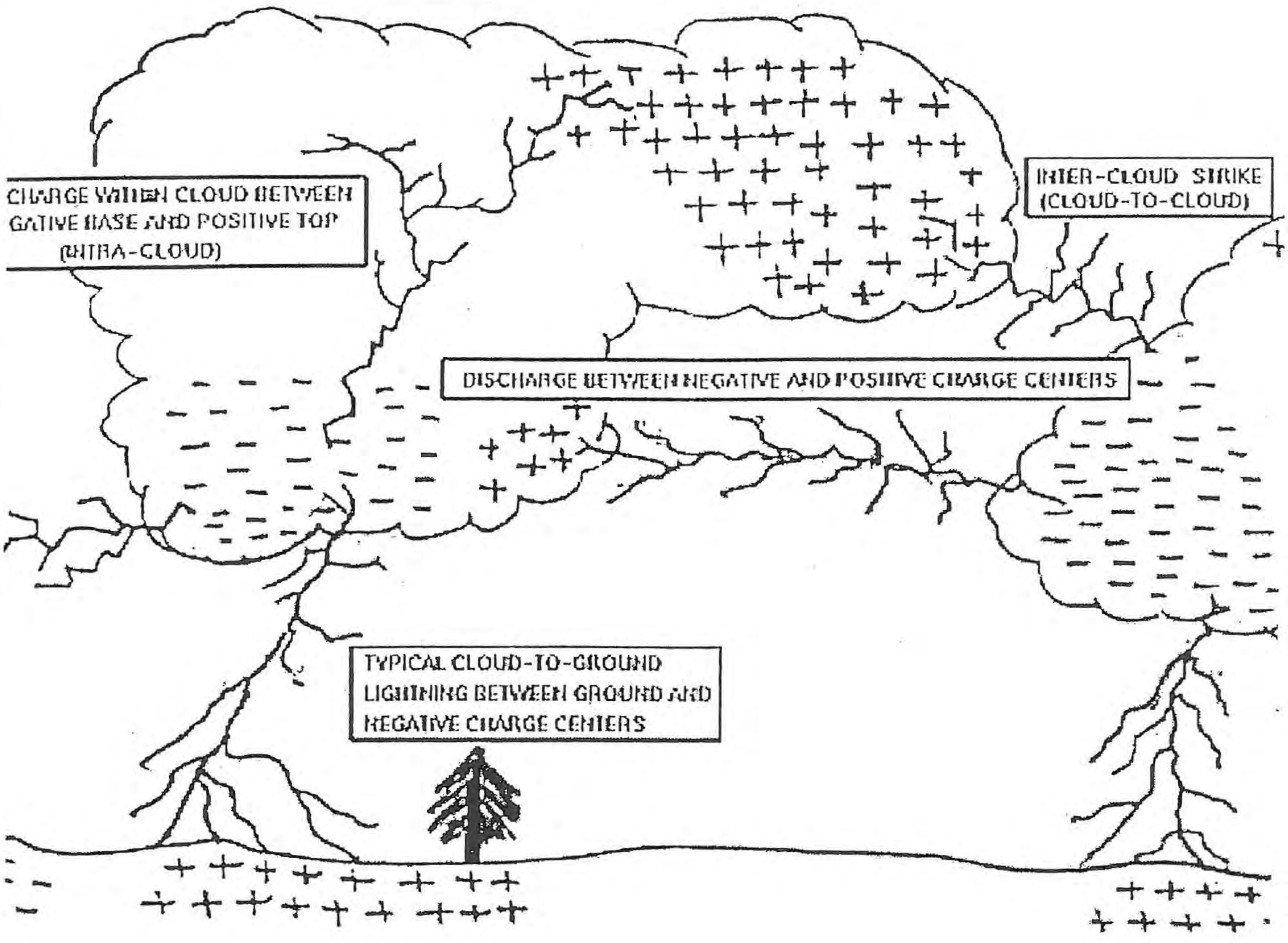
Record your findings in the following table:

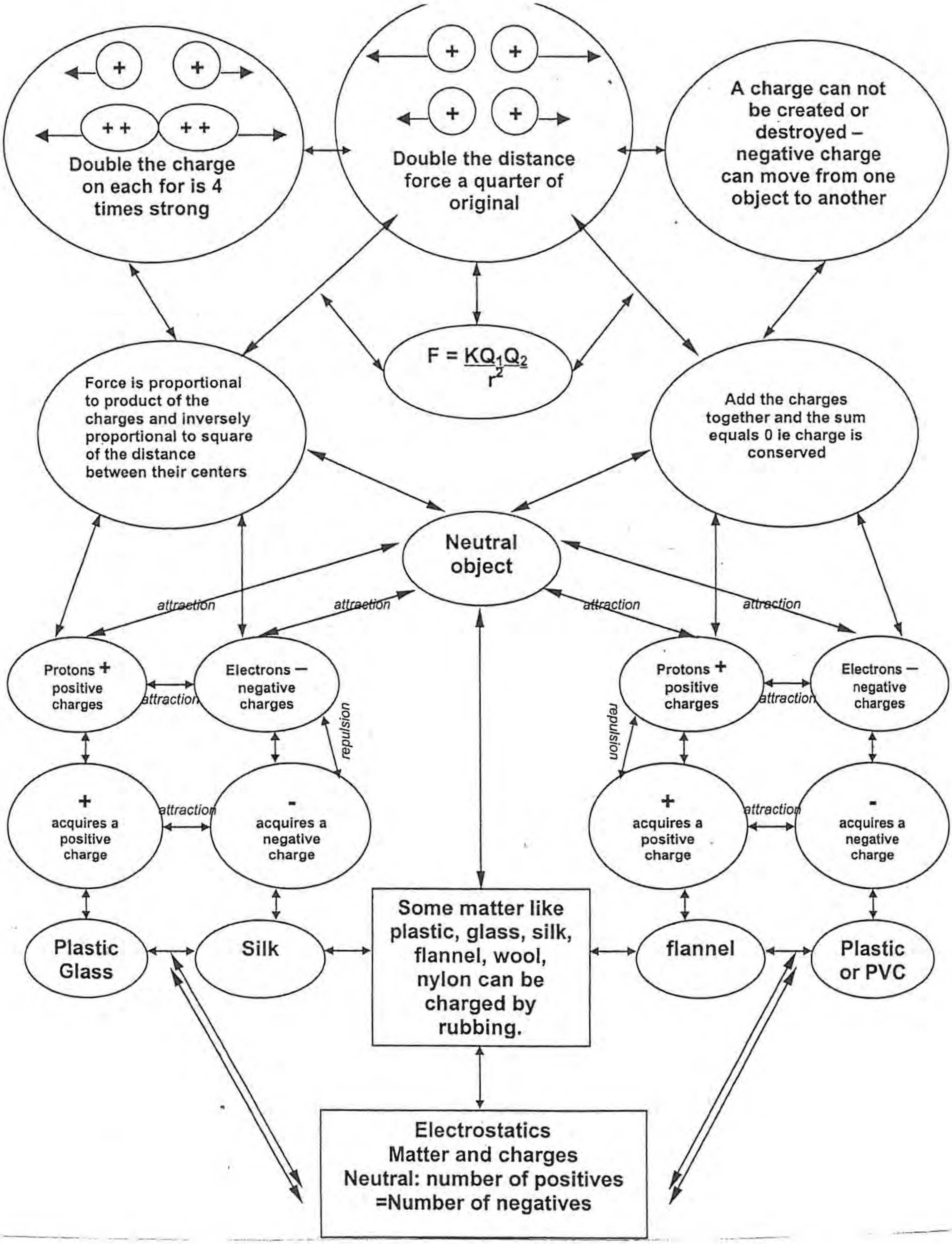
AMOUNT OF CHARGE	DISTANCE FROM STRIP	WHAT HAPPENS TO THE FORCE
	120 mm	

What can you deduce about the FORCE between CHARGES as the distance between the charges CHANGES?

EXPLAIN YOUR ANSWER CLEARLY--

Now, use the information you gathered in Activities 2(a) and 2(b) and write in your OWN words your deductions.


