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Becoming a science teacher: Narratives and conceptions

Dale Lesley Taylor

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Abstract

This research project explored the classroom practices, and the conceptions and identities which informed those practices, of early career physical science teachers who qualified through the four year initial teacher preparation programme in which I was involved. Taking the view that education is a complex system, where both the agency of the individual and her past and present contexts affect learning, implies that individual histories fundamentally affect the way student teachers make sense of and appropriate their initial training. Moreover what counts as good science teaching is contested and context dependent. I spent two days in the classrooms of eight of my past students, writing narratives of their lessons, and talking to them about their lessons and about what they saw as having influenced their practice. Narrative inquiry was used to explore the teachers' identities and phenomenography to explore their conceptions of teaching. The threat of classroom reactivity was addressed by reducing it and by accounting for it by asking teachers afterwards what they thought the effect of the observer had been. The threat of researcher subjectivity was addressed by rich data, teacher and peer feedback, the use of established methods of analysis, and transparency.

A grounded analysis revealed that the activities in the lessons could be classified according to the teachers' underlying purpose (the introduction of new subject matter content, the application of that content, feedback on learners' work, or revision of work done previously) and the mode of engagement (exposition, question and answer, or conversation). Some teachers had strong preferences for particular modes of engagement while others worked with a wider repertoire. For lessons where the purpose of the lesson was the introduction of new physics or chemistry content, the 'content object' (the propositional and procedural science knowledge and the transformation thereof) was identified and assessed using a rubric with three dimensions (the accuracy of the content, the appropriateness of the content and the transformation of that content to make it accessible to learners) which was developed in working with the data. The best lessons were those where good transformation of mostly accurate content took place. The study shows how learners contribute significantly to the quality of the subject matter content of a lesson by their questions, answers and silences. A conversation mode of engagement is useful for promoting learner contributions. The sample became teachers for a variety of reasons, and their professional identities reflect diverse influences, many of which are outside their initial teacher education. However for three of the teachers in this study, their teacher education programme was a defining experience, core to their current identities as teachers. Thus an initial teacher education programme can have a major influence on teachers, particularly teachers who know their own school experiences of science teaching to be deficient. Small inputs in teacher education may lever up large but unpredictable ‘butterfly’ effects. Despite the challenges involved, it seems there are still young people who want to become teachers, but bursaries are key to making this a reality. A mentoring programme may support teachers in township schools in their vision of making a difference. A phenomenographic analysis revealed four conceptions of teaching science, with two dimensions: whether the science knowledge to be taught is seen as problematic or not, and the nature of the mediation of that knowledge, either by transferring the knowledge from the teacher to the learners or by creating space for learners to acquire the knowledge. Since the subject matter content of a lesson is key to the overall success of a lesson, conceptions of teaching which recognise that subject matter knowledge can be problematic may be more powerful. The results of this study speak back to the vision of teacher educators about the kinds of teachers they want to produce.

Keywords

classroom observation, classroom reactivity, complexity, conceptions of teaching, content object, learner contributions, learning to teach, narrative, phenomenography, science education, science fairs, teacher education, teacher identity

Declaration

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

Dale Lesley Taylor
28^{th} day of August in the year 2013.

Presentations Emanating from this Research

Taylor, D., & Lelliott, A. (2013). *Is classroom observation a good measure of normal classroom practice?* Paper presented at the 21st Annual Meeting of the Southern African Association for Research in Mathematics, Science and Technology Education, University of the Western Cape, Cape Town.

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Glossary of Terms and Abbreviations

B Ed	Bachelor of Education degree – a four year initial teacher education programme
Butterfly effect	A large, unpredictable effect arising from a small input.
Break	Recess
Crit lesson	A colloquial term for a lesson taught by a student teacher, observed by a tutor who 'crits' (critiques) the lesson, i.e. judges the lesson against certain standards, and ultimately assigns a mark reifying the quality of the student's teaching.
Didactic contract	The tacit understanding which a teacher and her learners have about their respective roles in the classroom.
HDE	Higher Diploma of Education - four year teaching diploma which was replaced by the B Ed.
Intervention school	A school which uses donor funding to give a good educational opportunity to disadvantaged youths who would otherwise probably be attending a township school
Ja	Yes (Afrikaans)
Learner	School pupil
Multicultural school	A well-resourced and well-functioning school, which was a privileged white school under apartheid
National Curriculum Statement	The document containing the South African national school curriculum.
Natural Sciences	The South African school science subject for Grades 7-9 which encompasses physics, chemistry, biology and earth science.
PCK	Pedagogical Content Knowledge; the subject specific knowledge which teachers use in transforming subject matter content to make it accessible to learners, comprising knowledge of learner prior conceptions and alternative conceptions, instructional strategies and materials, useful representations, metaphors, difficulties students have in comprehending the content, and curricular saliency.
Physical Sciences	The school subject for Grade 10-12 which encompasses physics and chemistry. These disciplines cannot be studied separately in the South African school system.
Private school	An elite, well-resourced institution, typically with white learners in the majority.
Q&A	Question and Answer - a mode of classroom engagement where the teacher asks a series of questions and learners answer, either drawing on their own knowledge or information given in a text.

Rural school	Rural schools are found in the underdeveloped poor rural areas and are generally worse off than township schools. ‘Rural’ in South Africa connotes poverty, and lack of infrastructure and services.
SMK	Subject Matter Knowledge – disciplinary knowledge
Teaching methodology	Teaching methodology courses are intended to teach student teachers the methodology of teaching i.e. how to teach.
Township school	A school in a township (black residential areas). The term ‘township’ has similar connotations to the term ‘inner city’ in first world settings, although townships are significantly displaced from city centres.

Chapter 1: Introduction

For nearly a decade, I was involved in the initial preparation of physical science teachers for the South African education system, teaching both physics and science teaching methodology[1]. Initially I saw my role as being to give my students a basket of good ideas for teaching science. The ‘good ideas’ drew on my own conception of science teaching. But after a few years I realised that my students’ take-up of such was limited if my ‘good ideas’ did not fit with their own conceptions of science teaching. The Draw-A-Science-Teacher Test (Thomas, Pedersen, & Finson, 2001) helped me understand the chasm which often existed between my students’ conceptions of science teaching and mine. Figure 1 is a typical first year student teacher’s response to the instruction ‘Draw a picture of yourself as a teacher in a classroom teaching a good science lesson.’ (Gundry, 2007). The time on the clock suggests a hard-working teacher – one who is working after normal school hours – but the teaching involves telling the canon of science rather than doing science. No test-tubes or measuring instruments or other artefacts of science are present – artefacts which are essential in my conception of science teaching. Clearly this student’s conception of science teaching was very different from mine.

Figure 1: First year student teacher’s response to the Draw-A-Science-Teacher Test

[1] Science teaching methodology courses are intended to teach student teachers the methodology of science teaching i.e. how to teach science.

The picture is also a window on the student teacher's professional identity: he identifies himself as a hardworking teacher who is committed to his students and who knows physics well, as evidenced by a board full of writing with no textbook present. Over time I realised that teacher identity is key to teacher education, and that a student teacher starts a teacher education programme already holding a vision of the kind of teacher she wants to be. I came to see my role as working with students' teacher identities; helping them to develop their identities and be more effective as the kinds of teachers they wanted to be, in part by giving them access to other conceptions of science teaching. This means that my own identity as a teacher educator shifted considerably. However, despite these realizations, I still had very little idea of the long term effects of my work. I had no idea what actually happened in the classrooms of teachers after they graduated. I did not know what kinds of teachers they were or what conceptions they held about science teaching once immersed in the practice of it.

Nor was my problem unique: historically most initial teacher education was in the hands of government colleges rather than universities and so university research into science teacher education tended to focus on in-service programmes. Moreover, the pre-service research on initial science teacher education which does exist typically explores students' ideas at the end of particular courses rather than following them into their classrooms (Adler, Pournara, Taylor, Thorne, & Moletsane, 2009). However was been some tracking of mathematics graduates of the one year Post Graduate Certificate in Education and its predecessor (Breen & Millroy, 1994; Ensor, 2004). Hindle (2003), as the South African Deputy Director-General of Education, included the "need to track the careers of some of the newly trained teachers" (p. 334) on a research agenda for teacher education. Internationally Luft (2007) calls for research which "captures the experiences and development of the new science teacher" (p. 536).

In regard to research on teaching more generally, Malcolm and Alant (2004) in their review of science education research in South Africa note that research "has provided information on what teachers do and don't do, especially in their classrooms, but little on why they do what they do" (p. 79). They suggest "a need for deeper explorations of teachers and teaching, more closely linked to the contexts in which teachers work and why they do what they do" (p. 77). Clark and Linder (2006) claim that in South Africa:

> we have so little understanding of the ‘realities of schooling at the chalk face’ that it hardly seems an exaggeration to propose that we know virtually nothing at all about how individual teachers cope and respond to the challenges of practice, either under existing conditions or when faced with implementing change. (p. 2).

The design of this research project started in 2007 and addressed these research needs by tracking early career teachers into their classrooms. In this chapter I first present my research questions and then give an overview of my research design. Thereafter I locate my research epistemologically and contextually.

1.1 Research Questions

I wanted to spend time in the classrooms of my past students. I wanted to know what they did, and how they saw what they did. Thus my research project was designed to explore the classroom practices, and the conceptions and identities which informed those practices, of early career physical science[2] teachers who qualified through the four year initial teacher preparation programme in which I was involved. My research addressed the following research questions:

1. What is the form of the activities in early career physical science teachers’ lessons?
2. What is the quality of the science content of their lessons?
3. How do these teachers narrate their professional identities?
4. What conceptions do these teachers have of science teaching?

The first two questions addressed my curiosity about what actually happens in the classrooms of my past students. I wanted to use a wide-angle lens, taking in the breadth of the repertoire of their practice, and thus chose activities as my unit of analysis for the first question. An activity could take a whole lesson or a lesson could be comprised of a number of activities. However I realised that this research question only addressed the form of lessons and not the subject matter content, and so I formulated the second research question during the course of data analysis. The last two questions interrogate the ways in which teachers see themselves and their work. The third research question explores their identities as teachers, using their narratives as a window. The last question explores teachers’ conceptions of teaching, specifically science teaching. These four questions use

[2] In the South African school curriculum, physics and chemistry are taught as one subject, called Physical Sciences, in grades 10-12. Physical science teachers are also expected to be able to teach Natural Sciences, which encompasses physics, chemistry, biology and earth science, to grades 8 and 9.

different lenses on the practice of teachers by exploring three different constructs: classroom practice, teacher identity and conceptions of teaching. These constructs are related: teachers' conceptions of teaching affect how they construct their identities; their conceptions of teaching and their identities affect the decisions they make with regard to practice; and classroom experiences inform teachers' conceptions and identities.

In order to answer these questions, I followed eight of my past students into their classrooms. I used two research instruments, classroom observation and semi-structured interviews, and spent two non-consecutive days with each teacher. More details of these instruments are given in Chapter 3. Data collection happened over a period of two years, and amounted to 57 observed lessons, and nearly thirteen hours of interviews.

1.2 Key Concepts

The research design incorporated two different approaches, narrative inquiry and phenomenography, which were used to explore identity and conceptions respectively. These two approaches fit well together since they are both concerned with people's experiences. In the following three sections, I will explain what I mean by identity and conceptions, and explain how the two approaches work with these constructs.

1.2.1 Identity

I will look at identity through the lenses of four major contributions to the understanding of identity in education: Gee (2000), Wenger (1998), Sfard and Prusak (2005) and Holland, Lachicotte, Skinner, and Cain (1998). These lenses come from different perspectives: Gee's field is linguistics thus his approach is discourse analysis; Sfard and Prusak are mathematics educators interested in how identity affects learning; Wenger comes from the perspective that learning happens in communities of practice; and Holland et al. are anthropologists. These differences are reflected in their definitions of identity. For Gee identity is about being a certain 'kind of person', expressed in a label such as 'teacher' or 'learner-centred'. Wenger sees identity as the experience of such a way of being, which encompasses more than just a label. Sfard and Prusak define identity as stories about persons, though they acknowledge that these result in a person experiencing a 'sense of identity'. Holland et al. define identity as follows:

> People tell others who they are, but even more important, they tell themselves and then try to act as though they are who they say they are. These self-understandings,

> especially those with strong emotional resonance for the teller, are what we refer to as identities. (p. 3).

Despite these differences, these authors agree on five aspects of identity which I will describe in order to work towards a definition of identity.

The first aspect is that identity involves the act of identifying. This means ascribing labels to people, thus in Gee's terms identifying a person as a certain 'kind of person'. Gee distinguishes between four types of identity: nature-identity which describes genetic characteristics counted as significant in a culture such as race and gender; institution-identity which labels a person's position within an institution; discourse-identity which is the way the person is recognised in discourse with others; and affinity-identity which arises from any groups the person chooses to belong to, such as clubs or religious organisations. A person can identify themselves as well as others, and thus is identified both by themselves and others. The focus of research is usually on self-identification since "first-person self-told identities are likely to have the most immediate impact on our actions" (Sfard & Prusak, 2005, p. 17).

However this self-identification happens in the context of and in relation to identities made available by others. A particular context, such as a community of practice, places constraints on the identities of individuals within that context. However an individual does not simply accept the identities available in a particular context, but rather negotiates possibilities: "building an identity consists of negotiating the meanings of our experience of membership in social communities" (Wenger, 1998, p. 145). Negotiation implies that identity is not simply in the head of the individual but needs to gain traction in the context – an identity needs to be recognised by others. Identities are not only constructed in a context, they are also "possibilities for mediating agency" (Holland et al., 1998, p. 4) within the constraints of the context. In all, identity is the "pivot between the social and the individual" (Wenger, 1998, p. 145).

The agency of the individual in negotiating her identity in a particular context means that she engages in the construction or authoring of her own identity. For Sfard and Prusak this happens through story telling. Gee includes storytelling in a wider view of identity construction: for him identity is constructed through 'Discourse' which he defines as comprising speech, actions, body language, dress and using things. For Wenger storytelling is part of reification, which works together with participation in the construction of identity. The twin dimensions of telling and acting are also recognised by Holland et al., as reflected in their definition above. Similarly the identities which other people ascribe to a person inform their behaviour towards that person.

Since both the context and the individual influence identity, identities are not stable but change over time. Identities have a trajectory through time, with past and future identities both involved in the present: “our identities incorporate the past and the future in the very process of negotiating the present” (Wenger, 1998, p. 155). Thus “identity talk makes us able to cope with new situations in terms of our past experiences and gives us tools to plan for the future” (Sfard & Prusak, 2005, p. 16). Gee sees each individual as having “a unique trajectory through ‘Discourse space’. Sfard and Prusak distinguish between a person’s ‘actual’ identity in the present and her ‘designated’ identity which is what she hopes to become in the future. This implies that an aspect of identity is a vision for the future: imagination of “new images of the world and ourselves” (Wenger, 1998, p. 176) or “imaginings of self in worlds of action” (Holland et al., 1998, p. 5). The corollary of this is that identity is never a finished product – it is always a work in progress (Holland et al., 1998; Wenger, 1998). A designated identity may be pronounced by what Sfard and Prusak call a ‘significant narrator’ who is often a relative.

In addition to identities changing over time, an individual possesses multiple identities, for example a person may be a left-handed, passionate teacher and soccer player (Gee, 2000). For Wenger multiple identities are a consequence of individuals being members of more than one community of practice. Wenger points out that this leads to multiple trajectories, though these trajectories are not independent but interact and require effort to reconcile, a process which may never be completed. Palmer (1997) sees integrity across a teacher’s different identities as key to good teaching.

I have described five features of identity which are common to all of the four perspectives on identity which I have interrogated: identities identify, and are contextual, constructed, changing and multiple. These features concur with the conclusions Rodgers and Scott (2008) make from the identity literature, but they also include an emotional aspect to identity. This concurs with Holland et al.’s idea of identity as ‘self-understandings’ with “strong emotional resonance” quoted above. Zembylas (2003a) argues that emotion is central to identity. In summary, an identity identifies a person as a certain kind of person, and is authored with emotion through labelling, storytelling and actions within the constraints of and in relation to a particular context, and facilitates agency in the context. I have spoken of the concept of identity generally, but the identity which is central to my research is that of teacher self-identity. In Gee's terms I am interested in teachers' institution-identities and discourse-identities – their identities as science teachers and as the kinds of science teachers they identify themselves as through their narratives.

1.2.2 Narrative Inquiry

I used narrative inquiry to explore the teachers' identities. The term 'narrative' gets used in different ways in different contexts (Riessman, 2005). Thus before I talk about narrative inquiry, I will explain what I mean by narrative. A narrative is a story, a tale with a plot. Bruner (1996) categorises thought as 'logical-scientific' or narrative. Logical-scientific thought deals in generalisations, whereas narrative thought deals with specific episodes or stories. Logical-scientific thought has prevailed in research, but narrative thought is important in understanding how people make sense of their lives, for "It is only in the narrative mode that one can construct an identity and find a place in one's culture" (Bruner, 1996, p. 46). Thus narratives are a window on identity – in fact, as mentioned in the previous section, Sfard and Prusak (2005) define identity as stories about self. Riessman and Speedy (2007) suggest that the 'narrative turn' in the social sciences and beyond has been spurred on by increased awareness of our identities in a rapidly changing world.

Bruner (1986) notes that narratives often contain an evaluation or lesson – a story comprises not only what is remembered, but also how it is interpreted. Thus a narrative is not merely a look at the past, but is the way in which the storyteller makes sense of and justifies the present: "Narrative is retrospective meaning making – the shaping or ordering of past experience" (Chase, 2005, p. 656). This means that all narrative is constructed – the story teller constructs a story in a way which is coherent and makes sense to her, selecting incidents which she sees as significant so that "Each person is a historian of the self" (Sexton, 2007, p. 49). In the same way that a history is never a neutral account of 'how things were', "Narratives do not mirror, they refract the past" (Riessman, 2005, p. 6). The choices the narrator makes identify the narrator in a particular way for a particular audience.

This construction happens at a point in time and space, and changes over time and space – the same person will construct different narratives at different times, in different contexts and for different audiences. The underlying assumption is that people are always learning or changing (Clandinin & Connelly, 2000). In summary, a narrative is a story constructed by a narrator about her past which makes sense of her present and identifies her in a particular way for a particular audience, at a particular point in time and space.