CHARGE WITHIN CLOUD BETWEEN
GATIVE BASE AND POSITIVE TOP
(INTRA-CLOUD)
INTER-CLOUD STRIKE
(CLOUD-TO-CLOUD)
DISCHARGE BETWEEN NEGATIVE AND POSITIVE CHARGE CENTERS
TYPICAL CLOUD-TO-GROUND
LIGHTNING BETWEEN GROUND AND
NEGATIVE CHARGE CENTERS


+ +
++ ++
Double the charge on each for is 4 times strong
Double the distance force a quarter of original
A charge can not be created or destroyed – negative charge can move from one object to another
$F = \frac{KQ_1Q_2}{r^2}$
Force is proportional to product of the charges and inversely proportional to square of the distance between their centers
Add the charges together and the sum equals 0 ie charge is conserved
Neutral object
attraction
attraction
attraction
attraction
Protons + positive charges
Electrons – negative charges
attraction
repulsion
Protons + positive charges
Electrons – negative charges
attraction
repulsion
+ acquires a positive charge
- acquires a negative charge
attraction
+ acquires a positive charge
- acquires a negative charge
attraction
Plastic Glass
Silk
Some matter like plastic, glass, silk, flannel, wool, nylon can be charged by rubbing.
flannel
Plastic or PVC
Electrostatics
Matter and charges
Neutral: number of positives =Number of negatives

APPENDIX B

ELECTRICITY BY DISCOVERY

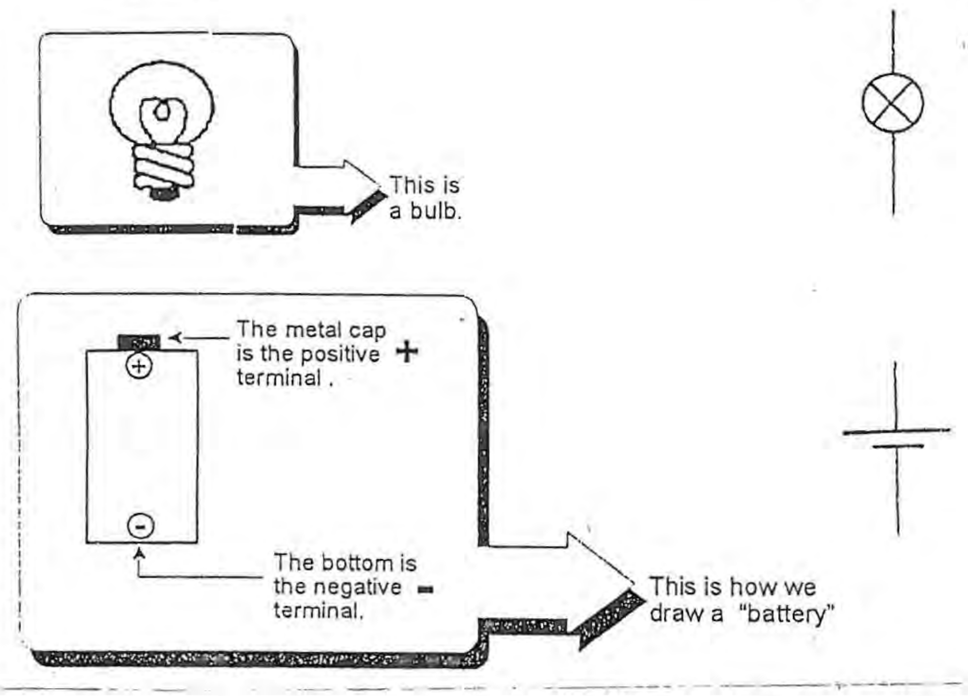
Concept sheet #1

Challenges to your understanding of electricity (prior knowledge):

Activity 1

The diagram in Activity 1 shows bulbs and cells. Carefully look at the diagram on this page before doing the Activity.

Picture | Symbol used



Each of the diagrams A – P below shows a light bulb joined to a cell using a piece/pieces of copper wire. Look carefully at each of the diagrams. **Predict** which of the bulbs will light up. Do and write down your predictions individually first and then in groups.

Choose **Yes OR No OR I do not know** to answer.

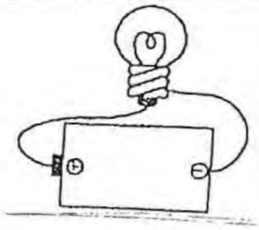
Draw a circle around your choice as shown alongside.

A

Do you think

bulb **A** will

light up? Explain.



Before: Yes/No/I do not know

Individual:

Group:

After: Yes/No/I do not know

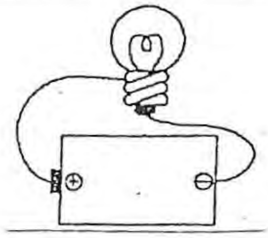
Group:

B

Do you think

bulb **B** will

light up? Explain.



Before: Yes/No/I do not know

Individual:

Group:

After: Yes/No/I do not know

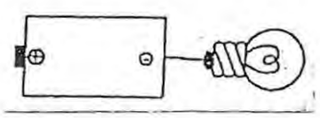
Group:

C

Do you think

bulb **C** will

light up? Explain.



Before: Yes/No/I do not know

Individual:

Group:

After: Yes/No/I dot not know

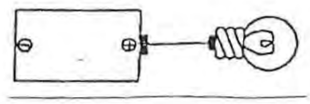
Group:

D

Do you think

bulb **D** will

light up? Explain.



Before: Yes/No/I do not know

Individual:

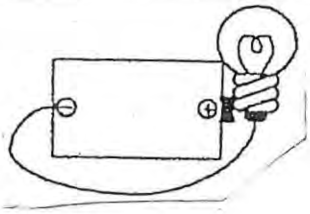
Group:

After: Yes/No/I dot not know

Group:

E

Do you think bulb **E** will light up? Explain.



<u>Before</u>: Yes/No/I do not know

Individual:

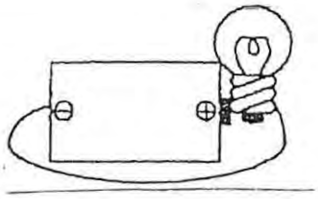
Group:

<u>After</u>: Yes/No/I do not know

Group:

F

Do you think bulb **F** will light up? Explain.



<u>Before</u>: Yes/No/I do not know

Individual:

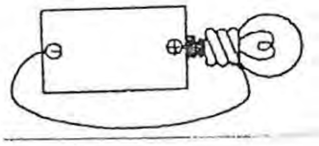
Group:

<u>After</u>: Yes/No/I do not know

Group:

G

Do you think bulb **G** will light up? Explain.



<u>Before</u>: Yes/No/I do not know

Individual:

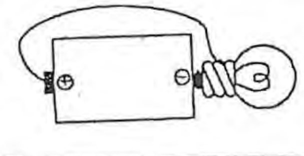
Group:

<u>After</u>: Yes/No/I dot not know

Group:

H

Do you think bulb **H** will light up? Explain.



<u>Before</u>: Yes/No/I do not know

Individual:

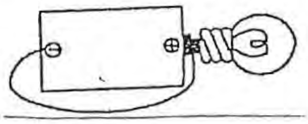
Group:

<u>After</u>: Yes/No/I dot not know

Group:

I

Do you think bulb **I** will light up? Explain.



Before: Yes/No/I do not know

Individual:

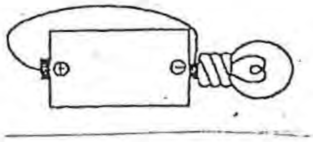
Group:

After: Yes/No/I dot not know

Group:

J

Do you think bulb **J** will light up? Explain.



Before: Yes/No/I do not know

Individual:

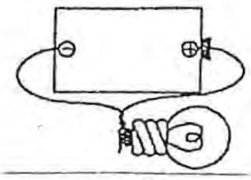
Group:

After: Yes/No/I dot not know

Group:

K

Do you think bulb **K** will light up? Explain.



Before: Yes/No/I do not know

Individual:

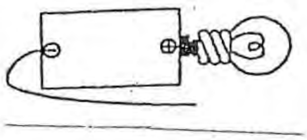
Group:

After: Yes/No/I dot not know

Group:

L

Do you think bulb **L** will light up? Explain.



Before: Yes/No/I do not know

Individual:

Group:

After: Yes/No/I dot not know

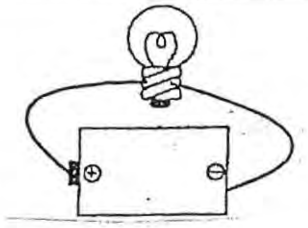
Group:

M

Do you think

bulb **M** will

light up? Explain.



<u>Before</u>: Yes/No/I do not know

Individual:

Group:

<u>After</u>: Yes/No/I dot not know

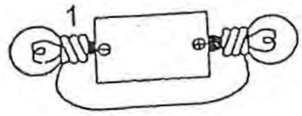
Group:

N

Do you think

bulbs **N** will

light up? Explain.



<u>Before</u>: Yes/No/I do not know

Individual:

Group:

<u>After</u>: Yes/No/I dot not know

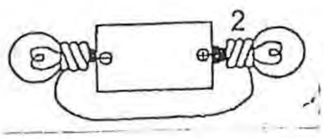
Group:

O

Do you think

bulbs **O** will

light up? Explain.



<u>Before</u>: Yes/No/I do not know

Individual:

Group:

<u>After</u>: Yes/No/I dot not know

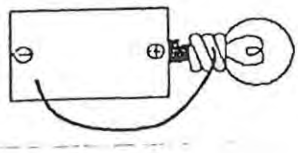
Group:

P

Do you think

bulb **P** will

light up? Explain.



<u>Before</u>: Yes/No/I do not know

Individual:

Group:

<u>After</u>: Yes/No/I dot not know

Group:

Activity 2

Materials: 1 cell, 1 bulb and a connecting wire.

Task:

Using the given materials, make a bulb light up.
Draw a sketch of your set-up in the space provided.

Now, connect your materials in a different way and make the bulb light up.
Draw a sketch of this set-up.

Write down a list of conditions in order for your bulb to light up.

Challenge: explain how a battery works and why does the bulb light up?

Activity 3

Did you know that you could make electricity without a battery or generator?

Materials: a lemon, a pineapple, a tomato, a potato, a zinc plate or corrugated iron, a copper plate or a 5c piece coin, your tongue, LCD clock, a thermometer, a bulb and a voltmeter.

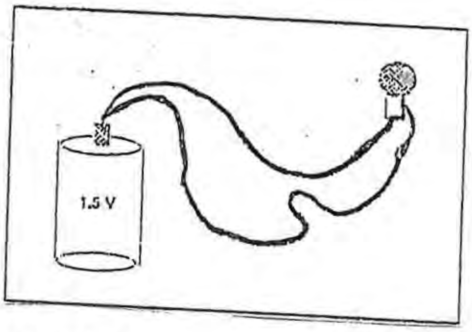
Challenge: Using the given materials, set-up a complete circuit to demonstrate how electricity is generated. Draw your circuit diagram. Write down a procedure for your experiment and give a detailed explanation how it works or why it does not work.

Concept sheet # 2

You have completed **Sheet #1** with your best of ideas about electricity. This sheet will look at some similar situations as in **Concept Sheet #1**, and also some new situations. The idea is to see whether your understanding was appropriate and to help develop it further where necessary.

Challenge 2.1:

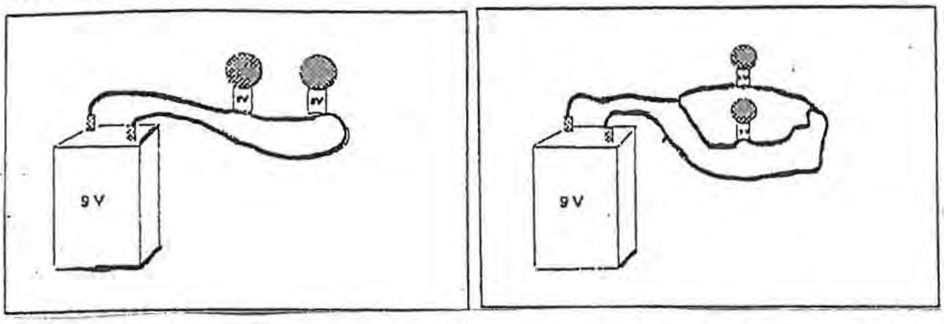
To light a bulb, a child has made the connection shown in the drawing. Make that same connection with the materials you have.



What happens?

Can you make it better? Draw your own connection below:

Challenge 2.2:



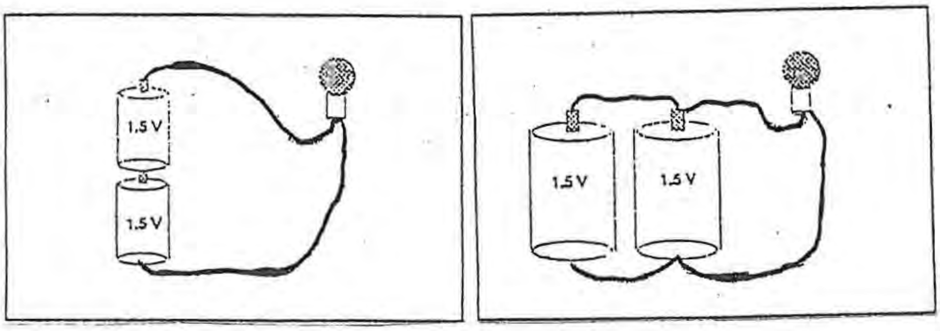
To see what happens when two bulbs are connected, Nomsa made two different types of connections shown in the two drawings, using a 9V battery and two 6V bulbs.

Do you think there will be a difference in brightness for the bulbs in the one connection or the other?

Make the two types of connections yourself. What do you see?

Can you try and explain this?

Challenge 2.3:



Now, instead of two bulbs, a child has used two batteries to make a connection. The batteries used are now 1.5V batteries. The bulb is again a 6V bulb.

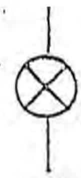
Do you think there will be a difference in the brightness of the bulb with the one connection or the other?

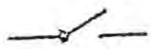
Make the type of connection yourself. What do you see?

Can you try to explain this?

Investigation – Cells and Lamps

You are supplied with the micro-electricity kit, containing a number of components. In our exercise we shall use SYMBOLS to denote components.

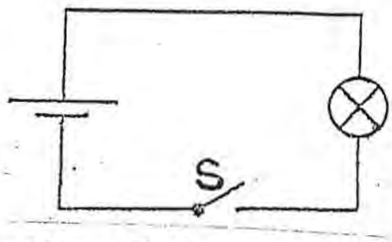
The SYMBOL for a cell ("battery") is:  For a lamp we shall use: 

and a switch  shown open circuited (i.e. no connection)

Task 1 – Cells in series

(a) Connect up the following circuit, using your components.

CIRCUIT DIAGRAM



The lines connecting the components indicate conducting wires.

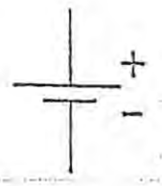
On pressing S, your bulb should light up and burn dimly.

(b) Now, connect a second cell in **SERIES** (one after the other) with the first. Press S.

(i) Observe and explain:

(ii) Draw a circuit diagram representing this connection

It is usual to denote the knob end of a cell the positive terminal (+) and the flat end, the negative terminal (-). By convention the positive terminal of the cell has been connected to the RED wire and the negative terminal of the cell to the BLACK wire. In a circuit diagram, the longer bar of the cell symbol represents the positive terminal:



(c) Turn one of your cell-boards around, thus REVERSING its Polarity in the circuit. Press S.

(i) Observe and explain:

(ii) Draw a circuit diagram representing this connection

(d) Now connect three cells in series to form a battery (of cells) so that their polarities are all in the same direction. Press S.

(i) Observe and explain:

(ii) Draw a circuit diagram representing this connection

(e) Reverse the polarity of one of the cells relative to others.
Press s.

(i) Observe and explain:

(i) Draw a circuit diagram representing this connection

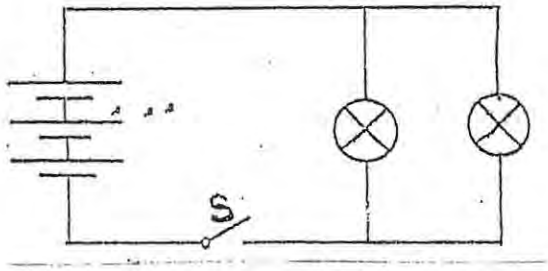
Note:

(i) In this Activity we have connected **ONE BULB** in **SERIES** with a battery of cells.