Thus narrative inquiry is "trying to make sense of life as lived" (Clandinin & Connelly, 2000, p. 78). Hence it is appropriate to use narrative inquiry to explore how science teachers make sense of themselves as teachers. Narrative research has proved useful in understanding teaching and learning in the complexity of the South African education system (e.g. Case, Marshall, & Linder, 2010; Henning, 2000; Jita, 2004; Lelliott & Pendlebury, 2009; Marshall & Case, 2010). However there are varied approaches to what gets called narrative inquiry (Chase, 2005; Polkinghorne, 1995; Riessman & Speedy, 2007), a point I will elaborate in Chapter 6. I invited teachers' narratives by asking them to "tell me the story of what has made you the unique teacher you are today" and by asking follow-up questions. Their responses are narrated in Chapter 6.

1.2.3 Conceptions in Phenomenography

While I used narrative inquiry to explore teachers' identities, I used phenomenography to explore their conceptions of teaching. Phenomenography is a research approach which investigates people's conceptions of a particular phenomenon, although this term has its limitations:

> A 'conception', the basic unit of description in phenomenographic research, has been called various names, such as 'ways of conceptualizing', 'ways of experiencing', 'ways of seeing', ways of apprehending', 'ways of understanding', and so on. […] The reason for using so many different synonyms is that although none of them corresponds completely to what we have in mind, they all do to a certain extent. (Marton & Pong, 2005, p. 336).

The term 'conception' could be seen as implying that the object of research is in the head of a person, whereas from a phenomenographic perspective, it is constituted in the relationship between a person and the phenomenon, in this case between a teacher and her job (Marton, 1981). This means that conceptions change as the teaching context changes. Science teaching is not an abstract concept in the head of a teacher but a lived experience, so another phenomenographic term which I could use for the same object of research is ‘experience’. Then my fourth research question would be ‘What experiences do these teachers have of science teaching?’ But ‘experience’ could imply passivity on the part of the teacher – being at the receiving end of what happens in a school rather than allowing for the agency of the teacher. I thus chose the term ‘conception’ over ‘experience’, although the research object I was interested in has elements of both teachers’ experience of teaching and how they conceive it.

Phenomenography explores conceptions from a ‘second order’ perspective: instead of researching the phenomenon itself – i.e. the researcher’s first order experience of the phenomenon – phenomenography researches it from the perspective of the sample (Marton, 1981). Phenomenography attempts to uncover the full range of conceptions experienced by a sample, thus the researcher explores variation in conceptions (Marton & Booth, 1997). Individuals are not tied to particular conceptions: a particular person may demonstrate different conceptions of a phenomenon at different times (Marton, 1981). In this way phenomenography is different from constructivist research into alternative conceptions (Wandersee, Mintzes, & Novak, 1994) – sometimes referred to as misconceptions – which sees an individual as ‘having’ a particular conception. Since individuals are not tied to particular conceptions, differences in individual contexts within the sample are ignored and the data is pooled (Marton & Booth, 1997). However the overall context of the research *is* significant: phenomenographic studies are always done with a particular population who have something in common, (e.g. physicists (Ingerman, 2003), computer programmers (Booth, 1992), lecturers (Prosser & Trigwell, 1999)) about a phenomenon which is significant for them. At the same time, the sample should be as diverse as possible within that population so that a wide range of conceptions in uncovered. In this study, the population was early career qualified and practising secondary school physical science teachers who graduated from a four year undergraduate programme at the University of the Witwatersrand. The sample covered a wide range of variation in the population of interest insofar as the teachers taught in diverse schools and came from a variety of educational backgrounds themselves (detailed in section 3.2).

In phenomenography, the conceptions together form an ‘outcome space’ (Marton & Booth, 1997) which represents the full range of variation of conceptions emerging from the data. The conceptions have some logical relationship to each other or structure in the outcome space. My experience is that the process of uncovering this structure is one of the strengths of phenomenography which distinguishes it from other grounded analysis (Strauss & Corbin, 1990): seeing the conceptions in relation to each other brings new insights about the conceptions (D. Taylor, 2011).

Thus far I have introduced two constructs related to teaching: teacher identity and conceptions of teaching. How do these two constructs relate to each other? The subjects of the two constructs are different: teacher identity is about a person, whereas a conception of teaching is about her work. Identity is focused inwards whereas conceptions of teaching are focused outwards. Self-identity could be construed as 'conception of self'. But a phenomenographic analysis of conceptions of self would throw up a limited number of conceptions, whereas an identity is unique to an individual since it interacts with her individual contexts, history and other identities. Thus I think to reframe self-identity as conceptions of self would be unhelpfully limiting. Although the two constructs are distinct, they are related and influence each other, since it is the same person involved in both. The conception a teacher has of teaching is related to the 'kind of teacher' she sees herself as.

1.3 The Theoretical Location of My Research

Having described the approaches I used in my research, I now want to locate my research in broader contexts. There are two ways to locate research: one is its position in knowledge and the other is its context in space and time. In other words there are two contexts for research: one theoretical and the other practical. In this section I locate my research theoretically, and in the next section I give its practical context. In locating it theoretically, I first make my ontological and epistemological positions clear, and then locate the research in two bodies of research: teacher education research and science education research.

Underlying any research are ontological and epistemological assumptions. Ontology is an assumption about the underlying nature of reality, in this case social reality. According to Blaikie (1993), in the social sciences there are essentially two possible ontological positions: the realist view that there is a single social reality 'out there' which is independent of any observer, or the constructivist view that social reality is constructed and interpreted by people, which means there are multiple realities.

Do the research approaches which I use, phenomenography and narrative inquiry, have underlying ontologies? Svensson (1997), in talking about phenomenography, argues that a research approach does not presuppose an ontology. But Marton and Booth (1997) claim phenomenography has a non-dualist ontology, i.e. a constructivist ontology in Blaikie's terms. In other words "the only reality there is, is the one that is experienced" (Uljens, 1996, p. 114). Whether taken from a phenomenographic perspective or not, this is my view: social reality is socially constructed.

Epistemology is an assumption about the nature of knowledge. Realist ontology allows two different mappings of knowledge onto reality: reality can be seen as able to be known perfectly or imperfectly (Blaikie, 1993). Positivism is an epistemology that reality can be known perfectly and hence recognises one truth. In contrast epistemology which recognises the limitation of human knowing admits multiple truths. Constructivist ontology precludes the mapping of knowledge onto an external reality. Instead knowledge is the way in which experience is represented, and so epistemology is an assumption about the correspondence of knowledge to experience. Both non-positivist stances, realist and constructivist, agree that all that can be known is how the world is experienced or perceived, and hence the ontological differences between these two stances are not always obvious.

Phenomenography makes the epistemological assumption that there is a limited number of qualitatively different ways in which a group of people experience a phenomenon. Phenomenography also makes the epistemological assumption that the different ways of experiencing a phenomenon can be known: they can be uncovered through dialogue and represented and communicated. However there is not one single 'right' way to do so, so phenomenographic outcome spaces are never final.

Like phenomenography, narrative inquiry is concerned with peoples' experiences: "The study of narrative, therefore, is the study of the ways in which humans experience the world" (Connelly & Clandinin, 1990, p. 2). Thus experience is foregrounded, whether or not there is seen to be an external reality. A narrative is one of many possible constructions of history, and there is no way to know that history objectively. Moreover, as explained, a particular person may construct her narrative differently at different times and for different audiences. This is analogous to the phenomenographic stance that a person may conceptualise a phenomenon in more than one way depending on the context in which the phenomenon is encountered.

My research did not only use phenomenography and narrative inquiry, it also used classroom observation. What is the implication of foregrounding experience in classroom observation? Classroom observation is the experience of an observer in a classroom, and there are multiple ways of experiencing the same lesson. I took the view that all that I could know of what happened in a classroom was my experience of it, with my experience affected by my subjectivity. Hence I describe my subjectivity later in this chapter, and explore the consequences of that subjectivity for classroom observation in section 3.7.3.

Having situated my research ontologically and epistemologically, I now situate it in the research literature. My research is located at the intersection of teacher education research and science education research, though I draw on literature which is outside of the intersection, particularly research on teacher education. In teacher education Borko, Whitcomb, and Byrnes (2008) identify five genres of research: research which looks for the effects of teacher education, practitioner research such as self-study and action research, design research to investigate the implementation of an intervention, interpretive research, and critical research. This project is interpretive research, which is "at its core, a search for local meanings" which "seeks to perceive, describe, analyse, and interpret features of a specific situation or context, preserving the complexity and communicating the perspectives of the actual participants" (Borko et al., 2008, p. 1025). I will talk more about the complexity of teaching in Chapter 2. Interpretive research is an important genre in qualitative research in education:

> In one sense, this is the major purpose of all qualitative research [in education] – to inform our deep understanding of educational institutions and processes through interpretation and narrative description (Soltis, 1990, p. 249).

Phenomenography and narrative inquiry are both methodologies in the interpretive genre.

A weakness in interpretive research is that power relations are only seen from the taken-for-granted perspective of participants, and hence are not questioned (Cohen, Manion, & Morrison, 2000). Thus in Chapter 2 I pay some attention to the interplay between the power of the structure of contexts and individual agency (section 2.1.3), in Chapter 6 I consider how teachers' identities both facilitate their agency in their contexts and are constrained by their contexts (section 6.4.2), and in the final chapters I consider individual agency in adverse contexts (sections 8.4.3 and 9.3.4).

In science education, Erickson (2000) identified three research programmes about student learning over the last two decades of the last century: the Piagetian research programme, the constructivist research programme, and the phenomenological research programme which was then emerging and which Erickson saw as the way forward. Although my research is not about student learning of science, it is consonant with this last research programme, which includes phenomenography. While the Piagetian and constructivist research programmes see learning as constructing cognitive structures, the phenomenological research programme sees learning as "a set of relationships between the learner and the world" (Erickson, 2000, p. 281), consistent with my description of conceptions in section 1.2.3.

1.4 Context

Interpretive studies provide "an image of teaching as a complex intellectual endeavour that unfolds in an equally complex sociocultural context" (Borko et al., 2008, p. 1025). Thus context is critical in interpretive research, particularly in narrative inquiry (Clandinin & Connelly, 2000). The purpose of this section is to describe the context of this study. The context of this study can be seen as one of rapid change in education – both structurally and in regard to curricula (Kruss, 2008). I will briefly describe these changes at a national level, and then consider the way these changes played out in my local context.

1.4.1 The National Context

There was massive structural change in education after South Africa's first democratic elections in 1994. At tertiary level, the teacher training colleges were either moved from the government departments of education into the universities or closed, a process which ended by 2001 (Kruss, 2008). At school level, the formerly racially delimited departments of education were restructured into departments delimited by province. This means that schools are no longer officially racially defined and so multicultural schools now exist. But the township[3] and rural[4] schools which were black under apartheid are still completely

[3] Under apartheid, black Africans were forced to live either in 'homelands' which were largely rural or in 'townships' bordering towns. Both were crowded and under-serviced. Today townships are black residential areas, which are usually better off than the many informal settlements (with dwellings often constructed

black (both staff and learners[5]) – a consequence of South African demographics. These schools typically offer a poorer quality of education to communities battling with socioeconomic problems – a legacy of the deliberate neglect of black schools and their communities under apartheid (N. Taylor, Muller, & Vinjevold, 2003). In contrast the multicultural schools are typically well-resourced and well-functioning schools, which were privileged white schools under apartheid.

In addition to the structural changes in education, there were significant curriculum changes both in schools and in teacher education. In teacher education, the four year Higher Diploma in Education (HDE) was replaced by a four year degree, the Bachelor of Education (B Ed), which gave the initial teacher qualification more status. Such teaching degrees are available in many countries, but what is unusual is that at some South African institutions (mine included) the same lecturers often teach both the academic discipline (such as physics or chemistry) and the teaching methodology courses to student teachers. The alternative route into science teaching is still a three year Bachelor of Science degree followed by a one year teaching qualification.

At school level, a new curriculum was phased in from 1998. The 2008 grade twelves were the first cohort to graduate from this curriculum. Education is always political (Gutmann, 1987), particularly in South Africa, and the new curriculum was the new government's flagship for education. 'Social transformation' was identified as one of "the key principles and values that underpin the curriculum" (Department of Education, 2003, p. 1) with the hope expressed that:

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from corrugated iron) which have sprung up post-apartheid, although both are typically supplied with electricity. Any schools in these informal settlements are also referred to as township schools. The term 'township' has similar connotations to the term 'inner city' in first world settings, although townships are significantly displaced from city centres.

[4] Rural schools are found in the underdeveloped poor rural areas and are generally worse off than township schools. 'Rural' in South Africa connotes poverty, and lack of infrastructure and services.

[5] In the post-apartheid South African school curricula, school pupils are referred to as 'learners'. This reflects an attempt to imbue pupils with greater status, but the term can be criticized for implying that teachers have somehow stopped learning. Nonetheless, it is the term which I will use throughout to refer to school pupils.

> Social transformation in education is aimed at ensuring that the educational imbalances of the past are redressed, and that equal educational opportunities are provided for all sections of our population. (Department of Education, 2003, p. 2).

The desire to break from the past resulted in a huge pendulum swing, most notably the move away from a content driven curriculum to a curriculum which initially did not specify content but was rather ‘outcomes based’. (Department of Education, 2002) The pendulum gradually swung back towards its original position in successive curriculum documents (Nakedi, Taylor, Mundalamo, Rollnick, & Mokeleche, 2012). In response to a review which criticised the lack of content specification (Chisholm, 2000), content was specified in the *Revised National Curriculum Statement* for grades 0-9 (Department of Education, 2002), and in the grade 10-12 curriculum published for the first time a year later (Department of Education, 2003). The latest curriculum documents were published towards the end of 2011, and although these were described by government as a streamlined repackaging of the previous documents (Motshekga, 2010), the content of the Physical Sciences curriculum has shifted considerably and so is a new curriculum. The effect of all these changes has been continually shifting ground for teachers (Nakedi et al., 2012).

Despite all this change, there proved to be considerable inertia in practice in many schools (Rogan & Aldous, 2005). Jansen (2003) points out that the new curricula identify teachers in ways which conflict with their existing identities and posits “that unless we understand the identity dilemma faced by teachers, we cannot begin to disrupt ‘the grammar of schooling’” (p. 118). In Gauteng, the province where my sample taught, all government schools were equipped with some science apparatus, but teachers in the black township and rural schools are still faced with large classes of learners from disadvantaged backgrounds affected by poverty, violence and HIV/AIDS. So these teachers, who themselves typically received inadequate science education, have tended to continue with teaching practices rooted in the apartheid past. The implementation of curriculum change is always fraught (Macdonald, 2003), but in the South African context of inequality, those in the black schools are worst off. Given Physical Sciences’ role as a gateway subject into tertiary science and engineering programmes, this means that the changes in education have largely failed to realise their goal of social transformation.

In summary, across all schools, the structural and ideological transformation of education means that teachers are expected to teach a curriculum which is significantly different from the school curriculum they themselves were taught at school. There is a particularly large gap between teachers' own twelve year 'apprenticeship of observation' (Lortie, 1975) and the ways in which they are now expected to teach. Thus the challenge for teacher education in South Africa is to prepare teachers to teach differently from how they were taught, in a wide range of schools which are all negotiating change in some way.

However the data for this study were collected in a period of relative stability, 2009 to 2011, before the latest curriculum documents were published. The curriculum documents defining the grade 10-12 curriculum in operation when this study was conducted were published over the period 2003 – 2008, and the grade 8-9 curriculum was published in 2002. The curriculum reached its full implementation in 2008 with the first grade twelve examinations on the curriculum written at the end of 2008. So at the time of this study, teachers were no longer guessing as to what the final examination would look like or how their learners would perform on it. Moreover, the core documents of this curriculum were published in 2002 or 2003 before the sample of this study finished their studies, as the sample graduated over the period 2004 – 2008. So these teachers were all teaching the curriculum for which their teaching qualification had prepared them to a greater or lesser extent.

1.4.2 The Local Context

I now consider how the national changes played out at the University of the Witwatersrand where I taught. From the beginning of 2002, the Johannesburg College of Education was incorporated into the university but continued to operate separately from the Faculty of Education, with the College and the Faculty on different campuses. The first B Ed curriculum was designed during 2001 and 2002, and implemented from 2003. This B Ed degree allowed students to specialise as secondary school physical science teachers with mathematics as their second teaching subject. The only preparation which they got for teaching the life and earth science components of the grade 8-9 Natural Sciences curriculum was part of a second year teaching methodology course.

Under strong leadership, the college and the faculty were brought together into a single integrated Wits School of Education from 2005 (Kruss, 2008). After the restructuring, the first big project of this single structure was a revision of the B Ed curriculum, which had proved to be weak in some aspects of its structure. This was a participatory process which involved much theoretically and practically informed debate. The revised B Ed curriculum which emerged from this process was implemented from 2010. This revised B Ed curriculum includes more subject methodology and another year of study in the sub-major. Students who take Physical Sciences as their major start by studying the breadth of the natural sciences for two years before focusing in on the physical sciences. This is to help them cope with the demands of the school curriculum where physical science teachers are expected to teach Natural Sciences to grades eight and nine. However the sample in this study all studied the old B Ed curriculum or the HDE which preceded it, which also did not prepare teachers to teach across the whole of Natural Sciences. In other words the teachers in this study studied a curriculum which was recognised to be inadequate both in terms of subject specific teaching methodology and in terms of preparing teachers to teach the life and earth science themes in the subject Natural Sciences.

In this process of curriculum reform, there was a realization of the need to articulate the vision of the staff of the Wits School of Education, especially given that the staff had come from a College and a Faculty of Education which were quite different in their outlook on education, with a measure of suspicion on both sides. Thus through a collaborative process, a document was produced which was entitled *A Vision for a B.Ed Graduate: what kind of teachers for South Africa do we want to produce at Wits?* (Appendix A). This document identifies nine characteristics of the desired 'kind of teacher' the School of Education wanted to produce. In the final chapter, I consider how the results of my research talk back to this vision.

The sample in this study graduated either from the first B Ed or from its predecessor, the HDE. The majority of the students with a physical science major in either of these qualifications started university as survivors of the tough end of the South African education system – the black schools which have made only a partial recovery from apartheid education. Such students are a relative cream: people with considerable potential and typically the top achievers from their schools. But their school experiences of science were mostly dismal, resulting in poor performance in the final grade twelve Physical Sciences examination. They were only able to take science at university level because the B Ed degree has considerably lower entry requirements than a Bachelor of Science degree.

This means that, though they were typically hard-working, their learning of school physical science was limited to memorization and ‘plug and chug’[6] strategies, and they found it challenging to work with conceptual understanding in the university context. It also means their conceptions of school science teaching and their emerging teacher identities were limited by on their own experiences – their ‘imagination of the possible’ (Slonimsky, 2007) was constrained by limited role models, as illustrated by Figure 1 (page 1). In contrast, a handful of the students majoring in physical science came from milder parts of the South African education system – from a range of multicultural schools, with varied approaches to science teaching.

1.4.3 My Story

In Chapter 6 I will give the narratives of my sample, but here I give my own narrative. This is important in narrative inquiry – the researcher’s biography is part of the story of the research (Josselson & Lieblich, 1993; Riessman, 2005) such that “we see ourselves as in the middle of a nested set of stories – ours and theirs” (Clandinin & Connelly, 2000, p. 63). I gave a part of my narrative at the start of this chapter where I talked about my own realizations in teacher education, and here I give more. My story continues in the next section where I try to make my subjectivity explicit.

I started out planning to be a nuclear physicist, and completed an honours degree in physics paid for by the state nuclear facility, such scholarships being one of the benefits of being a white South African under apartheid. However due to a cut in state expenditure on nuclear energy, I was released from my obligations to my bursars at the end of my studies and I switched to education in part because of a social justice agenda. A teaching practicum at a township school made me realise I would need to start teaching in a well-run school if I was to make a difference in education. I taught physical science for twelve years at a well-resourced school which was a white school under the apartheid government

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[6] ‘Plug and chug’ refers to a strategy often used for dealing with examination questions involving calculations. The algorithm for this strategy is: 1) Write down all the values given in a question. 2) From the units of these values, identify the associated symbols and the symbol of the unknown quantity. 3) Find a ‘formula’ on the information sheet which contains all these symbols. 4) ‘Plug’ the numbers into the formula. 5) ‘Chug’ through the calculation to get the answer. This strategy means that it is not necessary to actually read the words surrounding the values in a question. But it is a strategy which ‘worked’ insofar as it produced many correct answers in the national grade twelve Physical Sciences examinations.

when I started in 1989 and a multicultural school under the new government when I finished. I was employed by the University of the Witwatersrand at the beginning of 2002 which is when the former Johannesburg College of Education was incorporated into the university.

I was immediately given all the physical science methodology classes to teach, with no indication of what had happened previously in these courses. The assumption was that a good science teacher would automatically know how to teach other science teachers. Lecturers were left to figure out a pedagogy of teacher education for themselves, based on their own experiences. Thus I drew largely on my own ideas in designing the methodology courses. Over the last decade, the complexity of teacher education has come to be better understood, both within the Wits School of Education and internationally, as I will explore in Chapter 2.

I was also given all the physics courses to teach, a total of four half-courses in physics. In contrast to methodology, the content of an undergraduate curriculum in physics is a fairly standard offering worldwide, as evidenced both by undergraduate physics textbooks and by presentations at the biennial International Conference on Physics Education (e.g. Berrada, Ashraf, & Outzourhit, 2007). I felt the weight of this authoritative discourse in selecting the content for my courses, though I believe that students should encounter the strangeness of modern physics early on (Gundry, 2004). In the presentation of the content I had the opportunity to model my conception of good science teaching.

I was involved in both iterations of B Ed curriculum design. For the first, I arrived once the structure of the curriculum had been decided upon, and I was given the task of deciding what content should go into physics courses. For the second, I was part of a think tank which met weekly for a number of months during 2008, and which proposed the eventual structure of the new curriculum. I was then involved in leading the implementation of the first year of that curriculum.

In designing the physical science teaching methodology and physics courses for the original B Ed degree, I worked from my own conception of science teaching and my own notion of what student teachers need. The latter was based on my own experiences as a physical science teacher in a well-resourced school, my supervision of various student teachers at that school, and the year which I had spent teaching HDE students.

I also led the team of secondary methodologists working across all disciplines in the revised B Ed. In running a couple of workshops with this team, I realised that it was in our subject methodology courses that we found ourselves most vulnerable. As we taught people how to teach, we knew that they saw how we ourselves taught our disciplines – our failings as teachers were out in the open for public consumption. Moreover, while in our disciplines there was a canon of knowledge, teaching methodology lacks such a canon. Overall I invested a lot of time and energy in trying to decide how best to prepare teachers. I realised that the design of teacher education programmes is far from straightforward, a point I explore further in section 2.5.

1.4.4 My Subjectivity

Peshkin (1992) argues that, since we cannot achieve objectivity in social sciences research, we need to acknowledge and explicitly identify our subjectivities. In this way we can bring to our research an awareness of the subjective lenses through which we view our data and communicate our perspectives to our audience. Thus I will attempt here to identify my own subjectivities with respect to my research project. I will identify four identities which are relevant to my research: my science teacher self, my social justice self, my methodology lecturer self and my researcher self.

I identify myself as a passionate science teacher. I derive meaning and satisfaction from what I do in the classroom. I see conceptual understanding as the most important aspect of learning physics. Thus I think constructivism is a useful theory for understanding how learning in science happens and fails to happen. According to constructivism, learning is not about merely adding new mental constructs, but changing existing ones in the light of new evidence, a process called accommodation (Piaget, 1964). Thus learning happens through individual meaning-making of the input which an individual apprehends, and a person’s existing knowledge is central to the meaning-making process. I see constructivism as particularly applicable to science because a lot of science knowledge is counterintuitive, but is expressed in a form which seems to make sense, so that students do not recognise that it conflicts with their beliefs about the world (Meyer & Land, 2006). However constructivism does not explain lack of transfer of knowledge from one context to another. Influenced by phenomenography, I now see alternative conceptions not as obstacles but as possible stepping stones to scientific conceptions.

How does this translate into what I do in the classroom? I try to facilitate students' active mental engagement with content in a variety of ways. Talking and writing are key to meaning-making, so I give students opportunities to explain their understanding to a partner, and to write in their own words. Tutorials where students work in small groups are key because of the opportunity for talk and for active meaning making which they provide, especially if students have first worked on problems on their own. I recognise that students do not necessarily attach the same meaning to my words as I do, so I see pictures, diagrams, demonstrations and hands-on engagement with apparatus as key to shared understanding, and use such wherever possible. However I recognise that students do not necessarily 'see' what I see, and so observation needs mediation. Demonstrations or activities which use the 'predict-observe-explain' sequence are particularly useful: asking students to predict what will happen makes them aware of their preconceptions, and observation that is counter to what they expect creates the cognitive dissonance necessary for accommodation. However because accommodation is effortful, students may find other unscientific ways to explain or dismiss an observation. A key tenet of mine arising from constructivism is that it is pointless to answer questions that students are not asking. In practice this means setting up a situation which piques their curiosity or makes them aware of what they don't know. Situating physics in 'real life' examples helps. Finally I believe that students need closure on the scientific view: they need clear feedback on whether their ideas are right or wrong from a scientific point of view.

The above discussion is about facilitating conceptual understanding of physics. I also believe it is important that students have the opportunity to 'do' science through investigations which are as open as possible, and where they get to make decisions, rather than following a recipe. My concern with practical work has been that they should not lose sight of the big picture – the aim of the experiment – in the detail of taking measurements and plotting graphs. In summary, I see both the understanding of science and the ability to do science as key for science teachers, a prerequisite to their developing understanding and skills in their learners.

On the other hand, I am ambivalent about some of the curriculum innovations in science education which I will discuss further in section 2.2.5. I feel the Nature of Science movement (Abd-El-Khalick & Lederman, 2000) underplays the canon of accepted science which classroom science mostly draws on. I recognise that argumentation (Erduran, 2004) is important in establishing science knowledge, but know that both my students and I find it difficult to distinguish between the different aspects of an argument, and I cannot see how to incorporate it into my practice. I am also critical of the current South African school physics curriculum, insofar as the goals of inquiry-oriented science and relevance have been undermined by the sheer volume of content to be covered. Finally, while I am concerned with alignment between teaching and assessment, and recognise the importance of feedback and the role that assessment plays in shaping 'what counts', assessment is something of a necessary evil in my experience of practice. I see marks as the currency of education, and so I use marks to encourage students to engage in what I consider to be sound learning practices, such as regular tutorial work.

I went into education because of my 'social justice' self, and so this is also key to my teacher identity. I see quality science education as providing access to powerful knowledge. I aspire to acknowledging the dignity of students in my interactions with them, expressing warmth and acceptance, and I make the effort to learn as many names as I can. Occasionally I refer to Indigenous Knowledge, thus acknowledging some students' home cultures. I made a considerable effort to learn some Zulu in order to engage more with students, and to understand how the grammar of African languages shapes understanding in science. I encourage women in science, and take note of the gendering of examples I give for homework and in assessment.

My science teacher identity was fairly stable over the period in which I lectured the teachers in the sample in this study, having developed over the twelve years for which I was a secondary school teacher. In contrast my methodology lecturer identity was still developing, as described in the introduction to this chapter and in section 1.4.3. My understanding of teacher education continuously evolved and was different when I performed this research from what it had been when I taught the sample.

Another developing identity was that of my researcher self. This was in embryonic form when I first started to work on a possible research proposal for this project in 2006, and is still developing at the end of this research project. I reflect on the development of this self in the section 8.1. My researcher self therefore drew heavily on the other selves I have described above.

I have referred to four of my identities: my science teacher self, my social justice self, my methodology lecturer self and my researcher self. How did these affect my research? My science teacher self focused on classroom interaction and the ways in which conceptual understanding is developed – as is reflected in my first two research questions, about the form and content of lessons. In answering my second question about the content of science lessons, I focused on the scientific concepts, but glossed over what was communicated about the nature of science or the way in which scientific knowledge was argued for. I simply ignored assessment. My research was not concerned with whether teachers were living up to the identities prescribed by the current curriculum or by any particular curriculum innovation.

My social justice self included under-resourced township schools in the sample. This self noticed attempts to connect with learners' home knowledge, the use of different languages, and the positioning and participation of girls. My social justice self wanted to understand the meanings which teachers give to their work, so my research took an interpretive approach, exploring conceptions and narratives. My social justice self would like to have taken a more critical stance on education in South Africa but my researcher self lacked the background and confidence to use critical theory.

My methodology lecturer self knew that conceptions of teaching and identity as teacher are central to teaching, and so my research addressed these constructs, although initially my researcher self shied away from identity as an analytical lens. I have identified some ways in which my subjectivities have affected my research, but I recognise this list is not exhaustive, and that an outsider is likely to see more than I can from my subject position.

I first attempted to capture my subjectivities when writing my research proposal, and found it difficult to express as a coherent whole, although I recognised then that I was ignoring assessment even though it is central to teaching and learning. Over the course of this research project, my methodology lecturer and researcher selves were shaped by the research as they responded reflexively to the research, and grew in the process. In reflecting at the end of this project on the impact of my subjectivity, I am surprised and wryly amused at some of the ways in which my subjectivities have played out in the course of my research. For example, initially I did not include a research question about the content of science lessons, but I added it when I found that my first question about classroom practice failed to address the conceptual knowledge which my science teacher self sees as central to science teaching.

1.5 Conclusion

I started this chapter by noting both local and international calls for research into the thinking and practice of teachers, particularly early career teachers. I have now painted a picture of the national and local context in which that research need is situated – an education system characterised by continual change, which has impacted me and to which I have contributed locally. I have also presented my research questions which address that research need and explicated concepts which are key to this research project: identity, narrative and conceptions.

The rest of this thesis takes the story started in this chapter through to its conclusion. In Chapter 2 I explore what theory and other research have to say about the complexity of teacher learning. I explore my methodology in depth in Chapter 3, first constructing a framework for thinking about the validity of my research, and then critiquing my research in terms of that framework. There follow four chapters of data analysis which address each of my four research questions in turn. In Chapter 8 I reflect on the research design, and summarise and synthesise the results of my research in relation to my research questions. Finally in Chapter 9 I consider how the research talks back to the field in regard to teacher education and education more broadly, and then in regard to the context out of which it came.

Chapter 2: Literature Review

The goal of teacher education is to prepare teachers to teach effectively in schools. The purpose of my study was to follow up teachers who had been through a particular programme, and explore both their classroom practice and their thinking. This prompts the question, how does teacher education relate to what actually happens in schools? This suggests three further questions: what do teachers need to learn, how does that learning happen, and hence what should happen in initial teacher education programmes? Taken for granted in all of the above questions is that there is a shared understanding of what teaching is. Hence a central question is: what is teaching? This question can be answered from the perspective both of teachers and of education researchers. A related question is: what counts as 'good' teaching? These six questions frame this chapter. The answers encompass both educational theory and research into practice.

Teaching is a complex process, and to make sense of it is necessary to reduce the complexity in some way:

> It is only because teachers find ways of reducing the complexity by constructing coherent, integrated ways of handling the complexity that they can cope and even prosper in the unceasing flow of information in the classroom. (Hewson, Kerby, & Cook, 1995, p. 517).

In a similar way, education researchers reduce the complexity of teaching by using models. These models are a way of understanding the complexity of teaching by simplifying it. But the boundaries of the various constructs used in these models are drawn in different places by different experts, creating a different kind of complexity. In this chapter I find my way through this complexity by engaging with different models and bringing them into relation with each other, though the correspondence is never perfect. Thus I acknowledge the differences and align myself with particular approaches.

2.1 Teacher Education and Learner Outcomes

There are different ways of understanding the relationship between teacher education and school practice. This is significant insofar as the way one understands the relationship frames the research questions that one can ask about the effectiveness of teacher education. There are three types of models which can be used for understanding this relationship: simple, complicated and complex. I will explain each in turn and then consider the implications of each model for research. In doing so I will draw on examples both from pre-service and in-service teacher education.

2.1.1 Simple Models

If we want to achieve desirable outcomes in learners, then few would disagree that we need good teachers engaging in sound educational practices in their classrooms. Using the same logic, if we want good teachers, we need a good teacher education programme. In other words, it could be argued that if we put the right inputs into teacher education, we will get the right outputs from the school system, as illustrated in Figure 2.

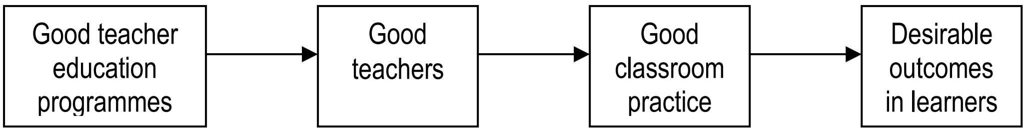

Figure 2: A simple model of education

Similar one-way flowcharts are used to illustrate the logic implicit in in-service teacher professional development by Clarke and Hollingsworth (2002) and Supovitz and Turner (2000), illustrated in Figure 3 and Figure 4 respectively. Supovitz and Turner explain their diagram as follows:

> The implicit logic of focusing on professional development as a means of improving student achievement is that high quality professional development will produce superior teaching in classrooms, which will, in turn, translate into higher levels of student achievement. (p. 965).

This Newtonian cause-and-effect model is appealing: those involved in initial or in-service teacher education dearly want to have a significant positive impact on the youth.

Figure 3: An implicit model of the purpose of teacher professional development (Clarke & Hollingsworth, 2002, p. 949)

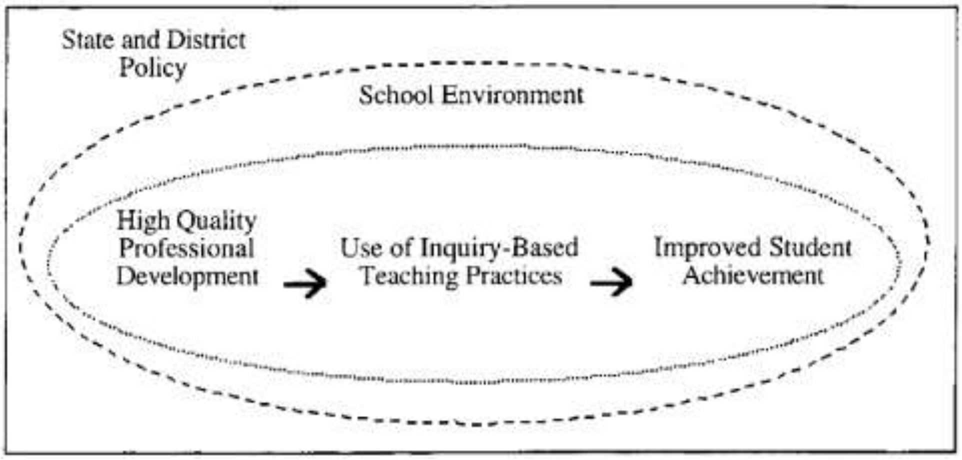

Figure 4: Model depicting theoretical relationship between professional development and student achievement (Supovitz & Turner, 2000, p. 965)

2.1.2 Complicated Models

However it is not difficult to critique these simple models: at every stage there are more inputs than the ones shown on the diagrams. A teacher is not only a product of her teacher training but also of her own schooling, family and culture. What happens in a classroom is not only a function of what the teacher does but also of what the learners do, and the culture and resources of the school and community. And like their teachers, learners are not simply the products of their classrooms. The reality is considerably more complicated than these simple models suggest.

Rogan and Grayson's (2003) Theory of Curriculum Implementation illustrated in Figure 5 provides a possible model for such a complicated system. This theory was developed in the context of in-service teacher professional development, but applies well to new teachers. The 'profile of implementation' in this model is the classroom practice of new or experienced teachers measured in terms of a new curriculum. This 'profile of implementation' affects and is affected by 'outside influences', and the 'capacity to innovate'. Unlike Figure 3 and Figure 4, 'professional development' is only one of several 'outside influences' which work together with the 'capacity to innovate' to affect what happens in the classroom. This model stops short of the learners but usefully illustrates a complicated view of the inputs to classroom practice.

Although the model is complicated, it is still possible to investigate relationships between different constructs, using the tools of statistics, as Rogan and Aldous (2005) have done. Their research has been useful in understanding the gap between the intended curriculum and the enacted curriculum in South Africa. So the model, while complicated, is still deterministic, and can be used to make predictions about the effect of various inputs in aggregated terms.