(ii) In case (b) above, cells assisted each other, thus producing a brighter light, whereas in (c), the cells opposed each other producing no light in the bulb.

Task 2 – Bulbs in parallel and series

(a) Connect up the following circuit. The two bulbs are connected in **PARALLEL.**



Observe and explain: Compare the brightness of the bulbs with the brightness of a single bulb in **Task 1** part (d).

(b) Draw a **CIRCUIT DIAGRAM** where **two** bulbs are connected in **series** with another bulb in **parallel** to these two series connected bulbs, power being supplied by a battery of three cells in series (all assisting).

Now connect up your circuit and operate it.

Observe and explain:

Task 3 – Cells in parallel

Connect a single cell to a single bulb as in **Task 1** (a). Now connect a second cell in parallel with the first. Make sure that the red terminals are connected to each other and the black terminals are connected to each other. In the space below, draw the **CIRCUIT DIAGRAM. Do not attempt to operate the circuit.**

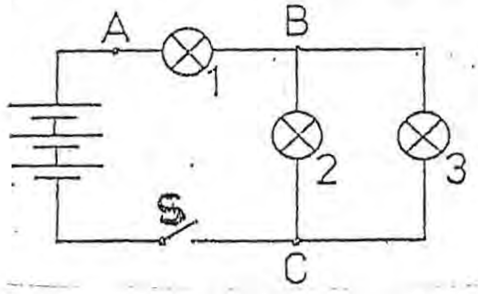
Now you may operate the circuit.

Observe and explain:

Task 4 – Bulbs in series and parallel

Connect this circuit. Upon closing "S" note the relative brightness of each bulb, that is:

Bulb 1
Bulb 2
Bulb 3



(a) Join points A and B with a piece of wire.

What do you observe? Explain your observation.

(b) Now remove the wire from A and connect it to point C so that B and C are now joined.
What do you observe? Explain your observation.

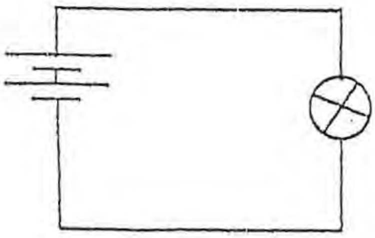
Practical electricity: Exercise 1

1. In each of the following cases, give the brightness of the bulbs and score according to the following scheme:

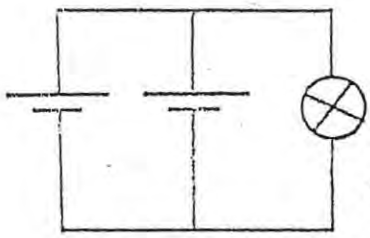
0 if the bulb is not lit at all;
1 if the bulb will light up dimly;
2 if the bulb will be bright.

"Bright" in this context means as bright as a single bulb in series with two cells also in series.

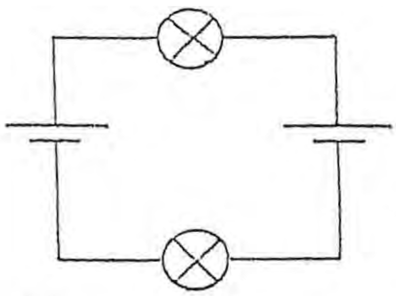
If you give the bulb(s) a zero score, indicate why.



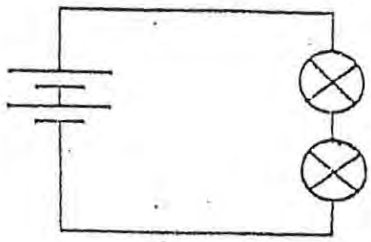
SCORE:



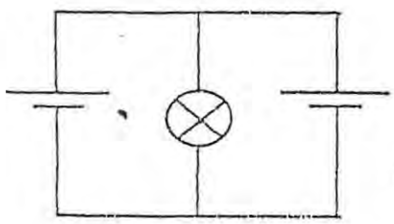
SCORE:



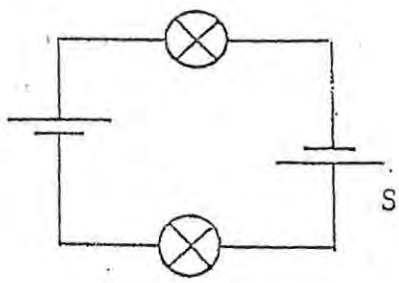
SCORE:



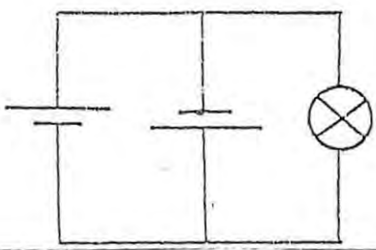
SCORE:



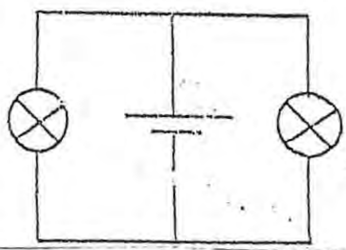
SCORE:



SCORE:



SCORE:

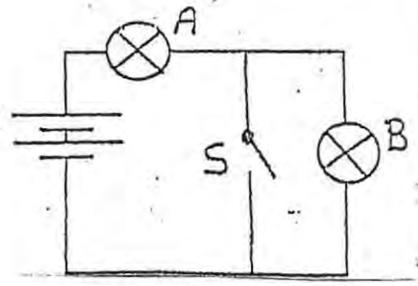


SCORE:

2. In the following circuit, when the switch S is closed,

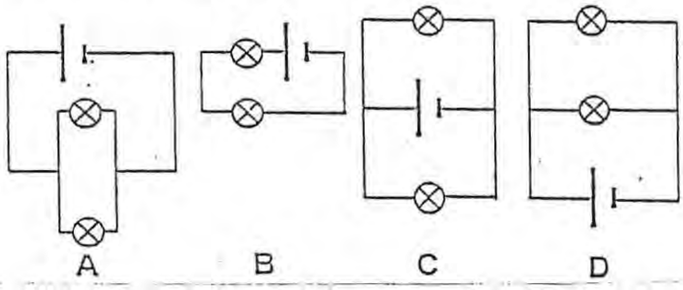
the brightness of bulb A changes from...........to...........and

the brightness of bulb B changes from............to............



In Question 3 – 5, to answer draw a circle around either **A** or **B** or **C** or **D**

3. The circuits show a single cell joined to two light bulbs. Which one of the circuits do you think is in a series circuit?



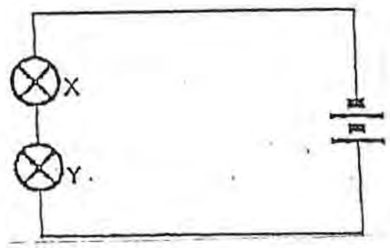
4. The diagram alongside shows two light bulbs **X** and **Y** in a circuit. If **X** is taken out of its socket,

A **Y** burns more brightly;

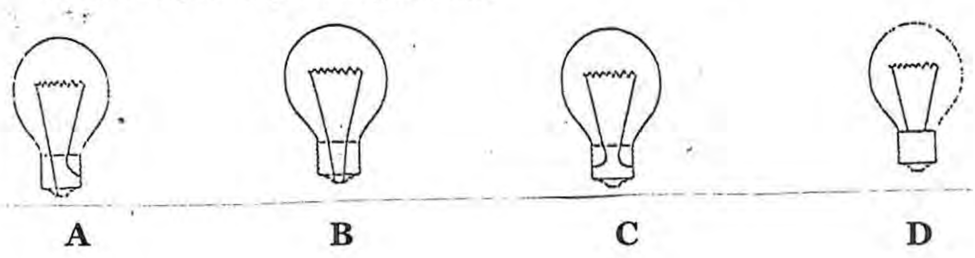
B **Y** burns more dimly;

C **Y** burns with the same brightness as it did before X is taken out;

D **Y** does not burn (light up) at all.