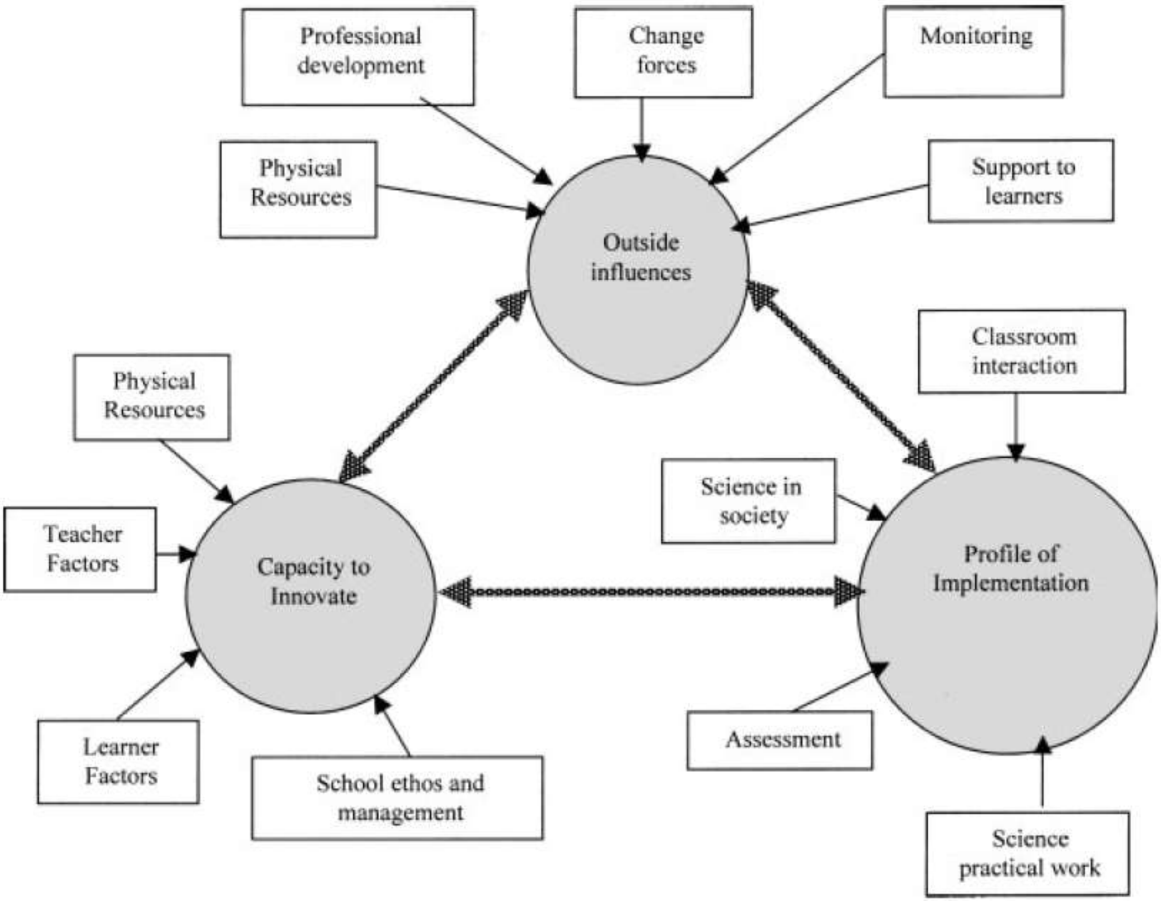

Figure 5: Rogan and Grayson's Framework as illustrated by Rogan and Aldous (2005, p. 314).

2.1.3 Complex Models

A third way of viewing education is as a complex system. Complexity science is used to describe complex systems and is used in a wide range of contexts. A bee colony is an example of a complex system – there is no top-down organization (the queen bee's role is merely reproductive) but the highly-organised system emerges from the action of individual bees. The whole is more than the sum of its parts, and its functioning cannot be explained by breaking it down into its constituent pieces the way a machine can. A complex system is emergent and adaptive: emergent insofar as its structure emerges in a bottom-up direction from the interactions of actors within the system, and adaptive insofar as it changes over time in response to outside influences or perturbations (B. Davis & Simmt, 2003). A complex system is not predictable: because of the agency of the actors in a complex system, similar inputs will have different effects. Moreover a small change in initial conditions may have a large, unpredictable effect – the so-called 'butterfly' effect[7].

Complexity science rings true for education where my experience is that policies and government departments have little effect on the personalities of schools, which arise instead from the actions of the teachers and learners within schools. Enactivism is a learning theory arising out of a complexivist view of education which:

> looks at each learning situation as a complex system consisting of teacher, learner and context, all of which frame and co-create the learning situation. The teacher, at best, can only perturbate the learners who will take on board what they are able to embrace at that moment as a result of their current predisposition from biological, historical and other contextual factors. (Breen, 2005, p. 240).

This view of education is valid both for school classrooms and for the classrooms of teacher education. Inputs in pre-service education are perturbations which affect different students differently, depending on their biological make-up and personal histories. Moreover, the subsequent enactment of pre-service learning by teachers is co-constructed with their learners in the contexts of different schools. Thus the 'teacher factors' and the 'learner factors' in Rogan and Grayson's framework assume greater importance – the agency of the teacher and learners is central.

Such a complexivist view is reflected in Prosser and Trigwell's (1999) Constitutionalist model of learning, Figure 6, which emerged from phenomenographic research into conceptions of teaching and learning. Within a particular 'learning and teaching context' such as a science classroom, each 'student's situation' is unique. Each student has her own set of prior experiences which affect her perception of the current context. The foregrounding of a student's perceptions of her situation has resonance with Brousseau's notion of the implicit 'didactic contract' whereby both teacher and learners have expectations of their own and each other's roles in the classroom (Brousseau & Balacheff, 1997). At the same time the current context affects *which* aspects of a student's prior experience are salient. The student's perception of the situation affects for example whether she will take a 'surface' or 'deep' approach to her learning, which affects her learning outcomes. There are no arrows in this model because Prosser and Trigwell argue

[7]The 'butterfly' effect refers to the question "Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?" posed by one of the pioneers of Chaos Theory in 1972 (Lorenz, 2000, p. 91).

"From the constitutionalist perspective, we consider students' prior experiences, perceptions, approaches and outcomes to be simultaneously present in their awareness" (p. 17). Prosser and Trigwell developed this model in the context of higher education, which implies it is applicable to student teachers. But it can also be used to think about secondary school science classrooms.

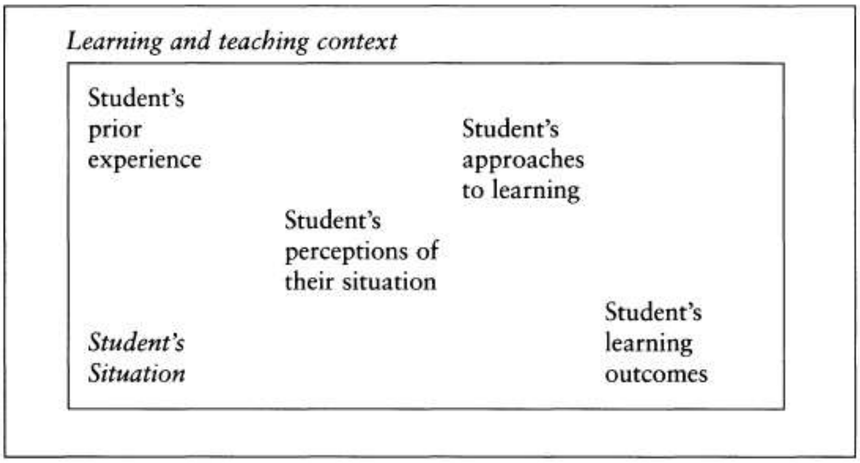

Figure 6: A constitutionalist model of student learning (Prosser & Trigwell, 1999)

Another example of a complex model is Clarke and Hollingsworth's (2002) model of professional growth, Figure 7, which they see as an improvement on Figure 3 above. The dimensions in this model correspond to the four circles in Figure 3, but the arrows go in many directions and reflect the agency of the teacher in enacting and reflecting so that "This model recognises the complexity of professional growth through the identification of multiple growth pathways between the domains" (p. 950). Overall, a complexivist view of education takes into account both the agency of the individual, and her past and present contexts.

The interplay between agency and context is complex. From a complexivist perspective, the structure of a context emerges from the actions of individuals within that context. However an individual experiences the combined actions of other individuals as the structure of that context. The structure of the context imposes constraints on the agency of the individual: the power of the individual to act is constrained by the power or structure of the context. However some agents within a context have more power than others. This means that the relative weights of context and agency differ for different people in a particular context, and for the same people in different contexts. Sociology offers ways to understand the interplay between agency and the structure of a context: "Theorising the interplay of structure and agency is the quintessential focus of sociological endeavour" (Willmott, 1999).

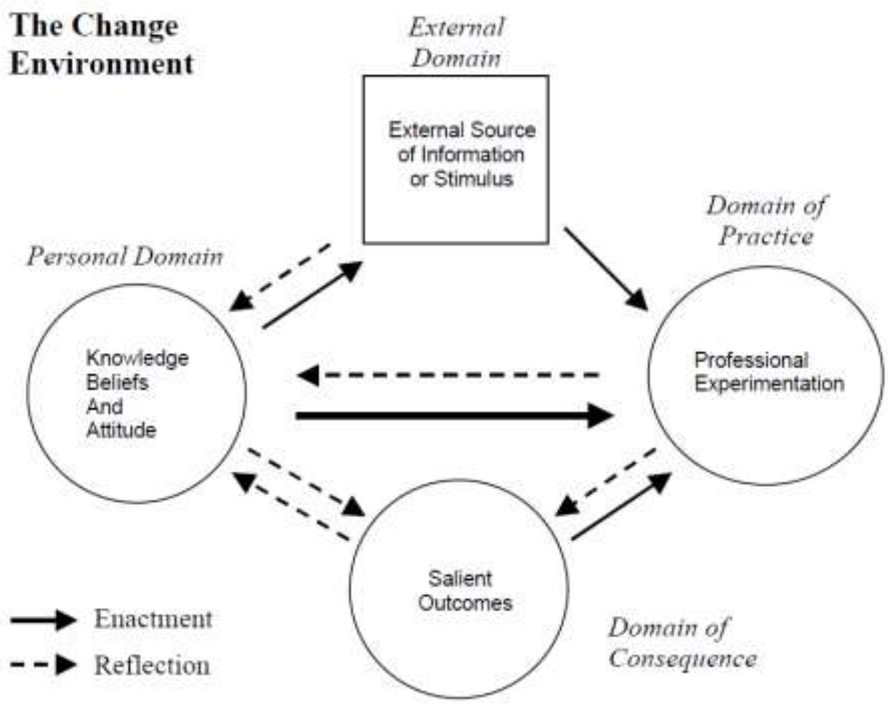

Figure 7: The interconnected model of professional growth (Clarke & Hollingsworth, 2002, p. 951)

The sociologist Bourdieu notes that "Every established order tends to produce (to different degrees and with very different means) the naturalization of its own arbitrariness." In other words people in a culture or institution perceive that 'the way things are' socially is natural, and the only way the social order could be. The reification of structure is the way in which those with more power maintain and use their power – they exert power by hiding behind reified structures which legitimate their power. As a result of the naturalisation of the social order, each person has a set of unconscious culturally determined, taken-for-granted dispositions to act in certain ways, which Bourdieu calls 'habitus'. Habitus is the unconscious internalisation of the external structure. I see conceptions of teaching as an aspect of habitus insofar as they comprise unquestioned beliefs and ways of acting as a teacher. A context limits agency by limiting the roles or identities available as part of the 'natural' order. An individual may be unaware of the extent to which her context structures her identity. However, as mentioned in section 1.2.1, identities also facilitate agency in contexts – they provides a means for individuals to negotiate the power of the context. Overall complex models best reflect this interplay between structure and agency.

2.1.4 Discussion

I have presented six models of factors affecting classroom outcomes, and classified them as simple, complicated or complex. The model that I use to think about teacher education affects the research questions which I can legitimately ask. If I regard education as a simple system, I can ask: what effect will a particular pre-service input have on future classroom practice? If I take education to be a complicated system, I can ask questions about such effects in aggregated terms. But if I regard education as a complex system, then I cannot establish causal relationships: it is not possible to predict the effect of any one input. This does not mean that inputs have no effect, but rather that the effect is complex. The kind of question which can legitimately be asked is: which perturbations in teacher education are likely to have productive outcomes even if those outcomes are different for different students?

The above questions are reflected both in the development of theories of learning and in the history of teacher education research in America. With regard to theories of learning, Hammerness et al. note:

> psychologists have moved from a behaviorists' quest for a direct relationship between stimulus and response, to a cognitive psychologists' exploration of how individual learning unfolds, to the broader focus offered by sociocultural theory on the contexts and conditions that promote learning. (2005, p. 389).

With regard to the history of teacher education research, Cochran-Smith and Fries (2008) identify that early research into teacher education saw teacher education as a curriculum problem – a problem of identifying the right content for teacher education. This content was based on the characteristics of effective teachers, with the assumption that if these characteristics were taught to teachers, effective classroom practice would follow – consonant with a simple model of education. Subsequent research focused on what methodologies to use to teach this content most effectively, reflecting a more complicated understanding of teacher education. From the 1980s there was awareness that learning to teach is a complex process, and so understanding how teachers learn to teach was on the research agenda. But much American research in the past twenty years has reverted to a simpler model, looking for policies in teacher education which lever up maximum improvement in classrooms. This last shift involves a move towards large scale quantitative studies which provide the data demanded by 'evidence based' policies. Such policies tend to ignore the differences in individual contexts.

My research is founded on an understanding of learning to teach as a complex process with context playing a significant role, as I will explain later in this chapter when I explore in some depth how teachers learn to teach. This means that I will be using phenomenography and narrative research to understand a complex situation. So it is appropriate to ask: how does complexity science sit with phenomenography and narrative research? Complexity science, phenomenography and narrative research have the same epistemological stance: what counts as a relevant world is inseparable from the perceivers. Moreover Davis and Simmt, in relating complexity science to mathematics education, argue that:

> We might say that complexity science is more a *meta-discourse*, useful for reading across theories that are concerned with different levels or aspects of complex, nested learning systems (2003, p. 142).

They claim that complexity science recognises different approaches as appropriate to use in answering different questions, and it is unproductive to attempt to integrate theories. Moreover the complexivist view of identity is consistent with my view of identity as constructed in contexts (section 1.2.1): "who we are arises in our moment-to-moment coping with the contingencies of our existences" (B. Davis, 2004, p. 213). I conclude therefore that phenomenography and narrative research are consistent with a complex view of teacher education.

2.2 What is Teaching?

At the start of this chapter, I said I would answer some questions relating to teacher education, but that a more fundamental question is: what is teaching? I will answer this question first from the perspective of teachers, by looking at the conceptions of teaching which teachers have, and then look at the terms which education researchers use to describe the work of teaching. Thereafter I will consider some conceptions related to teaching. Finally I will zoom in on the notion of 'good' teaching, and in particular good science teaching.

2.2.1 Conceptions of Teaching

Kember (1997) and Prosser and Trigwell (1999) report on a variety of phenomenographic studies which look at the conceptions of teaching of university lecturers. The studies typically find a hierarchical outcome space, with a conception of teaching as ‘information transmission’ at the bottom of the hierarchy, and teaching as ‘conceptual change’ at the top, for example:

F: helping students change conceptions

E: helping students develop conceptions

D: helping students acquire teacher knowledge

C: helping students acquire conceptions of the syllabus

B: transmitting the teacher’s knowledge

A: transmitting the concepts of the syllabus (Prosser & Trigwell, 1999).

This outcome space is hierarchical insofar as higher conceptions include lower conceptions, thus teachers who demonstrate higher order conceptions have a range of conceptions on which they can draw. Often the conceptions at the top of the hierarchy are characterised as learner-centred, while those at the bottom are characterised as teacher-centred.

These conceptions emerged from research with experienced tertiary teachers, but a few studies have looked at secondary teachers. One phenomenographic study looked at the conceptions of teaching and learning of sixteen Australian secondary school teachers (Boulton-Lewis, Smith, McCrindle, Burnett, & Campbell, 2001). The lowest conception of teaching in the hierarchy of their outcome space is similar to that of the outcome space described above, namely ‘transmission of content / skills’. But the conception at the top of the hierarchy is ‘transformation of students’. My observation is that this reflects that teachers hold two things in focus: their learners and their subject, but as one moves up the education system, the emphasis of teachers tends to shift from learners to subject. So in general secondary teachers place more emphasis on learners than do tertiary teachers. Hence the conception at the top of the Boulton-Lewis et al. hierarchy is entirely about students – ‘transformation of students’ – whereas the conception at the top of the Prosser and Trigwell hierarchy also has knowledge in focus: ‘helping students change conceptions’. Secondary and tertiary teaching are also different insofar as in tertiary teaching the teachers own the curriculum, whereas in secondary teaching the state owns the curriculum.

The above studies were not specifically about science teachers. A large-scale phenomenographic study which looked at the conceptions of Chinese secondary physics teachers found some conceptions similar to those above as well as conceptions not uncovered in western contexts: teaching as examination preparation, teaching as 'attitude promotion' which relates to "changes in students' attitudes to learning" (Gao & Watkins, 2002, p. 66) and teaching as guiding learners as to how to conduct themselves. These conceptions derive from Chinese cultural emphasis on examinations and behaviour. Aguirre, Haggerty, and Linder (1990) explored pre-service secondary science teachers' conceptions of teaching, but only found two conceptions, one teacher-centred, and one learner-centred. Another study looked at the conceptions of teaching of three science teachers in an alternative certification programme (Koballa, Glynn, Upson, & Coleman, 2005).

All of the above conceptions of teaching are about the *purpose* of teaching. One could argue that there is more to a teacher's experience of teaching than the purpose of teaching. But from the above I conclude that what has emerged consistently over many different contexts is that the driving purpose behind teaching is key to how teachers experience their teaching.

Some researchers outside of phenomenography have also looked at teachers' conceptions of teaching. Fox (1983) gave four 'theories' of teaching: teaching as transfer of knowledge; teaching as shaping students into a particular mould; teaching as travelling – taking students on a tour of the subject; and teaching as growing students. Hobden (2000) used metaphor to explore South African mathematics student teachers' beliefs about teaching, and classified them according to Fox's categories. Hoban (2005) identified four conceptions of teaching: teaching as craft, labour, profession or art. Whereas the first two conceptions emphasise technical skills mastered over time, the latter two recognise that the classroom is a complex space where personal judgement is important. Mellado (1998) explored the conceptions of two primary and two secondary pre-service science teachers, and expressed their conceptions in terms of teaching sequences. Hewson, Kerby and Cook (1995) looked at the conceptions of teaching held by secondary science teachers, finding conceptions which are multidimensional and unique to each teacher. Skamp's (1995) investigation into pre-service primary science teachers' conceptions of 'good' science teaching produced a list of criteria by which his sample judged good science teaching.

Overall while conceptions of teaching have been researched extensively at the tertiary level by phenomenographers, at the secondary level there are few studies either inside or outside of phenomenography, and most of these are not specific to science teachers. Moreover only one of the studies mentioned above looked at conceptions in the South African context, and this was done using metaphor not phenomenography. My fourth research question addresses this gap by asking what conceptions South African secondary science teachers have of science teaching.

2.2.2 What's in a Conception?

Phenomenographers see two aspects to conceptions: the referential aspect and the structural aspect. The referential aspect is the meaning of the conceptions, whereas the structural aspect is the internal structure of the individual conceptions and the external structure of the conceptions in relation to each other in the outcome space (Marton & Booth, 1997). In the previous section, I considered the referential aspect and the external structure of the conceptions in relation to each other. I now turn to the internal structure of the conceptions.

Out of their work on conceptions of teaching, Prosser and Trigwell (1999) developed the 'Approaches to Teaching Inventory' which consists of sixteen statements with a Likert-type scale. They categorise half the items as being about intentions and the other half as being about strategies. But Norton, Richardson, Hartley, Newstead and Mayes (2005) criticise this classification, and claim that Prosser and Trigwell's intention items are in fact beliefs about teaching, and their strategy items are teaching intentions. Thus the breakdown suggested by Norton et al. is:

conception = beliefs + intentions

Working from their belief-intention premise, Norton et al. used a questionnaire to find differences between beliefs and intentions and concluded "teachers' intentions represent a compromise between their conceptions of teaching and their academic and social context" (2005, p. 564). This resonates with Samuelowicz and Bain's earlier observation of:

> the possibility that academic teachers might have both 'ideal' and 'working' conceptions of teaching. It seems, from the limited data available, that the aims of teaching expressed by academic teachers coincide with the 'ideal' conception of teaching whereas their teaching practices, including assessment, reflect their working conception of teaching. (1992, p. 110).

Koballa et al. (2005) also found working and ideal conceptions of teaching with three novice teachers. This discrepancy between beliefs and intentions suggests that an analytical breakdown of conceptions into the constituents of beliefs and intentions is appropriate. Outside of phenomenography Pajares (1992) notes that in research into students' conceptions of scientific concepts, the term 'conception' is a "broader construct" (p. 320) which includes beliefs.

Ajzen's Theory of Planned Behaviour (section 2.2.2) also makes the distinction between beliefs and intentions. This theory is a tool used in psychology for investigating the beliefs which drive behaviour. Implicit in this theory is the assumption that people behave in ways which make sense to them. According to Ajzen's model, a person's beliefs inform her intention to act in a certain way, and her actual behaviour is determined by her intention as well as by her behavioural control, both perceived and actual. Ajzen breaks down the construct of belief into three categories of beliefs which inform a person's intention to act in a certain way. The first category is behavioural beliefs, which are beliefs about the value of certain behaviours, for example beliefs about the effectiveness of various classroom pedagogies. The second category of beliefs is normative beliefs which are beliefs about the behaviours which society require, for example beliefs about what the department of education, the curriculum and a particular school expects of teachers. The third category of beliefs is control beliefs which are beliefs a person has about her ability to implement the behaviours. These are related to the actual behavioural control she has in a particular context but what is more important than the actual behavioural control is the perception of that control. All three categories of belief are context dependent – the context imposes norms and constraints on a teacher, thus affecting her normative and control beliefs, and affects her behavioural beliefs, i.e. what a teacher thinks will work in a particular context. The Theory of Planned Behaviour is a simple causal model, but the reality is complex, for example classroom experiences act back on and change teachers' beliefs. Nonetheless it adds weight to my decision to explore not only classroom practices but the conceptions (comprising beliefs and intentions) behind those practices, and draws attention to the role of context in beliefs and intentions, consistent with phenomenography.

A group of American researchers working with Ajzen's Theory of Planned Behaviour have done research in science education similar to the phenomenographic research into beliefs and intentions. They have statistically analysed the relationship between science teachers' beliefs and intentions regarding aspects of curriculum reform. They found that control beliefs had the greatest effect on intentions to implement Science, Technology and Society approaches (Lumpe, Haney, & Czerniak, 1998) whereas behavioural beliefs had the greatest effect on intentions to implement other aspects of reform (Haney, Czerniak, & Lumpe, 1996). A later qualitative study compared the beliefs and classroom actions of a group of four teachers, and distinguished between central beliefs which affect practice and 'peripheral' beliefs (Haney & McArthur, 2002).

Beyond phenomenography and Theory of Planned Behaviour research, different researchers use the term 'beliefs' differently (Kagan, 1992a; Pajares, 1992), although Pajares' (1992) review of research into teachers' beliefs concludes that all are agreed that beliefs "play a critical role in defining behaviour" (p. 325). Two large scale American projects have explored science teachers' beliefs. Although neither project is explicit about the intentionality of the beliefs, both in fact look at beliefs about teaching and learning. The first is the Salish I project which used the Teacher's Pedagogical Philosophy Interview to explore teacher's beliefs, and categorised them as teacher-centred, learner-centred, conceptual or 'wobbling' between views (Simmons et al., 1999) – this last category is consistent with the phenomenographic view that a person may conceptualise a phenomenon in more than one way, depending on the context. The second project developed the Teacher Beliefs Interview which allocates respondents into one of five categories, ranging from teacher-centred 'traditional' to learner-centred 'reform-based' (Luft & Roehrig, 2007). In summary research into teachers' beliefs about teaching has yielded similar categories to phenomenographic research into teachers' conceptions of teaching.

However the 'beliefs' researchers do not see hierarchy in the same way as the phenomenographers: while the 'beliefs' researchers see learner-centred beliefs as superior to teacher-centred beliefs and so see them as hierarchical in that sense, they do not include teacher-centred beliefs in learner-centred beliefs in the way that phenomenographers include teacher-centred conceptions in learner-centred conceptions in their hierarchy. So while the categories are similar, the relationships between the categories are different in the two bodies of research. Nonetheless the similarity between the two bodies of research is striking, and hence it seems that 'beliefs' is the preferred American term for what are referred to as conceptions elsewhere.

2.2.3 Conceptions Related to Teaching

Phenomenography has also explored other conceptions related to teaching, such as conceptions of learning and conceptions of various disciplines, and the correlations between different conceptions. There are strong correlations between conceptions of learning and conceptions of teaching (Prosser & Trigwell, 1999). Academics with integrated conceptions of their disciplines are more likely to have a 'conceptual change' conception of teaching (Prosser, Martin, Trigwell, Ramsden, & Lueckenhausen, 2005). Entwistle and Walker (2000) propose that teachers' epistemological understandings of their subjects underlie their conceptions of teaching and learning – teacher-centred conceptions are based on a view of knowledge as absolute, whereas learner-centred conceptions are based on a relativist view of knowledge.

Outside of phenomenography, teachers' conceptions of science have been investigated in research into teachers' understanding of the Nature of Science (see section 2.2.5). Windschitl (2002) investigated the conceptions which six student teachers had of inquiry. Teachers also have beliefs about the purpose of laboratory work which are often at odds with their students' beliefs about the purpose of such (Berry, Mulhall, Gunstone, & Loughran, 1999). Although these various conceptions affect the way teachers go about their work, they are not the subject of my research.

2.2.4 Teaching as Transformation

A look at the conceptions which teachers have of teaching prompts the question, what conceptions do researchers have of teaching? In this section I will explore terms which education researchers use for teaching. Education researchers agree that teachers do not simply present knowledge but act on it some way. There are various words which get used for this process, for example transformation, unpacking and transposition. Each of these has a metaphorical reference to an action on an object. Transformation implies that the object is changed; unpacking conjures an image of unpacking a suitcase; and transposition implies the moving of an object from one position to another.

Lakoff and Johnson (1980) point out that much of our everyday thinking and language is metaphorical though we often don't notice it. Metaphor is helpful in providing a bridge between what we know and what we don't yet know (Sfard, 2000b) since "The essence of metaphor is understanding and experiencing one kind of thing or experience in terms of another" (Lakoff & Johnson, 1980, p. 455). But the metaphors we choose open up some possibilities and close down others.

> The very systematicity that allows us to comprehend one aspect of a concept in terms of another (e.g. comprehending an aspect of arguing in terms of battle) will necessarily hide other aspects of the concept (Lakoff & Johnson, 1980, p. 458).

Hence I see the choice of the word for what teachers do as significant, and will explore each of the three options (transformation, unpacking and transposition) in more detail.

Before I do so, I note that all three metaphors for teaching treat knowledge as an object, and so fit with a metaphor of learning as acquisition rather than learning as participation. Sfard (1998) warns that both metaphors are needed for a full understanding of learning. The 'learning as acquisition' metaphor aligns with the 'conduit metaphor' of teaching identified by Reddy (1979).

The first word I consider is 'unpacking'. Ball and Bass see unpacking as distinctive of the mathematical work of teachers. They explain:

> a powerful characteristic of mathematics is its capacity to compress information into abstract and highly usable forms. When ideas are represented in compressed symbolic form, their structure becomes evident, and new ideas and actions are possible because of the simplification afforded by the compression and abstraction. Mathematicians rely on this compression in their work. However, teachers work with mathematics as it is being learned, which requires a kind of decompression, or "unpacking", of ideas. (2002, p. 11).

This compression is also true of the physical sciences, where those initiated into the discourse can read a significant volume of information from a chemical equation, the periodic table or a physics formula. A science teacher decompresses or unpacks these representations to make the information accessible to novices. But there are also times when teachers compress their complicated knowledge into a simple model because the model is easier to work with. For example, teachers represent an atom as a single particle, when in fact the structure of the atom is a complex structure of many particles. Thus teaching science involves more than unpacking, and so I see the metaphor of unpacking as too limited to describe the work of science teachers.

With regard to 'transposition', French education researchers talk of the 'transposition didactique' or didactic transposition (Chevallard, 1987). Transposition suggests that the object which is moved is unchanged in the move. However I note that the didactic transposition is often explained by using the term ‘transformation’, for example:

> The transposition didactique […] has become a well-used label for the **transformation** of expert awareness (subject matter as it stands to the specialist) into instruction in behaviour (as it is construed by the student). (Mason & Spence, 1998, p. 343, emphasis added).

One could argue then that the use of the word of transposition reflects a limitation of translation, although transformation is also a word in French. This points to ‘transformation’ as a more appropriate term.

Bernstein talks of “the transformation of knowledge into pedagogic transformations” (1996, p. 39) and reifies this transformation as the ‘pedagogic device’. Geddis and Wood (1997) claim that “Shulman’s conceptualisation of teaching as *the transformation of subject matter into forms accessible to the learner* has provided a fruitful way of framing the pedagogic exercise” (p. 612, italics in original). They reference Shulman’s (1987) ‘model of pedagogic reasoning and action’ but this model involves six steps: comprehension, transformation, instruction, evaluation, reflection, and new comprehension. In other words transformation is only one of these six steps, and is distinct from and precedes instruction. Shulman sees transformation as involving the critique and selection of texts, representations such as analogies and demonstrations, teaching strategies, while adapting these to the teaching context by taking into account learner characteristics. So Geddis and Wood elevate transformation to capturing the whole process of teaching, which was not how Shulman used it. My use of transformation is consistent with Geddis and Wood’s approach, as I found that transformation proved a useful metaphor to use with student teachers, as they thought about teaching chemical equilibrium (Mavhunga & Rollnick, 2012).

The limitation of the transformation metaphor is that it could be interpreted as implying that the teacher’s knowledge no longer exists in its original form. In fact at the end of the transformation there are two objects: the teacher’s knowledge and her didactic offering. The didactic offering is not a replica of the teacher’ content knowledge, and so that is the sense in which transformation happens. The teacher may not perceive the distinction however: Rollnick, Mundalamo, and Booth (2012) found that teachers apprehended new content by thinking about the teaching of it. Furthermore, teaching may lead to change in the teacher’s knowledge (Akerson, 2005; Gess-Newsome, 1999b).

Teaching as transformation reflects a particular paradigm. In regard to paradigms, Davis (2004) presents a fascinating 'genealogy' of teaching. He identifies two conceptions of teaching in the spiritual domain and a further six conceptions external to it: instructing, training, facilitating, empowering, occasioning and conversing. He links these to the paradigms out of which they have come, namely rationalism, empiricism, structuralism, post-structuralism, complexity science and ecology respectively. Teaching as transformation fits most closely with the facilitating conception which includes mediating and modelling, and which comes from a structuralist paradigm, which is where Davis locates constructivism. This means that the metaphor I am choosing for teaching is not that of complexity science, although like the occasioning of complexity science, facilitating is creating conditions where learning is likely to happen, though the outcomes cannot be predicted. But from a complexivist view Davis suggests "Teaching and learning are not about convergence onto a pre-existent truth, but about divergence – about broadening what is knowable, doable and beable" (p. 184). In contrast school learning is about convergence onto the knowledge defined in the curriculum, and so in such a context I contend that a metaphor of teaching as facilitation or as transformation is appropriate.

2.2.5 Good Science Teaching

I have considered teachers' conceptions of teaching and the metaphors which researchers use for teaching. But I have not considered what counts as 'good' teaching. In this section I will consider various notions of good science teaching. Embedded in the notion of a good science teacher is the notion of a good teacher generally, for example, one who displays a high standard of professionalism. The current South African school curriculum considers a good teacher to be one who is learner-centred. But I focus here on that which is distinctive of good *science* teaching.

In the various science education reforms since the 1960s, there have always been two main goals of science education: science for scientists and science for all (Fensham, 1988). In other words, school science needs to provide the scientists and engineers of the future, as well as educate its citizens to participate in democratic processes in an increasingly technological world. The first goal provides for an elite; the second goal is about meaningful science for all.

These aims are good, but they sit in tension. Science for scientists needs strong classification in Bernstein's (1996) terms whereas science for all implies weak classification. Strong classification means that there are strong boundaries between science and other subjects so the content is constituted in terms of the structure of the discipline, with a focus on scientific concepts and theories. Thus students are given 'epistemological access' (Morrow, 2007) to the disciplines of science, and are able to work powerfully with the paradigm which science offers. On the other hand, weak classification means porous boundaries between science and other subjects, and between school knowledge and home knowledge. Thus students are able to make connections between science and other subjects, and between school and home. Weaker boundaries are exemplified in a Science-Technology-Society approach (Solomon, 1993). Strongly bounded content is constituted differently from weakly bounded content, both in scope and structure, and so the two goals of science education sit in tension with each other (Bernstein, 1996).

These two goals are evident in the current South African curriculum: the grade 7-9 Natural Sciences curriculum is an example of an integrated curriculum, with the science disciplines (physics, chemistry, life science and earth science) integrated around four themes (Department of Education, 2002). For example, the 'Energy and Change' theme considers the political and environmental consequences of energy access and use, thus constituting a weak boundary between science and energy use in daily life. In contrast, the physics content of the grade 10-12 Physical Sciences curriculum is similar in nature to the content of a first year university course in science, and is organised according to the traditional structure of the discipline (Department of Education, 2003).

The shift in emphasis from Natural Sciences to Physical Sciences could be argued to be appropriate since all school learners take Natural Sciences, but less than half take Physical Sciences beyond grade nine.[8] However, while Physical Sciences theoretically provides access to science in higher education, few learners achieve the level of science in their

[8]For example, 41 % of all who wrote the grade twelve examinations in 2008 wrote Physical Sciences (Department of Education, 2008)

school leaving examination which is required for entrance into higher education.[9] So the Physical Sciences curriculum serves the interests of a minority of the learners who study it. In addition the pre-2011 curriculum statements for Natural Sciences and Physical Sciences were not internally consistent: they both reflected diverse competing voices (W. Green & Naidoo, 2006; Ramsuran, 2005) and thus sent mixed messages to teachers.

In addition to the tension between 'science for all' and 'science for scientists', there have been various other curriculum innovations in science. A book intended for science teachers entitled *Improving Science Education* (Erickson, 2000) contains the 'usual suspects' in addition to science for all: teaching about the Nature of Science, teaching argumentation, and cultural border crossing. I will discuss each of these in turn, relating them to the South African curriculum.

Researchers argue that the Nature of Science, particularly its changing and contested nature, needs to be explicitly taught – learners do not come to a sophisticated understanding of the Nature of Science by being taught the canon of science (e.g. Flick & Lederman, 2004). Teachers also have a limited understanding of the Nature of Science (e.g. Abd-El-Khalick & Lederman, 2000). In South Africa, research on understanding the Nature of Science is linked to Indigenous Knowledge Systems (IKS) (Ogunniyi, 2008; Vhurumuku & Mokeleche, 2009). One of the principles upon which all South African school curricula are supposed to be based is 'valuing IKS' (Department of Education, 2003). Researchers at the Science and Indigenous Knowledge Systems Project at the University of the Western Cape use a Dialogical Argumentation Instructional Model to incorporate IKS into science lessons, and describe how they have used this with teachers and learners with topics such as fermentation (Diwu, Ogunniyi, & Langenhoven, 2011), and lightning (Hlazo, Ogunniyi, & Afonso, 2012; Langenhoven & Ogunniyi, 2011). They argue that understanding the difference between IKS and science provides a way into both understanding the Nature of Science and valuing IKS.

The Science and Indigenous Knowledge Systems Project also draws on the idea of explicitly teaching argumentation, specifically Toulmin's Argumentation Pattern, which

[9] For example only 29 % of those who wrote the 2008 grade twelve Physical Sciences examination achieved 40 % or more (Department of Education, 2008).

sees a good argument as containing a claim justified by warrants linked to evidence, and rebuttals of counterclaims (Erduran, 2004). The benefit of explicitly teaching argumentation to learners is that they become better at science, as well as gaining a better understanding of how science works with evidence, i.e. an aspect of the Nature of Science (Diwu et al., 2011; Hlazo et al., 2012).