5. Which of the following diagrams below represents the internal structure (inside) of a light bulb.



Concept sheet #3

Learning about voltage and current and about parallel and series connections.

On this sheet you are asked to fill in answers to some simple questions. The idea is to see what you already understand about electricity.

Question 1

What is

(a) Electricity?

(b) Voltage?

(c) Current?

Question 2

(a) What is a battery?

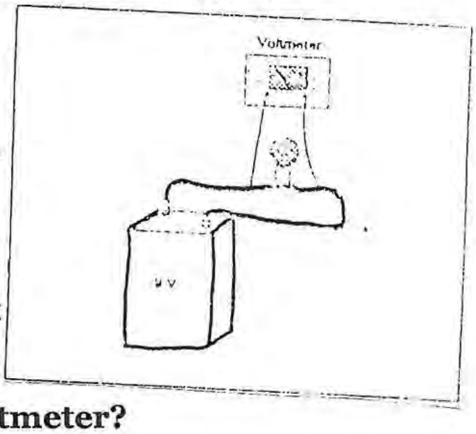
(b) What does 'positive' and 'negative' mean in the case of a battery?

Question 3

Why does an iron get hot when connected to a source of electricity?

Introduction

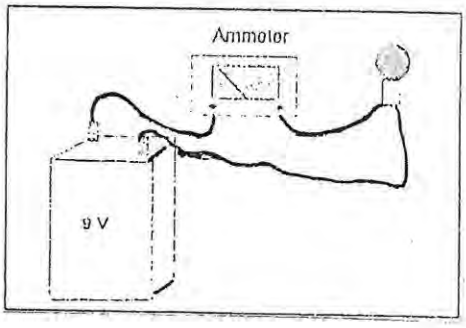
This sheet will help you to start developing a fuller understanding of **"voltage"** and **"current"** and what these mean in an electric circuit. You will use a "voltmeter" to measure voltage and an "ammeter" to measure current.



A VOLTMETER measures the amount of energy needed To move charges from one point to another in an electric circuit. This is called the voltage or "Potential Difference" The voltmeter is connected in such a way that it measures a difference over a part in the circuit in the way shown in the picture. This kind of connection is a **"PARALLEL"** connection: the voltmeter is positioned parallel to the part of the circuit it will measure.

What can you deduce about the resistance of a voltmeter?

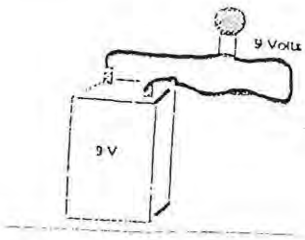
The current is the flow of charges (i.e. $I = Q/t$). Current is measured in units called **amperes.** The battery does not give you a fixed current, You can see it is not written on the battery what the current is.



An AMMETER measures the amount of current In amperes (A) going through a certain part in the circuit. This means that an ammeter has to be connected IN the circuit, next to the part you measure The given drawing shows how. In this kind of connection the ammeter is positioned "IN SERIES".

What can you deduce about the resistance of an ammeter?

Challenge 1



(a) Make the circuit as shown in the diagram

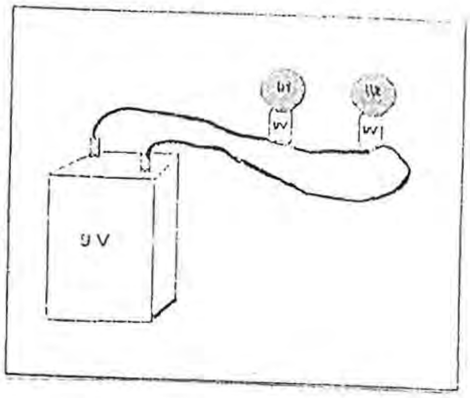
(b) Measure the current (in amperes) that goes through the bulb:..

(c) Measure the voltage or potential difference (often people say "p.d.") over the bulb:...................

Measure the p.d. over the battery:............................

DRAW every time how you connected you ammeter (both in case of the ammeter and the voltmeter)! Then write the results into your drawing next to the meter you have drawn.

Challenge 2



(a) Make the circuit in the drawing.

What kind of connection is used for putting B1 and B2 into the circuit?...........................

(b) Do you think there is a difference in current *before, between* and *after* the bulbs?

....

....

Measure the current going through bulb B1.........................
Measure the current going through bulb B2.........................
What is the current going through B1 and B2?.....................

(c) Do you think there is a difference in p.d. over B1 compared to that over B2; or over B1 compared to that over B1 and B2 together?

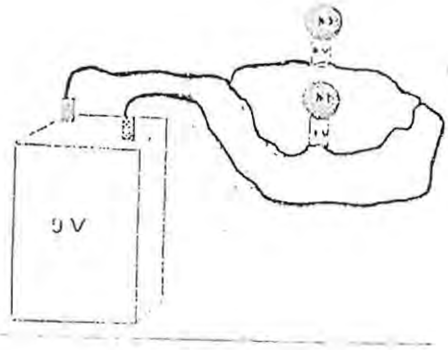
....

....

....

Measure the p.d. over B1:..................
Measure the p.d. over B2:..................
Measure the p.d. over B1 and B2 together:..........................

Challenge 3



(a) Make the circuit in the drawing.
What kind of connection is used for putting B1 and B2 into the circuit?..........................

(b) Do you think there is a difference in current Going through B1 compared to that going Through B2?..

....

And what about before and after the split?
....
....
....

Measure the current going through B1:...........................
Measure the current going through B2:...........................
Measure the current before the split into B1 and B2:...........................
Measure the current after the split into B1 and B2:..............................

(c) Do you think there is a difference in p.d. over B1 compared to that over B2; or in B1 compared to that over B1 and B2 together?
....
....
....

Measure the p.d. over B1:.......................................
Measure the p.d. over B2:.......................................
Measure the p.d. over the whole of B1 and B2:...............................

Challenge 4

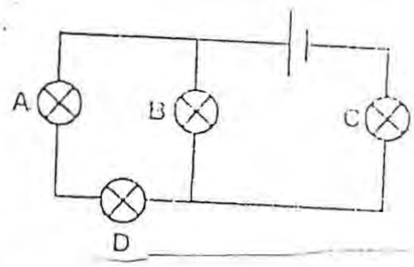
Write down whatever you have learned. Any unexpected things, anything that you already had understood or thought of, anything new, anything interesting. Discuss with your colleagues.

Practical electricity – exercise 2

To answer question 1 – 14, draw around either

A or **B** or **C** or **D**

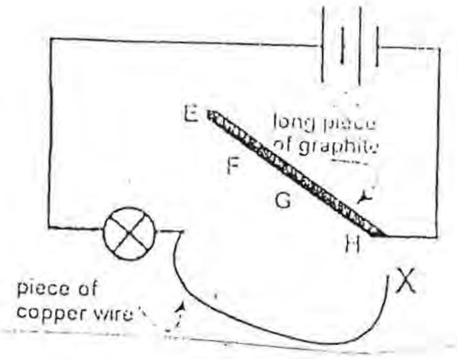
1. In the diagram alongside, one of the bulbs breaks. This makes all the other bulbs in the circuit go out. Which bulb breaks?



Question 2, 3 and 4 are about the circuit in the diagram. The diagram shows a piece of graphite (conductor of electricity) in a circuit. A piece of copper wire can be joined to the piece of graphite.

A piece of copper wire can be joined to the piece of graphite.

When **X** on the copper wire touches either **E** or **F** or **G** or **H** on the graphite, the bulb lights up. The bulb burns with different brightness when **X** Touches **E**, **F**, **G** and **H**.



2. Where should **X** be joined (to **E**, **F**, **G** or **H**) to make the bulb light as brightly as possible?

   A Join X to E on the graphite.
   B Join X to F on the graphite.
   C Join X to G on the graphite.
   D Join X to H on the graphite.

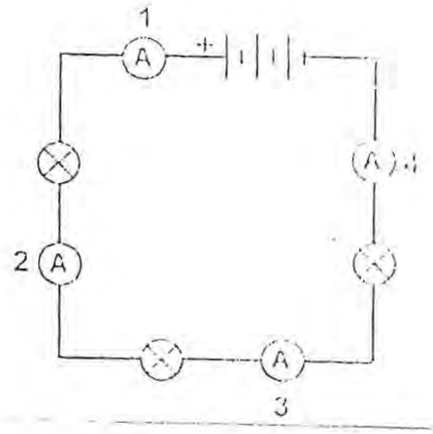
3. Where should X be joined to make the current in the circuit as high as possible?

   A Join X to E on the graphite.
   B Join X to F on the graphite.
   C join X to G on the graphite.
   D join X to H on the graphite.

4. Where should X be joined to make the resistance in the circuit as high as possible?

   A Join X to E on the graphite.
   B Join X to F on the graphite.
   C Join X to G on the graphite.
   D join X to H on the graphite.

5. The diagram shows three **identical** light bulbs and four identical ammeters (1, 2, 3 and 4) joined to three cells. Current flows from the positive terminal (+) of the cells to the negative (-) terminal of the cells.

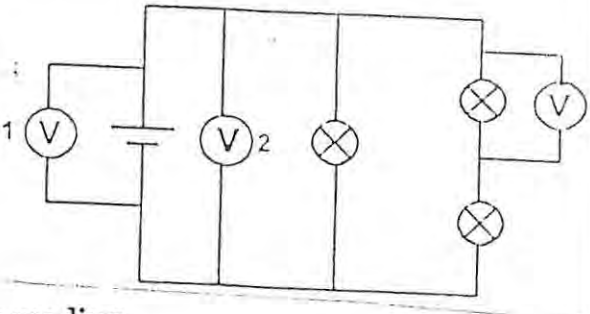


Which one of the statements below is correct?

A Ammeter 1 shows a higher (bigger) current than ammeter 2;
B Ammeter 2 shows a higher (bigger) current than ammeter 3;
C Ammeter 3 shows a higher (bigger) current than ammeter 4;
D All ammeters show the same reading.

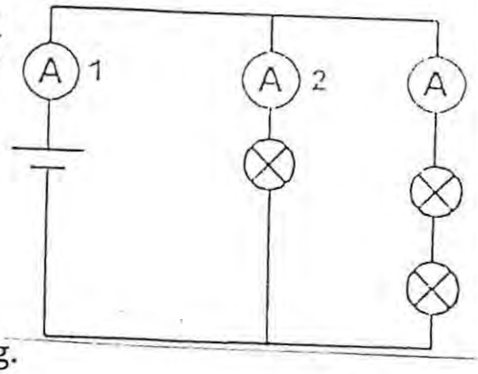
6. The diagram shows three identical bulbs and three identical voltmeters.

Which voltmeter shows the same reading?



A Voltmeter 1 and voltmeter 2;
B Voltmeter 1 and voltmeter 3;
C Voltmeter 2 and voltmeter 3;
D None of the voltmeters show the same reading.

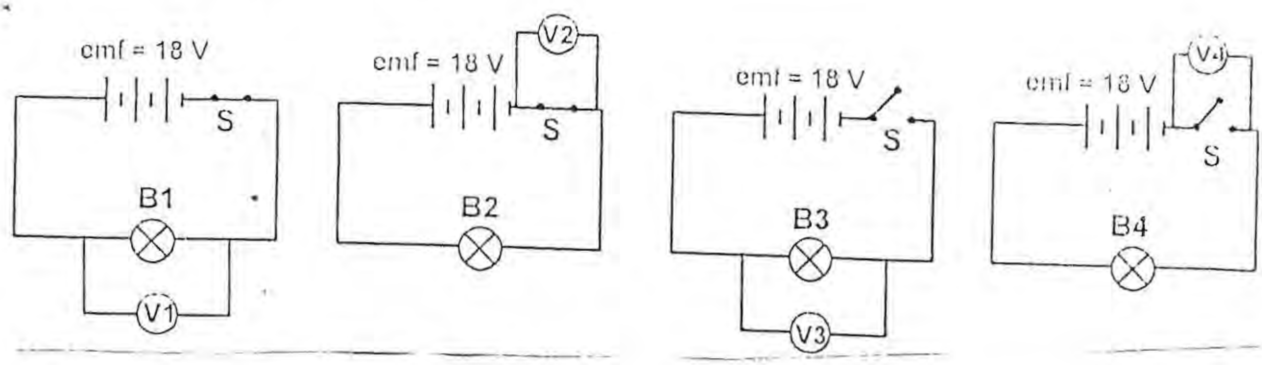
7. The diagram shows three identical light bulbs and three identical ammeters. Which ammeters show the same reading?



A Ammeter 1 and ammeter 2;
B Ammeter 1 and ammeter 3;
C Ammeter 2 and ammeter 3;
D None of the ammeters show the same reading.

Question 8 and 9 are about the four circuit diagrams below:

The bulbs are called B1, B2, B3, and B4. B1, B2, B3 and B4 are identical.
The batteries (three cells) and the voltmeters in each of the circuits are identical.



8. Which bulbs light up? Answer by drawing a circle around the bulbs in the table below. You may not circle more than one answer.

B1	B2	B3	B4

9. Complete the table below to show the reading (in volts) on each of the voltmeters.

V1	V2	V3	V4

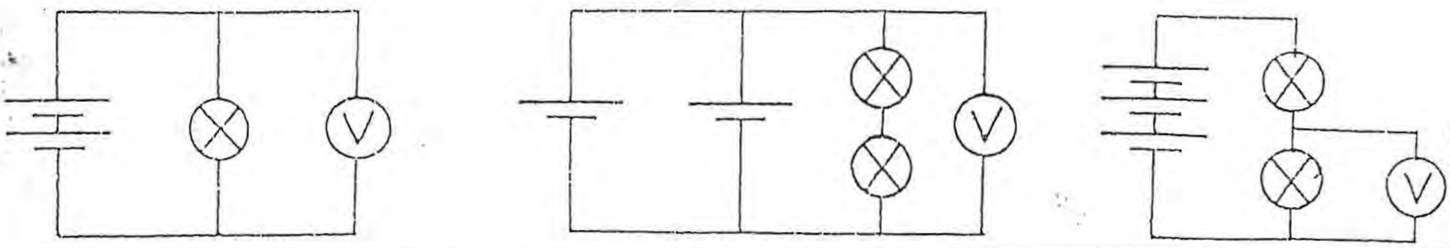
10. How can you make a 6 volts bulb light up the brightest only using 1.5V batteries? Try it out and use as many as you think are necessary. Draw the connections you made.
The type of connections I/we used:

Diagram:

11. You have two 6 volts bulbs and only one 9 battery. Can you light the two bulbs together without "blowing them up"? Try it out. Make a drawing of the connections.
The type of connections used:

Diagram:

12. The voltage across one cell is 1.5V. If all the bulbs and cells in the circuit below are identical, note down the voltage that each meter would measure.

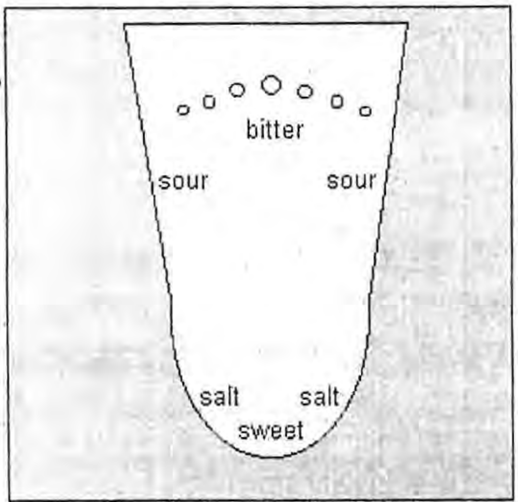


APPENDIX C

ELECTRICITY AND CHEMISTRY

Chemicals are used to produce electricity, and electricity can produce chemicals. Our study of chemistry will begin with two most common consumer products, **chemicals** that most of us use virtually everyday: **table salt (sodium chloride)** and **table sugar (sucrose)** are both white crystalline solids. It is difficult to tell them apart except by taste.

There are at least four types of taste receptors and they are distinguished by location of their receptors on the tongue as shown in the schematic rendering below:



Taste Bud: A Schematic View

- **The sour taste**
  This is the taste of acids. The more acidic the substance the more sour the taste. Acids include hydrogen ions in their chemical makeup.