The understanding of other ‘ways of knowing’ exemplified by the South African school curriculum’s IKS principle also underpins research into cultural border crossing, which recognises that the culture of the science classroom may be very different from a learner’s home culture, thus necessitating a ‘border crossing’ every time the learner enters the science classroom (Aikenhead, 2001). The further apart the two cultures, the more difficult the border crossing. Jegede’s (1995) theory of Collateral Learning illustrates the different types of learning which occur for students for whom the gap is large. For example, parallel collateral learning occurs when a student learns science concepts but does not allow them to interact with their cultural knowledge and so holds their culture and science separate and parallel. The difference in the home and school cultures is understood as coming from two different world-views: science is based on the Cartesian duality of body and spirit (dualism) whereas aboriginal cultures are based on monism (Onwu & Mosimege, 2004). This difference in world views is recognised in the current South African Natural Sciences curriculum: “One of the differences between modern science (and technology) and traditional, indigenous knowledge systems is that they have their origins in different world views” (Department of Basic Education, 2011a, p. 21).

Teaching about the Nature of Science and argumentation are both in part intended to help learners understand what scientists do. An earlier innovation with the same intention, and which has greater currency in curricula in English speaking countries than any of the above innovations, is inquiry-oriented science (Minner, Levy, & Century, 2010). This affords learners the opportunity of ‘doing’ science through investigations instead of only learning about it. One of the three Specific Aims for the South African Natural Sciences curriculum is in line with this trend:

> **Specific Aim 2: Investigating phenomena in Natural Sciences** Learners must be able to plan and carry out investigations as well as solve problems that require some practical ability. This ability is underpinned by an attitude of curiosity and an interest in wanting to find out how the natural world works. (Department of Basic Education, 2011a, p. 18).

Inquiry-oriented science builds on the 1970s Nuffield Science programme in the United Kingdom which emphasised practical work in science (Fensham, 1988), but the emphasis is on inquiry, rather than on following recipe-type instructions. Science education researchers have also considered learning outside the classroom, for example on museum and field visits, which often gives learners a view on the 'doing' of science (Braund, 2004).

Research into the above innovations has tended to focus on the extent to which teachers are implementing the innovation (e.g. Bianchini, Johnston, Oram, & Cavazos, 2003; Roehrig & Luft, 2004). The limitations of these studies are that they create simplistic binaries: teachers who are implementing particular innovations are deemed good, while those who are not are deemed less competent. While all of these curriculum innovations have achieved positive results in research settings, and some have been shown to be complementary to each other, all take time to implement properly and so they compete for the limited time available in science classrooms. They compete with each other as well as with the imperative teachers face to 'cover' a significant volume of prescribed science content knowledge. However the Erickson (2000) book I mentioned above does not acknowledge the conflict between these different voices.

But two subsequent books for science teachers do. The first is entitled *Dilemmas of Science Teaching* (Wallace & Louden, 2002), and acknowledges that teachers face real dilemmas in regard to the curriculum innovations above:

> Teachers want students to understand that the knowledge of science is conditional and constructed *and* they want students to know about the canonical explanations found in school science textbooks. Teachers want students to understand that scientific work is a passionate and non-linear activity *and* they want students to be able to follow the protocols of writing up lab reports. (p. 1).

This book is structured around stories written by science teachers about dilemmas they face, with science education researchers bringing their lenses to bear on these stories. The second book is entitled *Analysing Exemplary Science Teaching* (Alsop, Bencze, & Pedretti, 2005). This book also starts from stories written by teachers, but this time the stories are about lessons they consider exemplary. Different science education experts then bring their respective lenses to bear on the stories. These lenses include most of the lenses which I have described above, as well as lenses from education research which are not specific to science: affective factors, use of technology, inclusivity, and social justice. At the outset the editors question the notion of 'exemplary teaching': "we adamantly reject the very notion of an educational blueprint, a definitive guidebook for teaching success" (p. 4). Instead, drawing on Bruner, they see the narratives of teachers as embodying "complexity and pragmatism; a very different representation of effective practice than an atomised list of teacher competences" (p. 3).

This shift in thinking about good teaching has large happened this century, but Wildy and Wallace (1995) report how their beliefs about the value of active learning were challenged by watching a good science teacher who had tried out learner-centred approaches, found they did not work for him, and so reverted to his previous pattern of teacher-centred lecture-style lessons. They conclude that "the constructivist literature, as we and many of our colleagues have understood it, is inadequate because it presents a singular view of good teaching and learning" (p. 154). They present different criteria for good teachers, which include "have the confidence to make their own judgements about interpreting curriculum reforms" (p. 152) and "recognise and respect their students' agendas" (p. 153).

Wildy and Wallace's recognition of the importance of learners' agendas has resonance with Brousseau's didactic contract (see section 2.1.3), i.e. the usually tacit expectations which a teacher and her class have about their own and each other's roles in the classroom (Brousseau & Balacheff, 1997). In the South African context, respect is central to traditional African culture (Khupe, Keane, & Cameron, 2012). One way in which learners show respect is by keeping quiet in the presence of their elders and not asking them questions (Clark & Linder, 2006; Khupe et al., 2012). Harkness et al. (2007) explored cultural understandings of what constitutes an ideal learner in western cultures, and report that there are significant differences, based on cultural understandings of good children. For example, Spanish traditional values favour obedience and respect. The didactic contract of classrooms in cultures where respect is central is that the teacher's job is to present information and the learners' job is to absorb that information respectfully. In such a contract, the asking of questions or in any way challenging the teacher does not make sense. Thus what counts as good teaching needs to take into account local cultural contexts. Moreover, any curriculum innovation requires a teacher and her learners to renegotiate the didactic contract, which takes time and effort.

The idea that there is no blueprint for teachers has also gained traction outside of science education. Darling-Hammond and Bransford (2005), in the introduction to their book *Preparing teachers for a changing world: what teachers should learn and be able to do,* make the claim that “There is no one right way to behave as a teacher” (p. 5). As far back as 1992 Morrow (2007) noted his own and other teachers’ burnout through trying to live up to the image of an ideal teacher presented in South African teacher education programmes, while teaching large classes. He suggested a definition of teaching as ‘organising systematic learning’ with the recognition that this may take very different forms in different contexts. Maja et al. (1999) looked for patterns between South African teachers’ instructional approaches and grade eight learners’ performance in mathematics and concluded “The key finding of this study is that method does not seem to be as important as meaning during a lesson” (p. 128 of full report). Palmer (1997) argues that “good teaching cannot be reduced to technique” and elaborates:

> If good teaching cannot be reduced to technique, I no longer need suffer the pain of having my peculiar gift as a teacher crammed into the Procrustean bed of someone else's method and the standards prescribed by it. That pain is felt throughout education today as we insist upon the method du jour – leaving people who teach differently feeling devalued, forcing them to measure up to norms not their own. (p. 16).

In Palmer’s view, good teaching is centred neither on the teacher nor the learner, but on the subject matter content, with the integrity of the teacher central. This concurs with Wallace’s (2005) analysis of good science teachers’ accounts of lessons they considered exemplary. He found that there is an “underlying moral dimension” (p. 181) in teachers’ accounts and that the science content of a lesson is central to teachers’ concerns.

Variation theory (Marton, Runesson, & Tsui, 2004; Runesson, 2006) offers a view of good teaching which focuses on the subject matter content. According to variation theory, a person can only discern a feature or quality of something if she is aware of how that feature or quality could vary. For example, to discern blue, one needs to have experienced things which are not blue. To understand the concept of frame of reference, one needs to encounter different frames of reference. It follows that good teaching is that which affords learners the opportunity to experience variation in each of the critical features of the subject matter, one critical feature at a time.

Twenty five years ago, Fensham traced the history of science education and commented:

> we would be foolish not to recognise that we now know that effective science education in many of its aspects is much more difficult to achieve than the reformers of the 1960s ever dreamt. (1988, p. 5).

This statement still holds true. In this section I have asked what counts as good science teaching, and conclude from the competing voices described above that the notion of 'good science teaching' is contested. In addition to the fundamental tension between 'science for scientists' and 'science for all', the curriculum innovations of teaching about the Nature of Science, teaching argumentation, valuing IKS and acknowledging different worldviews, and inquiry-oriented science compete for the limited time available in the science classroom. In addition there is variation in individual teachers, their contexts and their learners' agendas, and these differences are critical. What works in one context with a particular teacher and her learners may not work in a different context, although there is agreement that the subject matter content of lessons is important. In summary, rather than aiming for 'best practice' in science education, we should instead aim for appropriate practices in diverse contexts.

Thus it is appropriate to research teaching across the diversity of South African contexts, looking for examples of good practice appropriate to particular contexts. As mentioned in the introduction to this thesis, actual classroom practice in the South African context is under-researched. Thus this research project looks at the classroom practice of eight teachers, across a diversity of South African classrooms. My first and second research questions look respectively at the form and content of science lessons. In addition, instead of researching whether teachers are implementing a particular curriculum or innovation, I use a grounded approach to answer my first research question, thus creating space for different manifestations of 'good teaching'.

The view that what counts as good depends on context sits well with a complexivist view of education but poses a challenge for teacher education. If 'good' science teaching is our goal, how do we reach that goal when 'good' has different expressions in different contexts? The challenge is to identify *what* teachers need to know as well as *how* they come to know it, and hence what should happen in teacher education. A complexivist understanding of teacher development hints that none of these questions is straightforward. Nonetheless they are critical and hence frame the remainder of this chapter.

2.2.6 Lesson Content – the Missing Link

In the last section I concluded that the subject matter content of lessons is central to good teaching. However research in science education has tended to ignore the science content of lessons, as has education research generally. Lijnse (2000) laments:

> As far as theorizing is concerned, science education research seems to aim primarily for a content-independent meta-position that links closely with general research in education. […] What is also almost always lacking is a description and discussion of the didactical quality of teaching/learning situations that were studied. (p. 310).

In contrast I noted in the last section that Wallace (2005) concluded that good science teachers see the subject matter content of lessons as central. It seems that good teachers know that subject matter content is central to lessons, but education research tends to have a blind spot for lesson content, focusing instead on form. Where education research does comment on content, it typically does so superficially. Why does research on teaching tend to have a blind spot for the subject matter content of lessons? In this section I will explore some possible answers to this question.

However I first want to make what I see as an important distinction between the subject matter content of a lesson and the subject matter knowledge (SMK) of a teacher. I find that these two are easily conflated and so it is important to be clear about the distinction. I noted in section 2.2.4 that teachers do not simply present knowledge but rather act on it some way, for which I have used the term transformation. Thus the didactic offering of a teacher is not a simply a replica of the teacher's SMK. Rollnick et al. (2008) make the distinction between domains of teacher knowledge and manifestations of teacher knowledge. Furthermore Adler, Slonimsky, and Reed (2002) criticise the assumption that a teacher's SMK can be inferred from her lessons. Although the teachers in their study increased in SMK, their results "suggest that there is no *simple* correlation between changes in teachers' subject knowledge base and changes in the overall quality of their teaching" (p. 8).

How then does education research tend to miss the subject matter content of lessons? One way in which education research has tried to improve teaching is by observing good teachers (McComas, 2005). Because good teachers deliver good subject matter content in their lessons, the subject matter content becomes taken for granted. Instead what is noticed is the form in which the content is packaged. Research questions in education are likely to be based on perceived problems, so if the subject matter content of lessons is not seen as a problem, then research doesn't address it.

In the USA, the high attrition rate of novice teachers is seen as a problem: novice teachers leave the profession at a far greater rate than experienced teachers in the context of existing shortages of teachers (Patterson, Roehrig, & Luft, 2003). The solution to this problem is seen to be twofold: mentoring of novice teachers and understanding their experiences. Thus recent science education research has investigated the efficacy of different approaches to mentoring (e.g. Chubbuck, Clift, Allard, & Quinlan, 2001; Heider, 2005; Luft, 2009) and tried to understand the constraints and difficulties which novice teachers face (e.g. Adams & Krockover, 1997b; Brickhouse & Bodner, 1992; Chubbuck et al., 2001; Flores, 2006; Patterson et al., 2003).

Another perceived problem is that of curriculum implementation. The previous section described the major curriculum innovations in science education. Since these innovations are about the form of science lessons, the form has come up for scrutiny, rather than the science content. When changes in curricula are about form rather than content, the focus of research on curriculum implementation is likewise on form rather than content. Shulman (1986) blamed curriculum emphasis on form back on education research: policymakers formulate 'evidence based' standards from education research findings, which are typically about the form of teaching. His intention in focussing on Pedagogical Content Knowledge (PCK), discussed in the next section, was a move back to lesson content.

However PCK research stops short of lesson content: the PCK movement looks instead at the specialised knowledge which teachers need in order to transform subject matter content for teaching, while assuming that the subject matter content is sound. For example Loughran, Mulhall and Berry's (2004) 'Content Representations' of PCK include content in the form of 'big ideas', but they have not critiqued the big ideas which teachers use. Their goal has been the uncovering of knowledge rather than critique thereof. Similarly, phenomenographers have developed a method for critiquing the transformation of subject matter content, using variation theory to consider variation in the ways of seeing the critical features of the subject matter which are made available to learners (Marton & Tsui, 2004). However both the PCK researchers and the phenomenographers work from the assumption that the untransformed lesson content is sound. This appears to be based on the taken-for-grantedness of teachers' SMK in developed countries (discussed in section 2.3.2).

In South Africa, teachers' SMK is not taken for granted (see section 2.3.2) and PCK researchers recognise that the foundation of SMK on which PCK is built needs to be solid (Rollnick et al., 2008). Yet research has also been shaped by a curriculum which has foregrounded form. As described in section 1.4.1, the school curriculum was officially 'outcomes based' until recently. This curriculum regarded the subject matter content of a lesson as a means to an end: the outcome of education was considered to be skills rather than subject matter content (Department of Education, 2002). In addition there was emphasis on form, with learner-centred teaching required. These emphases are reflected in some guides written for South African student teachers which ignore or underplay the role of teachers' subject matter knowledge in teaching (Rusznyak, 2008). The paradox is that while teachers' SMK was recognised to be often inadequate, there was a move away from the centrality of content in teaching. Jansen (1998) predicted early on that this would have disastrous consequences. Allais (2010) argues that an outcomes-based curriculum is fundamentally flawed because "outcomes-based education conflates pedagogy and curriculum" (p. 33). Thus was lost in pedagogy, and hence in research which focused on curriculum implementation. At the same time democratization of the classroom meant that the professional authority of teachers as sources of knowledge was unintentionally undermined (Slonimsky, 2010).

In summary, I see research as missing lesson content in two ways: firstly by taking it for granted at secondary level, particularly in first world settings where teachers are better qualified. This is confounded by the frequent conflation of lesson content and teacher SMK, based on the assumption that teachers' SMK translates easily into lesson content. Second, research responds to curriculum innovations, which have tended to be about form rather than content. The paradox inherent here is that what counts as 'best practice' is disputed, as pointed out in the previous section.

There are two exceptions to the 'content blind spot' rule which bear mention. Akerson (2005) explicitly critiques the science content of three grade two science lessons, as constructed in the conversations of the lessons. Similarly Davis (2011) considers the validity of the subject matter content of a grade eight mathematics lesson. Overall though, there is a gap in science education research in regard to the subject matter content of lessons. My second research question addresses this gap by asking about the quality of the subject matter content of some of the lessons I observed.

2.3 What Do Teachers Need to Know?

Having explored what teaching is, and in particular what good science teaching might be, I now ask what teachers need to know in order to teach. In regard to this question , Shulman (1987) identified seven domains of knowledge which teachers draw on in the act of teaching: four general domains – general pedagogical knowledge, knowledge of their learners, knowledge of context, and knowledge of educational purposes and values – and three domains of subject specific knowledge: SMK of the topic at hand, curriculum knowledge and PCK. Shulman mostly referred to these as different ‘categories’ of knowledge, but I am choosing the term ‘domain’ instead, as I think it is more appropriate and anyhow Shulman also provided other categories of knowledge (see section 5.1). Shulman defined PCK as “subject matter knowledge for teaching” and “the ways of representing and formulating the subject that make it comprehensible to others” (1986, p. 9).

Table 1: What do teachers need to know?

Dimension	Shulman (1987)	Feiman-Nemser (2008)	Hammerness et al. (2005)
Knowledge for teaching	SMK Curriculum knowledge Knowledge of learners Knowledge of context	Know	Understanding Conceptual tools
	Pedagogical knowledge PCK	Act	Practices Practical resources
Conception of teaching		Think	Dispositions
Teacher identity		Feel	Vision

While Shulman’s domains of knowledge have served a useful purpose in highlighting that there is subject-specific teaching knowledge that teachers need in addition to SMK and general pedagogical knowledge, these domains do not address two central dimensions of teacher knowing: conceptions of teaching (comprising beliefs and intentions, see section 2.2.1) and teacher identity. I will thus present two other ways of framing what teachers need to know, which address these dimensions. Table 1 gives a comparison between the three frameworks describing what teachers need to know. However the different authors draw their boundaries between constructs in different ways, and so the mapping of Table 1 is not exact.

Feiman-Nemser (2008) summarises what teachers need to learn using four actions: learning to know, act, think and feel like a teacher. Knowing like a teacher relates to Shulman's domains of knowledge, being "the different kinds of knowledge that good teaching depends on" (p. 698). Acting like a teacher requires a "repertoire of skills, strategies and routines and the judgment to figure out what to do when" (p. 699). This is related to Shulman's domains of general pedagogical knowledge and PCK, but the emphasis is on 'knowing how' rather than 'knowing that', in line with an adaptation of PCK to 'Pedagogical Content Knowing' (Cochran, DeRuiter, & King, 1993). 'Thinking' like a teacher includes both a teacher's beliefs and the metacognitive reflection which effective teachers engage in. Beliefs are part of conceptions of teaching. Metacognitive reflection relates to Schon's (1987) reflection-in-action and reflection-on-action which are distinctive of professionals. Reflection-in-action happens during teaching, and refers to the many decisions teachers make in the process of teaching, in response to classroom dynamics. Reflection-on-action happens after the act of teaching, as teachers reflect on what happened during a lesson and decide how to respond in subsequent lessons. The practice of reflection upon practice may lead to greater awareness of conceptions of teaching and identity, and hence develop these dimensions. Feiman-Nemser's 'feeling' like a teacher refers to the emotional and identity work which teachers need to do, particularly as they face disjunctures between the kinds of teachers they want to be and the realities of their contexts.

Hammerness et al. (2005) offer a similar framework for thinking about teacher learning. This framework has five dimensions: understanding, practices, vision, dispositions and tools. The 'understanding' dimension relates to Shulman's knowledge domains of SMK, general pedagogical knowledge and knowledge of context and learners. The 'practices' are Feiman-Nemser's 'acting' like a teacher. 'Dispositions' are "habits of thinking and action – about teaching, children, and the role of the teacher" (Hammerness et al., 2005, p. 387). Dispositions bring to mind Bourdieu's notion of habitus (see section 2.1.3), suggesting an acculturation process so that teachers take up their role in the education system smoothly. I suggested in section 2.1.3 that conceptions of teaching are an aspect of habitus. Thus dispositions relate to conceptions. A 'vision' comprising "images of the possible" (p. 386) is central in Hammerness et al.'s model, and vision is an aspect of identity (see section 1.2.1). The 'tools' dimension of Hammerness et al.'s model contains two disparate aspects, conceptual tools and practical resources, which I think should have been accommodated in 'understanding' and 'practices' respectively, and thus I have placed them accordingly in Table 1. Hammerness et al.'s framework emphasises that all of this learning happens in a particular community and context.

In summary, the answer to the question 'what do teachers need to know?' is that they need to know the 'what' of SMK and curriculum knowledge, and once situated in particular teaching contexts, they need knowledge of those contexts and of their learners. They need the know-how of general pedagogical knowledge and PCK. They need conceptions of teaching and professional identities in the contexts in which they teach. In addition they should be able to engage in reflection – part of Feiman-Nemser's 'thinking' and Hammerness et al.'s 'dispositions' – which will help develop their conceptions of teaching and their identity. In other words, what teachers need to learn is complex and multifaceted.

Which of these aspects is more important? I argued that beliefs inform behaviour (section 2.2.2), thus a teacher's conception of teaching (including beliefs) informs her classroom practice. A teacher's knowledge of a particular classroom strategy is accompanied by a belief about the efficacy of that strategy. Thus beliefs shape the saliency of knowledge. In this sense knowledge sits subordinate to beliefs and hence to conceptions. I see the same as being true of teacher identity: teaching knowledge needs to accord with a teacher's identity for it to be useful. This does not mean that conceptions and identity are more important than knowledge: knowledge is critical, but it depends on conceptions of teaching and teacher identity for its usefulness. I note that in practice the boundary between knowledge and belief is fuzzy: some propositions are contested as to whether they qualify as knowledge or beliefs because what functions as knowledge for one person may be a belief for another.

Of course anyone who teaches will have some knowledge, a conception of teaching and an identity as a teacher, even without training. But the quality of teaching is dependent on the richness of the knowledge, conceptions of teaching and identity of a teacher. The challenge for teacher education is to develop such richness. I will look in section 2.5 at ideas of what should happen in teacher education, after exploring how teachers learn in section 2.4. However I first want to look at research into PCK, SMK and teacher identity since they together with conceptions of teaching are central to my study, and I have already described research into conceptions of teaching (section 2.2.1).

2.3.1 Pedagogical Content Knowledge

Many researchers have taken up PCK research enthusiastically, but it is used inconsistently in different contexts (D. L. Ball, Thames, & Phelps, 2008; Gess-Newsome, 1999a; Kind, 2009; Park & Oliver, 2008). Gess-Newsome (1999a) classified the various interpretations of PCK as Integrative, Transformative or somewhere in-between, and Kind (2009) showed ten years later that this classification still works. Integrative models do not regard PCK as a separate knowledge domain, but rather regard PCK as what happens in classrooms when teacher use the other domains of knowledge. An example of such a model is Bishop and Denley's (2007) metaphor of PCK as a spinning top, where Shulman's other six domains of knowledge are different colours on the top which combine to produce 'white' PCK when the top is spun. Such models regard SMK as part of PCK.

Transformative models regard PCK as the transformation of SMK, pedagogical knowledge and contextual knowledge into a new form of knowledge. These models see PCK as a separate knowledge domain which does not include SMK. This is the view of PCK which I use, since I see PCK as comprised of elements which are distinct from SMK and general pedagogical knowledge. I see PCK as comprised of knowledge of learner prior conceptions and alternative conceptions, knowledge of instructional strategies and materials; knowledge of useful representations and metaphors, knowledge of difficulties students have in comprehending the content, and curricular saliency (Geddis & Wood, 1997; Loughran et al., 2004; Shulman, 1986). Curricular saliency is "the importance of various topics relative to the curriculum as a whole" (Geddis, Onslow, & Beynon, 1993, p. 588). PCK is more than the sum of its parts (Abell, 2008). These elements are largely topic specific. In other words, PCK is knowledge of students' alternative conceptions and difficulties relating to a particular topic, and knowledge of instructional strategies for that topic. But some instructional strategies cut across a subject, for example using the three levels of representation in chemistry, i.e. macroscopic, microscopic and symbolic (Treagust, Chittleborough, & Mamiala, 2003).

Some researchers include curriculum knowledge in PCK (Park & Oliver, 2008) but I contend that curriculum knowledge is available to anyone with sufficient SMK to read and make sense of a curriculum, whereas curricular saliency is peculiar to teachers and hence is part of PCK. Many researchers include 'orientation to teaching the subject matter' as an overarching aspect of PCK. Friedrichsen, van Driel, and Abell (2011) show that there is consensus amongst researchers that this orientation is a set of beliefs about the purposes of teaching. I have argued that beliefs about teaching are part of conceptions of teaching (see section 2.2.2), and indeed Friedrichsen et al. use the word 'conceptions' interchangeably with 'beliefs'. Moreover conceptions of teaching are often expressed in terms of the purpose of teaching (section 2.2.1), consistent with Friedrichsen et al.'s definition of orientation. Thus I am excluding 'orientation to teaching' from PCK, since I am taking knowledge (such as PCK) and beliefs as distinct. The fact that these 'orientation' beliefs are seen as overarching concurs with the positioning of knowledge as subordinate to beliefs (section 2.3). However Friedrichsen et al. also include some of the other conceptions mentioned in section 2.2.3 as part of their definition of science teaching orientations, i.e. they see orientation to teaching as broader than conceptions of teaching.

There has been considerable research into the PCK of both experienced and novice teachers. A tool which has proved to be useful is Loughran et al.'s (2004) Content Representation which uses various questions about the importance, difficulty and saliency of 'big ideas' to access and communicate teachers' PCK (section 2.2.6). The 'big ideas' are SMK, but the recognition that these ideas are significant and the knowledge of student difficulties and teaching strategies associated with these ideas is PCK. The fact that Content Representations have SMK as their starting point reflects that PCK is dependent on SMK. Likewise PCK builds on general pedagogical knowledge and draws on contextual knowledge – there are cultural influences on what learners have difficulties with. Thus there is hierarchy in Shulman's domains with PCK sitting above SMK, pedagogical knowledge and knowledge of learners and context. I contend that this hierarchy should not be mistaken for combination: PCK is more than a simple combination and includes distinctive aspects of knowledge.

Bernstein's (1996) recognition and realization rules are helpful in thinking about PCK. The teacher needs to achieve the realization rules of teaching in order to actually teach effectively, rather than just the recognition rules of knowing what they should be doing. A student teacher may recognise good practice in another teacher's classroom, but be unable to realise such in her own classroom. Or she may be able to use an existing inquiry-oriented activity, but not be able to produce such an activity herself in another context. So for PCK to be useful knowledge, a teacher needs to have achieved the realization rules of the PCK (Ensor, 2004). However, even if she has, this knowledge sits subordinate to her beliefs about science teaching: a teacher may have knowledge about a particular strategy, but choose not to use it because it does not fit with her conception of science teaching.

In summary, I take a transformative view of PCK, seeing it as distinct from other domains of teacher knowledge. I see PCK as comprised of knowledge of learner conceptions and difficulties, instructional strategies, and curricular saliency. I exclude SMK, curriculum knowledge and teaching beliefs or orientations from PCK. However PCK is built on a foundation of SMK, curriculum knowledge and contextual knowledge, and the saliency of PCK is shaped by beliefs about teaching which are a dimension of conceptions of teaching.

2.3.2 Subject Matter Knowledge

In order to give learners access to SMK teachers need to have adequate SMK themselves (Lotz-Sisitka, 2010). They need SMK in order to plan and to reflect on their planning (Reed, Davis, & Nyabanyaba, 2002). Thus sufficient SMK is necessary though not sufficient to teach. In this section I review some research into science teacher's SMK, though SMK has not come under the research spotlight to the same extent as PCK. I will treat SMK as something in the head of a teacher, available for recall. An alternative perspective is a sociocultural one, in terms of which:

> an individual's understanding of the concepts, theories, and ideas of a particular community is a dynamic process resulting from action in situations and from negotiating with other members of that community. (Traianou, 2006, p. 835).

From this perspective it follows that a teacher's knowledge expressed in the context of an interview or on a test is different from her knowledge expressed in the context of a lesson. While I think this perspective is valid, I will continue to talk about teachers 'having' SMK, as this provides a useful analytical way to make the distinction between the knowing of the teacher and the subject matter content constituted in a lesson.

In most American states, teachers are required to pass 'Praxis II' either for entry into teacher education programmes or else for certification as teachers. Praxis II is a multiple choice and short answer examination which tests potential teachers' SMK (Bucher, 2009). Thus in America, secondary teacher SMK is assumed to be taken care of by certification. Hence studies of teachers' SMK tend to be conducted only amongst primary school teachers. For example Burgoon, Heddle, and Duran (2011) found that 103 American primary school teachers possess alternative conceptions similar to those of learners. Luera, Moyer, and Everett (2005) concluded that American elementary teachers need sound content knowledge in order to implement inquiry-oriented lessons. Similarly O. Lee (1995) found that a middle school science teacher's limited SMK constrained her teaching strategies.

However secondary science teachers' SMK has been researched elsewhere in the world. Kind and Kind (2011) investigated the basic chemistry of about 150 British pre-service teachers and found that although they had the necessary qualifications and were mostly confident about teaching chemistry, those who had not specialised in chemistry in their degrees held alternative conceptions. Haidar (1997) investigated 173 pre-service chemistry teachers in Yemen, and found their chemistry SMK lacking in many respects. Abd-El-Khalick and BouJaoude (1997) did research with seventeen well qualified Lebanese intermediate and secondary teachers with varying experience, and found their SMK "lacking in all respects" (p. 684).

In South Africa the President's Education Initiative research project is usually cited as evidence that many secondary teachers have inadequate conceptual understanding of the subjects they teach. This project was a wide ranging conglomeration of 31 studies. The weakness of this project is that it conflated primary and secondary education. A closer look reveals that only five of the published studies looked exclusively at secondary schools. Another six studies looked at both primary and secondary schools. None of the five secondary studies explicitly mention lacks in teacher SMK. Instead Harley (1999) judged that the ten good teachers in his project, including three physical science teachers, all met the criterion "has sound knowledge of subject content." Maja et al. (1999) looked at grade eight mathematics teaching in twenty schools, and commented on better and worse teaching strategies but were silent on teacher SMK. However two studies which looked at ten schools in the rural area of Thohoyandou complained that teachers are under-qualified (Bayona & Sadiki, 1999; Onwu, 1999). The last study looked only at learner performance (Ota, 1999).

Furthermore only one of the studies which looked at primary and high schools together considered school teaching: Wickham and Versfeld (1999) looked at English teaching in four disadvantaged schools, and made no comment on teachers' SMK. The others looked at teaching African languages to teachers, using Sesotho in geography, learner progress, distance education and whole school development. So in summary, out of all the President's Education Initiative research project studies which investigated teaching in secondary classrooms, all that can be concluded in regard to secondary teachers' SMK is that teachers in Thohoyandou are under-qualified and, by inference, have poor SMK.

However this does not mean that teacher SMK is not a problem in South Africa. Lacks in teacher SMK are reflected in the many government sponsored in-service training programmes for teachers which deal with subject matter content, such as the Advanced Certificate in Education. Clark describes the content limitations of a committed teacher he worked with. He suggests that both her teacher training and subsequent in-service training have tended to be "plastering the conceptual cracks" (Clark & Linder, 2006, p. 192) of the science knowledge she acquired at school. He also reflects on her limited scientific literacy and general knowledge of science, commenting that these also contribute to the quality of science teaching. Lotz-Sisitka (2010) notes the impact of poor teacher SMK in situations where the 'vestiges of teacher memory' are the only resource which teachers use in teaching and so their inadequate SMK becomes the curriculum.

2.3.3 Teacher Identity

Apart from teacher knowledge such as SMK and PCK, education researchers are interested in teacher identity. In section 1.2.1 I noted Gee's (2000) distinction between different kinds of identities, including institution-identity and discourse-identity. Research into teacher identity in this century seems to come in three sorts. The first is concerned with Gee's institution-identity, the second and third are concerned with Gee's discourse-identity, with and without curriculum change respectively. Most studies don't use Gee's terms of institution-identity and discourse-identity, but I find the differentiation a useful one which has helped me to make sense of the body of identity research.

The first sort of teacher identity research looks at the process of beginning teachers developing an institution-identity of 'teacher' (e.g. Antonek, McCormick, & Donato, 1997; Franzak, 2002; Timoštšuk & Ugaste, 2010). These studies are concerned with how teachers come to feel like a teacher, and the struggles and contradictions inherent in the process, but are not concerned with how the identities of individual teachers differ.

The second sort considers the impact of curriculum change on teachers' discourse-identities. New curricula come with imaginings of certain kinds of teachers, and these often contradict teacher's existing discourse-identities, developed in the context of previous curricula and policies. The contradictions have been unpacked in America (Lasky, 2005; Pennington, 2007; Sloan, 2006), the United Kingdom (Woods & Jeffrey, 2002) and South Africa (Graven, 2000; Jansen, 2003; Parker, 2006). This research tends to talk about teachers' identities being threatened without spelling out what these identities actually are. These studies have resonance with other studies which look at the impact of curriculum change on teachers but are framed in terms of teacher agency rather than identity (e.g. S. J. Ball, Maguire, Braun, & Hoskins, 2011; Priestley, Edwards, Priestley, & Miller, 2012; Reio, 2005).

The third sort of teacher identity study is also concerned with discourse-identity, but without the backdrop of curriculum change. In England Smart (2008) identified three identities related to teaching style amongst sixteen novice secondary science teachers: teachers who want to use lots of practicals; teachers who want to "make science interesting exciting and relevant" (p. 10); and teachers who wanted to be like, or not like, a particular teacher they had had. Zembylas (2003b) describes the identity of an American teacher who was "enthusiastic about pedagogies that deviated from the norm" (p. 121). Sawyer (2002) looked at the development of two experienced Canadian teachers' identities, and labelled the different stages of their teaching careers. For example the English language teacher's stages were: "Year 1: imitating the act of writing", "Years 2-5: free will with poetry", and "Years 5-9: a coherent framework the kids could hang their hats on" (p. 742-743). Soreide (2006) found with five Norwegian elementary teachers that "four major constructions of teacher identity emerged: 'the caring and kind teacher'; 'the creative and innovative teacher'; 'the professional teacher'; 'the typical teacher'" (p. 536). However different from the other studies above, Soreide found all four of these identities were present in the interview data of all five teachers, with the teachers tending to align themselves with two of the identities and distance themselves from the other two identities. This may be because Soreide used discourse analysis across the data, instead of considering the data for each teacher separately. Some studies look at teachers' discourse-identities in relation to their race / culture and gender: Moore (2008) looks at three African American science teachers' identities, and Samuel and Stephens (2000) look at two black South African English teachers. These two studies found that the teachers' race / culture and gender informed their teacher identities, but do not give a clear description of these identities.

The studies of the third sort are important because, rather than just seeing identity as developing or threatened, they often describe the actual identities of different teachers', thus giving texture to the nature of teachers' identities. This is important because, as I will discuss in section 2.4.2, student teachers typically enter initial teacher education programmes with strong ideas of the 'kinds of teachers' they want to be. In order for teacher educators to engage productively with these identities, it is important to know something about the nature of teacher identities, both at the start of teacher education programmes and once teachers are in the field. However the total sample used in the studies of the third sort described above is only 29 teachers, across six countries. Only two of these teachers were South African. There is thus a need for further research which identifies and describes teachers' discourse-identities, particularly in the South African context of educational change. My third research question addressed this gap by exploring the discourse-identities of eight teachers, thus adding significantly to this corpus of research.

2.4 How Do Teachers Learn to Teach?

Having established what it is that teachers need to know, one could conclude that teacher preparation is straightforward: teach teachers what they need to know. But an understanding of education as a complex system suggests that this is not the case: a student teacher will only be able to take up what she is currently predisposed to take up due to her individual biology, history and context. Developing as a teacher is a complex process and the purpose of this section is to unpack that process. I start by considering why people become teachers. Thereafter I consider the problems of learning to teach which student teachers face, and models of the development of teachers which have emerged from research. Finally I consider the trajectory which teachers' knowledge, identities and conceptions of teaching take through different contexts.

2.4.1 Why Do People Become Teachers?

Nearly ten years ago, Hindle (2003) proposed a research agenda for teacher education in South Africa, the first item of which was research into why South Africans choose teaching as a career. Chuene, Lubben, and Newson (1999) had already answered this question with a group of 34 mathematics teachers, but I have found no subsequent research addressing this question. However the question of why people become teachers has been researched elsewhere in the world: in Taiwan (Wang, 2004), Malaysia (Azman, 2012), Australia (Manuel & Hughes, 2006; P. W. Richardson & Watt, 2006), Slovenia (Krečič & Grmek, 2005), Norway (Kyriacou, Hultgren, & Stephens, 1999), England (Andrews & Hatch, 2002; Jarvis & Woodrow, 2005; Kyriacou & Coulthard, 2000), Jamaica (Bastick, 2000; M. M. Brown, 1992) and America (King, 1993; Weiner, 1989).

Kyriacou and Coulthard (2000) classify three clusters of reasons which people give for choosing teaching: altruistic, intrinsic, and extrinsic. Altruistic reasons are about wanting to make a difference to society. Intrinsic reasons are about enjoyment and self-realisation in teaching as well as affinity to the subject being taught. People who see themselves as well suited to teaching are in this category. Extrinsic reasons are about social status and conditions of employment, such as working hours, job security and remuneration. My observation is that these three types of reasons are present in all the above mentioned studies except the Taiwanese study (Wang, 2004) which did not find altruistic reasons. However the reasons given vary according to local conditions, for example in Taiwan teachers are relatively well-paid and are accorded high social status, whereas in many countries the opposite is true. Thus it is appropriate to explore why South Africans become teachers, and, in particular, science teachers. In answering my third research question, which asks how the teachers in this study narrate their identities, I will consider the reasons they chose a science teacher identity.