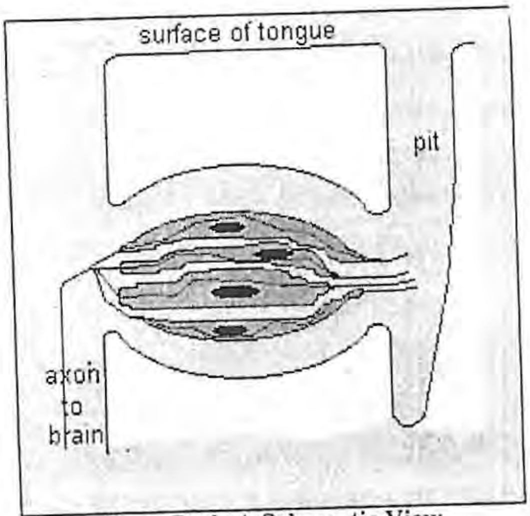
- **The salty taste**
  Ionized salts are responsible for eliciting this taste perception. Different salts have slightly different tastes because they also contain other basic taste components.

- **The sweet taste**
  There is a long list of substances that yield the sweet taste. You will be familiar with sugars (e.g. sucrose, fructose, glucose, maltose, lactose) but

- **The bitter taste**
  Like the sweet taste, there is a long list of substances that elicit the bitter taste. Most are also organic. One significant group of organic substances that taste bitter is the alkaloids. This may have survival

value since many of the deadly toxins in poisonous plants are alkaloids and intense bitter tastes are normally rejected.

In addition to the basic tastes of sweet, sour, salty and bitter, some researchers say studies show that a meatlike taste, known as **umami**, exists. While many researchers continue to map the molecular underpinnings of taste perception, others are investigating the "broccoli dilemma". Why do some hate it and some love it? Scientists plan to investigate how these findings translate into food preferences and influence health. For example, supertasters may face higher risk of cancer if they find broccoli and other veggies that carry cancer-preventing vitamins too bitter to stomach. (see: http://wwwsfn.org/briefings/taste.html). The normal adult tongue has about 10 000 taste buds, the **receptor for taste**. Each looks somewhat like an onion, about 0.03 mm in diameter and 0.06 mm in length. The taste bud is made up of taste cells. What is unusual is that each taste cell lives for only about a week and they continually regenerating. A taste bud will contain a mixture of new and mature taste cells. Here is a schematic view of a taste bud showing four taste cells:



Taste Bud: A Schematic View

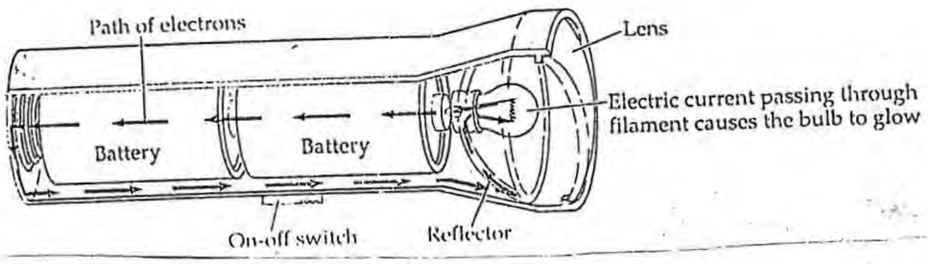
As with most sensory receptors the structure stimulated is a specialized **dendrite**. The taste cell has a hair-like dendrite structure extending into the pit that leads to the surface of the tongue. (See http://www.science.wayne.edu/-wpoff/cor/sen/tastanat.html). Going back to our exploration of sugar and table salt, there is another important way they differ, and that is through their electrical behaviour in water. The difference is how each of these consumer products conducts or does not conduct electricity when it is dissolved in water and this also tells us a great deal about their composition. We can observe the difference with a simple flashlight (torch), some salt, sugar, a bit of warm water, and a sponge. (This demonstration works well with new cells or batteries and a new flashlight with clean electrical contacts).

Activity 1

In a small glass/beaker dissolve a tablespoon of sodium chloride (NaCl) (table salt) in about a quarter of a cup of water. Do the same with a tablespoon of sucrose (table salt) in another beaker. Now wet two sponges with these solutions.

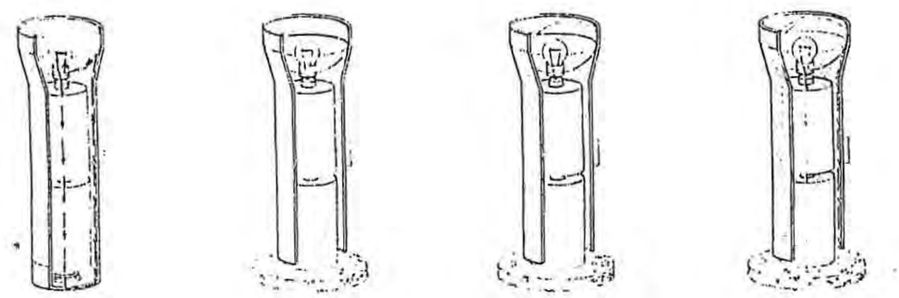
Turn the flashlight on and unscrew its back or front part. Normally, the flashlight goes off when you remove its back or front part. The spring that you see on the back part of the flashlight does two jobs. It pushes the cells/batteries firmly up against the bulb and it serves as part of the flashlight's electric circuit, which is simple, the path the electrons follow within the flashlight.

Electrons are extremely small particles that carry a negative electrical charge. The movement of electrons along a circuit produces an electric current. Electrons leave the base of the cells/batteries, travel to the bulb over the metal parts within the flashlight, move through the bulb's filament-the small narrow wire in the light bulb that heats up and emits light as electrons flow through it and then back to the cells/batteries. The spring is part of this circuit. It acts as the path that carries the electrons from the bottom of the nearest cell to the inside wall of the flashlight (see diagram below).



When we unscrew the back/front part of the flashlight we interrupt the path and so the light goes out. We are going to try and light the flashlight by replacing the metal spring with something else.

Can you predict what will happen if sponges wet with water, sugar solution and salt solution are placed between the spring and the cell inside a flashlight? See diagram below.



Since the voltage of the flashlight is so very low, this demonstration of the difference in electrical behaviour between salt and sugar is simple and safe enough for you to carry out (does not damage the flashlight or cells/batteries as long as they are cleaned and dried thoroughly at the end. The remarkable difference between sucrose (sugar) and sodium chloride (table salt), is that sodium chloride conducts electricity when dissolved in water, but sugar does not. Substances that conduct electricity when dissolved in water are called **electrolytes.** Those that don't conduct electricity are called **non-electrolytes**. The difference in electrical conductivity between salt and sugar arises from differences in the chemical compositions of these two everyday substances. More exactly, it comes from the differences in the kinds of forces that hold matter together in the two.

Note:

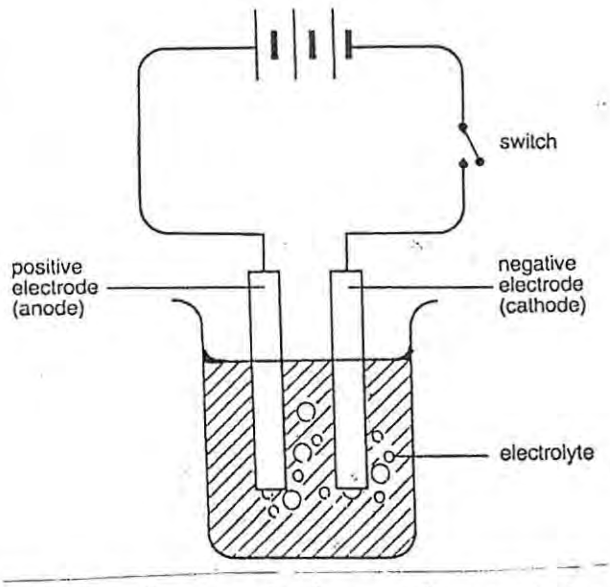
- "Pure" water is a very poor conductor of electricity (or poor electrolyte) as is a solution of sucrose (sugar in water). Water slightly ionizes. A solution of sodium chloride (salt in water) is a good conductor of electricity since sodium chloride (**NaCl**) ionizes completely, that is, dissociates into ions (**Na^+ and Cl^-**).
- Atoms are among the fundamental particles of the science of chemistry and make up matter. By matter we mean simply all the different kinds of substances that make up the material things of the universe.
- Molecules are groups of two or more atoms held together by forces of chemical bonds.
- Ions are atoms or groups of atoms that carry a positive or a negative electrical charge.

CHEMICAL ELECTROLYSIS OF WATER

Electrolysis:

An electric current can have a chemical effect. It can cause a chemical substance to change. For example, it can cause water to change its nature. Water consists of two elements **hydrogen (H_2)** and **oxygen (O_2)**. Hydrogen and oxygen are both gases.

Electrolysis means to separate a substance into its parts using an electric current. To separate water into hydrogen and oxygen, we must pass electric current through it. Since water is not a good conductor of electricity, to make it a better conductor we can add a small amount of acid (for example **HCl**) or base (for example **NaOH**) to it. The water containing acid is called acidified water. Electrodes are pieces of metal or carbon rods connected to an electric current. They connect the electric current to the liquid conductor and the liquid conductor is called an **electrolyte**.



During the electrolysis of water, hydrogen forms at the negative electrode. This electrode is called the cathode. Oxygen is formed on the positive electrode and this is called the anode. You should have noticed that more hydrogen was formed than oxygen. This is because water (**H_2O**) is made up of two parts of hydrogen and one part of oxygen.

ELECTROCHEMICAL CELL

What do the cell processes look like on the microscopic scale?

Figure 1 shows a microscopic representation of zinc/copper electrochemical cell before the cell reaction has started (the connecting wire has only just been attached to two electrodes).

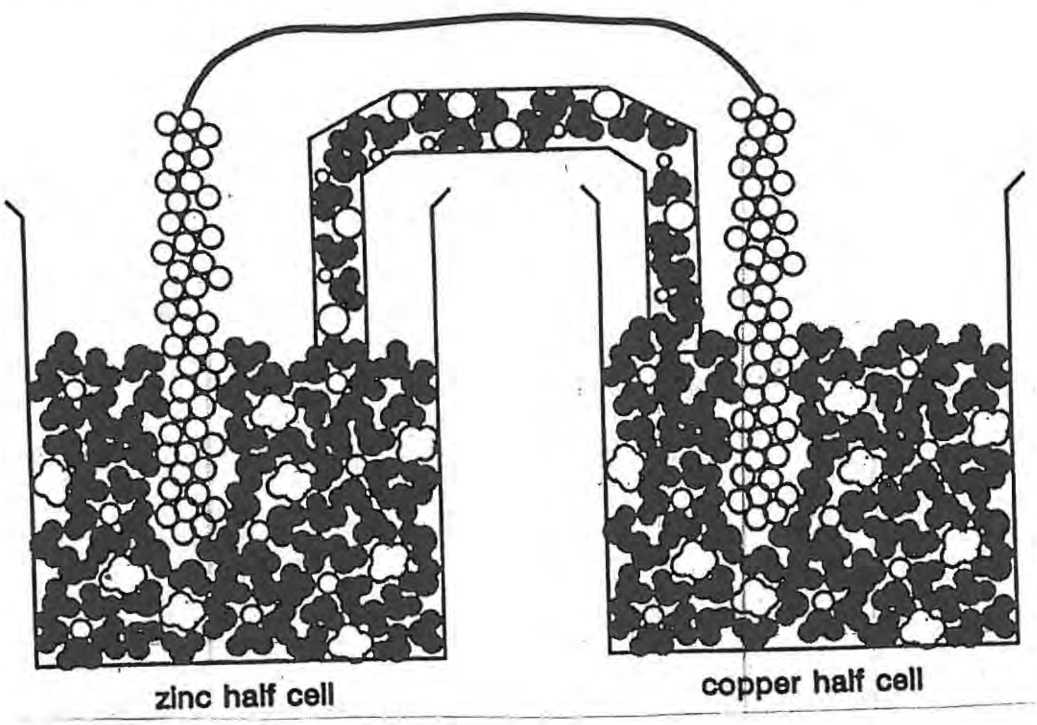


Figure 1

Take five different coloured pencils. With one colour, colour in the zinc atoms in the zinc rod and the zinc ions in the zinc sulphates solution. With a second colour, colour in the copper atoms in the copper rod and the copper ions in the copper sulphates solution. With a third colour, colour in the sulphate ions in the zinc sulphate and copper sulphate solutions. With the fourth and fifth colours, colour in the sodium and chloride ions in the sodium chloride solution in the salt bridge.

Fill in Table 1.1 below

Cell Component	Number of atoms or ions						
	Zn	Zn^{2+}	Cu	Cu^{2+}	SO_4^{2-}	Na^+	Cl^-
Zinc half cell							
Copper half cell							
Salt bridge							

Figure 2 below is a microscopic representation of the same cell after some time. Use the same five coloured pencils to colour in the atoms and ions as you did before.

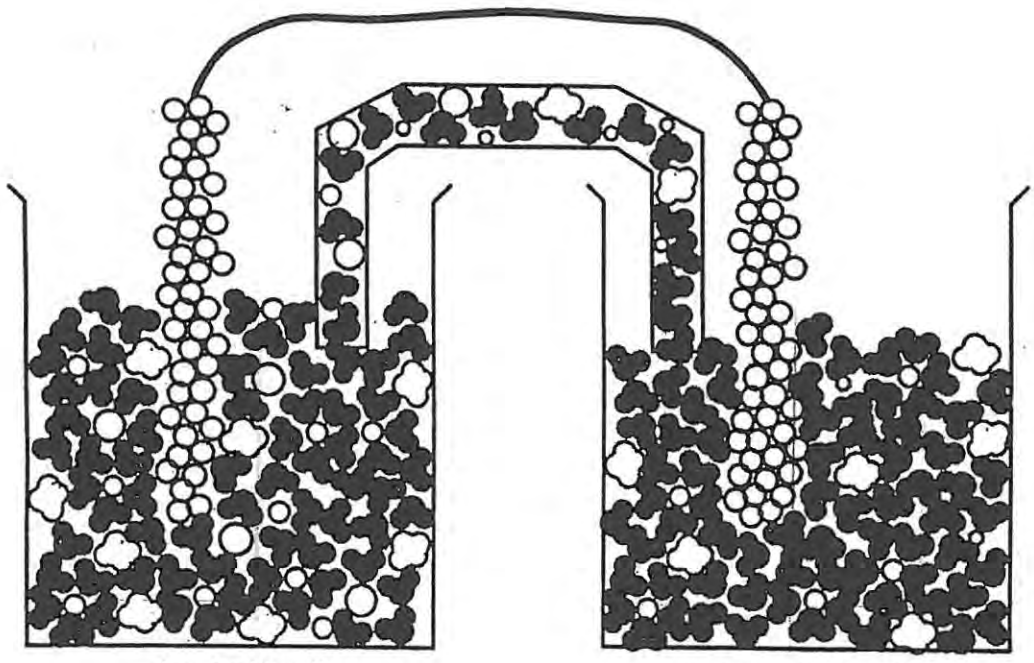


Figure 2

Fill table 2.1 below

Cell Component	Number of atoms or ions						
	Zn	Zn^{2+}	Cu	Cu^{2+}	SO_4^{2-}	Na^+	Cl^-
Zinc half cell							
Copper half cell							
Salt bridge							

Compare table 1.1 and table 2.1 in the space below and comment on your observations. ---
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What is an anode and a cathode?

The electrode at which the oxidation half reaction occurs is called the anode. The electrode at which the reduction half reaction occurs is called the cathode.

In the copper/zinc electrochemical cell, which half cell (the copper half cell or the zinc half cell) contains the anode.

In the copper/zinc electrochemical cell, which half cell (the copper half cell or the zinc half cell) contains the cathode.

In the nickel/magnesium electrochemical cell, which half cell (the nickel half cell or the magnesium half cell) contains the anode.

In the nickel/magnesium electrochemical cell, which half cell (the nickel half cell or the magnesium half cell) contains the cathode.

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3. **RADMASTE, Wits University.**

APPENDIX D

A FRAMEWORK FOR THE ACTIVE INTERVIEWS