2.4.2 The Learning Problem

Choosing to become a teacher is the first step in becoming a teacher. Thereafter a teacher needs a qualification which certifies that she has learnt to teach. Hammerness et al. (2005) summarise three problems in learning to teach. The first of these is Lortie's 'apprenticeship of observation', which "requires that new teachers come to think about (and understand) teaching in ways quite different from what they have learned from their own experience as students" (p. 359). The second is what they call 'the problem of enactment' which is the problem of putting knowledge into action. The third problem is what they term 'the problem of complexity', which is that teaching "requires integrating many kinds of knowledge and skills in making judgements about how to pursue multiple goals with learners who have diverse needs" (Darling-Hammond, Hammerness, Grossman, Rust, & Shulman, 2005, p. 390). The second and third problems refer to the enormous complexity of teaching to which I referred in the introduction to this chapter. In this section, I will explore the first problem, and the ways in which research with novice teachers talks to it.

The apprenticeship of observation means that students enter teacher education programmes with their own conceptions of teaching, which include their beliefs about teaching (see section 2.2.2 for the relationship between conceptions and beliefs). These initial conceptions of teaching tend to be resilient to change. Koballa et al. (2005) found the conceptions of teaching held by three novice teachers to be resistant to change despite instruction. Glass (2007) notes that while a student she studied gained some technical skills, his beliefs were unchanged. Rusznyak describes a passionate and hard-working student South African B Ed student whose beliefs about teaching:

> rendered his university tutors' attempts at guidance largely ineffective. This in turn frustrated this particular student teacher, as he struggled to understand what was expected of him. (2009, p. 30).

Samuel describes South African students teachers' conceptions of teaching as "deeply rooted in their own personal biographies" (2003, p. 265). Calderhead and Robson (1991) found that the conceptions of teaching held by twelve primary school teachers had a big influence on how they interpreted their teacher training. However some studies find that teacher education programmes do have some effect on student teachers' conceptions (BouJaoude, 2000; Fletcher & Luft, 2011; Hobden, 2000; Skamp, 1995). Wood (2000) found that getting student teachers to research learners' conceptions of SMK shifted their conceptions of teaching significantly towards learner-centred conceptions.

The apprenticeship of observation also means that students start teacher education programmes with their own teacher identities. Some researchers refer to teacher identity as image of self-as-teacher. This is consistent with Wenger's observation that "We often think about our identities as self-images" (1998, p. 151) although he argues for identity involving more than self-image because of the participation aspect of his conception of identity. Eick and Reed (2002) explored the images which some American student teachers had of themselves as teachers, and found that the images with which students enter a teaching course are resilient, so that only students who have 'inquiry-oriented' identities at the start are likely to embrace the use of inquiry-oriented methods in the classroom. Eick and Reed note that both positive and negative role models count – there are teachers students want to emulate and teachers students want to avoid being like. This is confirmed by Sexton (2007) who interviewed 35 Australian students entering a teacher education programme, and by Samuel (2003) who found that poor primary and secondary experiences of learning English encouraged South African students to become English teachers.

In summary, student teachers enter teacher education programmes with conceptions of teaching and identities of themselves as teachers which are resilient. These conceptions and identities are the lenses through which they view the offerings in a teacher education programme. Kagan concludes:

> The personal beliefs and images that pre-service candidates bring to programs of teacher education usually remain inflexible. Candidates tend to use the information provided in course work to confirm rather than to confront and correct their pre-existing beliefs. Thus, a candidate's personal beliefs and images determine how much knowledge the candidate acquires from a pre-service programme and how it is interpreted. (1992b, p. 154).

Similarly Smart (2008) reports that the identities of British student teachers affected how they saw the relevance of their courses. Thomas and Pedersen observe that American students:

> come to our classes to build a house, and they enter the classroom having already framed, roofed, and finished their house, we can influence the color scheme and the floor coverings – but can do little to change their prebuilt house. (2003, p. 320).

Kagan explains the resilience of students teachers' conceptions and identities from a constructivist perspective: as with all learning, people have preconceptions or, in Piaget's (1985) terms, existing cognitive structures. It is easier to assimilate new information into these existing cognitive structures rather than do the work of changing cognitive structures – 'accommodation' in Piaget's terms. However accommodation can be precipitated by cognitive dissonance. This implies that pre-service teachers' conceptions and identities are shaped far more by their experiences in school classrooms than by any theory they encounter. This explanation is consistent with the complexivist theory of enactivism: an individual's capacity to learn is related to her individual history and context. Both history and context are reflected in Trigwell and Prosser's constitutionalist model of student learning, illustrated in Figure 6 (p. 30). The prior experience of a student is her individual history, and her perception of her current situation is her current context from her point of view.

Teacher educators might decry these initial conceptions and identities, but Kagan argues that they are essential: "without a clear image of self-as-teacher, the reconstruction process is perverted, and the novice may be doomed to flounder" (1992b, p. 155). Anderson, Smith and Peasley (2000) see potential in *any* initial belief concerned with learner experience – for example, that learners should have fun – they argue that this has the potential to be a seed for developing a learner-centred approach. This is similar to the way unscientific alternative conceptions can be a starting point for learning scientific conceptions.

2.4.3 Stages of Development

If teachers' initial conceptions of teaching and identities are the starting point for learning to teach, how do they develop as teachers? Figure 8 shows three of the 'stage' models put forward as a description of how teachers develop. I have aligned stages which I see as similar in Figure 8, although there are different emphases in the different models. The first model is Berliner's (1988), which consists of five stages: novice, advanced beginner, competent, proficient and expert. The novice relies heavily on rules of practice while learning from experience. The advanced beginner becomes more strategic in her use of the rules she has learnt – realising there are situations where the rules should be broken. The competent performer is aware of the choices she has and takes responsibility for what happens in her classroom. The proficient performer has advanced pattern recognition skills, and relies more on intuition. Not all teachers reach the level of the expert, who makes her performance seem effortless.

The second model is Kagan's (1992b), which draws from her review of forty qualitative studies of pre-service and novice teachers. A student teacher comes to a teacher education programme with 'beliefs about teaching and learning', and an 'image of self-as-teacher'**.** Beliefs about teaching are part of her conception of teaching (section 2.2.2), and beliefs about learning are part of her conception of learning. Her image of self-as-teacher is her identity as a teacher. Her conceptions and her identity are shaped by her personal history, in particular 'exemplary teachers' in her own schooling and her 'image of self as learner'. The student teacher then needs to accomplish three developmental tasks. The first is to reconstruct her image of self-as-teacher, i.e. to do identity work. This stage is precipitated when she first encounters discipline problems and thus is influenced by her changing, less idealistic picture of learners – in other words she needs to negotiate her identity in the classroom context. The second task is to develop 'procedural knowledge': "standard routines that integrate instruction and management" (Kagan, 1992b, p. 15). Once these are in place she can move on to the third task which is to focus on learners' experience and learning. In these three stages, the student teacher's focus shifts from herself, to teaching, and then to learning.

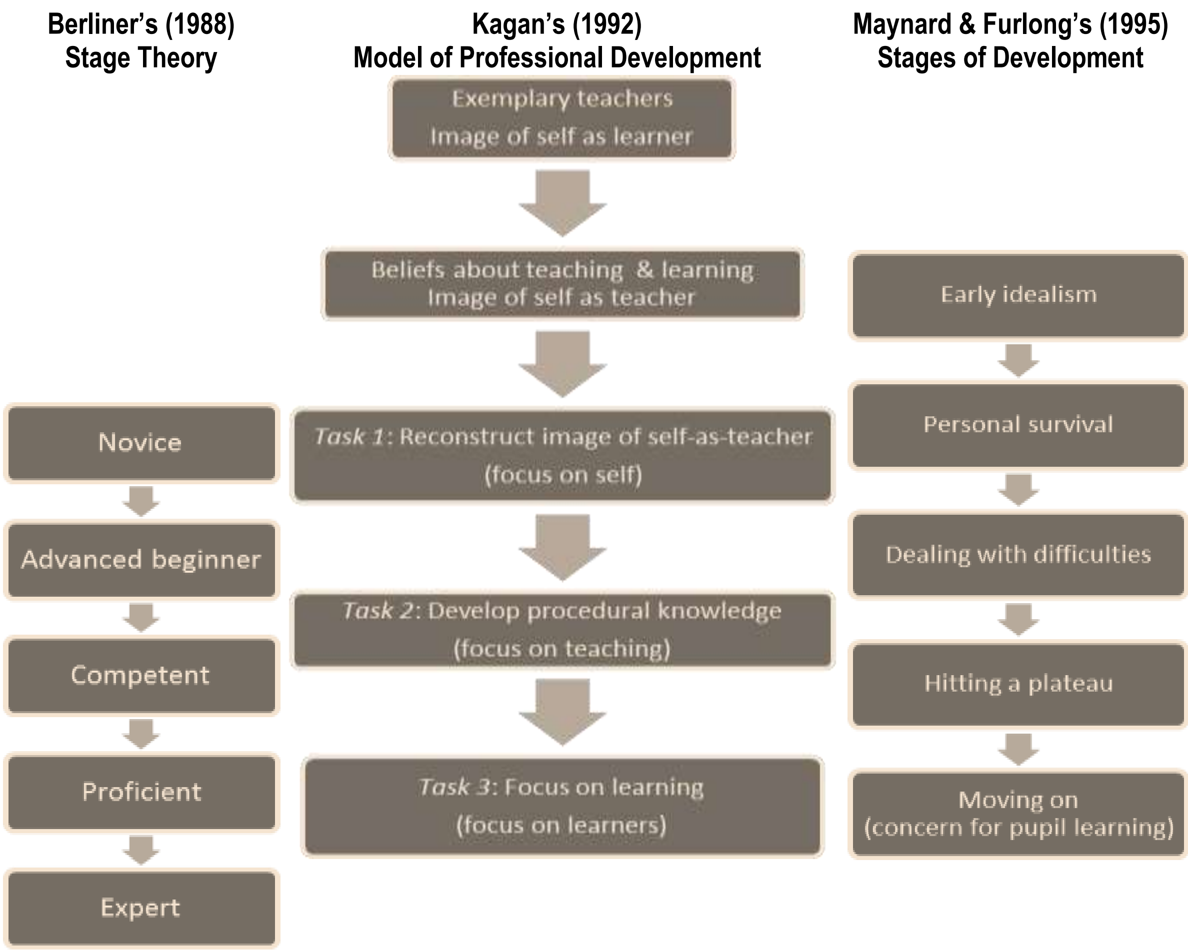

Figure 8: Models of teacher development

Kagan's tasks fit well with Maynard and Furlong's (1995) Stages of Development which are illustrated on the right side of Figure 8. The 'early idealism' with which a student teacher enters a programme is replaced by a quest for 'personal survival' as she encounters the realities of classrooms. As Kagan puts it, "most novices become obsessed with class control, designing instruction, not to promote pupil learning, but to discourage disruptive behaviour" (1992b, p. 155). Maynard and Furlong note that a student teacher learns to 'deal with difficulties' by imitating the practice of more experienced teachers, and so 'hits a plateau' where Kagan's procedural knowledge is in place and she feels she is teaching well. With encouragement from a tutor, she may be ready to 'move on' – to focus on learners' learning and experiment with new approaches.

How do these stages correspond with conceptions of teaching? Both Kagan's and Maynard and Furlong's models involve a shift from focusing on self to focusing on learners. I noted earlier that higher order conceptions are typically learner-centred, whereas lower order conceptions are teacher-centred. Thus there is a correspondence between later stages and higher order conceptions of teaching, and earlier stages and lower order conceptions of teaching. Higher order conceptions are inclusive of lower order conceptions, and in a similar way the learning achieved in earlier stages is held onto in later stages. The conceptions research does not represent developmental stages, but nonetheless allows that teachers may develop to include higher order stages in their repertoire of conceptions.

These stage models are appealing, but they have been criticised. Hammerness et al. (2005) claim that they were based on research "conducted at a time when most teacher education programs were fairly weak interventions" (2005, p. 381) and so underestimate what it is possible to achieve in teacher education. Rusznyak (2008) found that none of the 66 South African student teachers in her doctoral study progressed through all of Maynard and Furlong's stages. She concludes that the Maynard and Furlong model "describes only one possible developmental trajectory out of numerous possibilities" (p. 407), and puts forward a model comprising five facets, illustrated in Figure 9. Maynard and Furlong's stages only cover two of these facets, classroom management and teaching strategies. The additional facets involve the teacher's own knowledge and understanding of content, her preparation of lessons, and how she monitors learning in her classroom. Teachers do not proceed at the same rate through all five facets (as assumed in Maynard and Furlong's model), although there is a hierarchy within each facet.

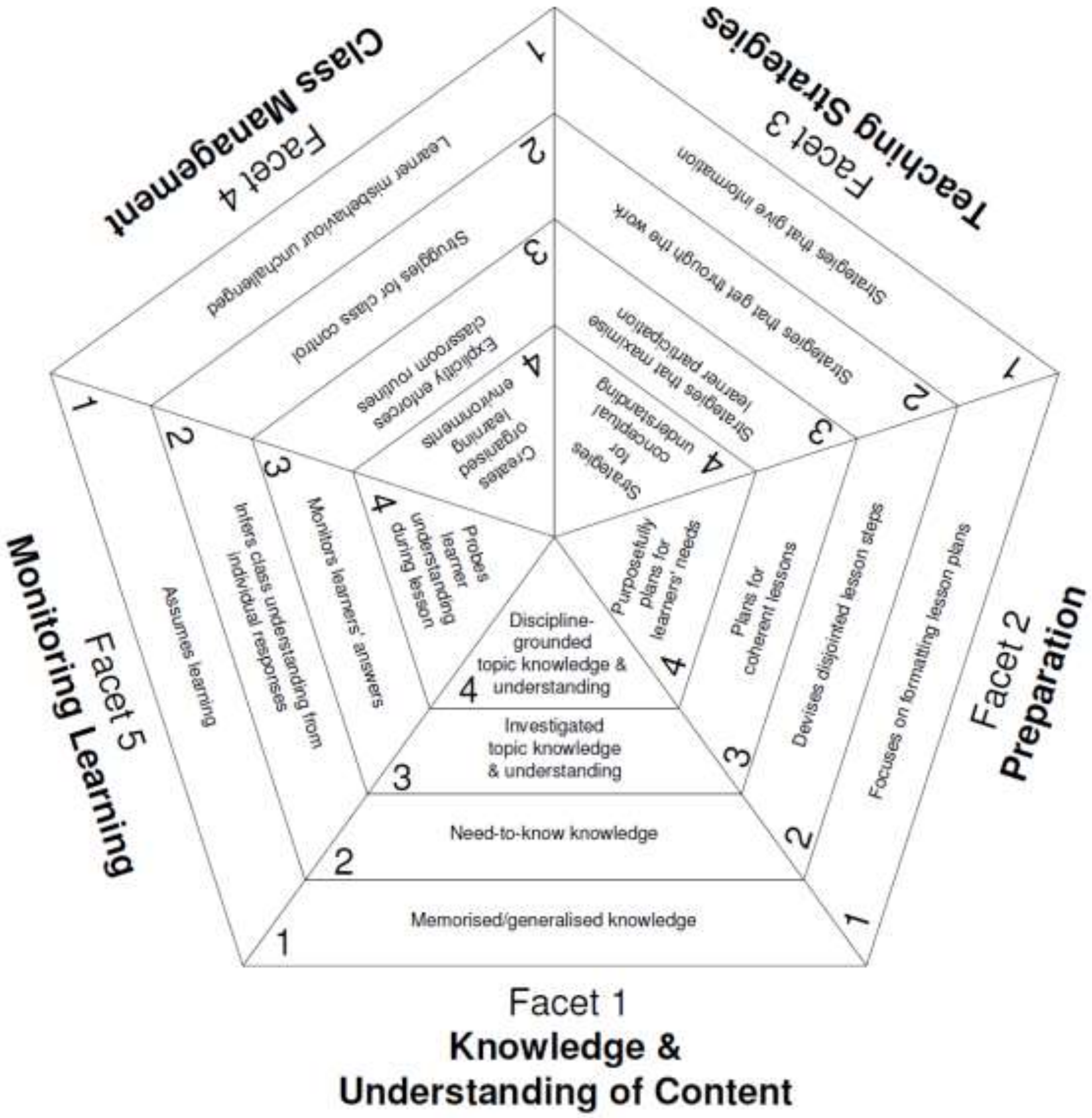

Figure 9: Levels of teaching practice across five facets (Rusznyak, 2008)

Rusznyak also found that a teacher's development is context dependent, so that teachers may appear to regress in more challenging contexts. Feiman-Nemser explains how student teachers' contexts "enable and constrain their adoption and use of new knowledge and practices and their on-going learning" (2008, p. 701). Studies that follow teachers into their first year of teaching reach the same conclusion about the dependence of development on context. Fletcher and Luft (2011) found that five science teachers who had moved towards learner-centred beliefs about teaching in an initial teacher education programme shifted back to teacher-centred beliefs about teaching during their first year of teaching. Similarly Simmons et al. (1999) found that over their first three years of teaching, science teachers on average became less student-centred in their beliefs about teaching. In South Africa, most of a group of novice mathematics teachers said they found student-centred teaching difficult and so many preferred to use a chalk-and-talk method, whereas none of a similar cohort of pre-service teachers preferred chalk-and-talk methods. Thus:

> rather than conceptualizing the process of teacher developments as moving lockstep through a series of universal stages (regardless of setting or experiences), teacher educators are now emphasizing the interrelationships between teachers' *learning and development* and the *context* of teachers' learning. (Hammerness et al., 2005, p. 389).

The effect of contexts on conceptions is consistent with the phenomenographic position that a conception is not some independent entity in the head of a person, but is rather constituted in the relationship between a person and a phenomenon (Marton, 1981), in this case the phenomenon of teaching in a particular context.

Novice science teachers may also exhibit a significant gap between their espoused beliefs about teaching and their classroom practices. They may claim to be learner-centred while observers classify their classroom practice as teacher-centred (Mellado, 1998; Simmons et al., 1999). This may be because they have learnt the rhetoric of learner-centred practice in their teacher education programme, without being able to implement it in practice. In Bernstein's terms, they may have the recognition rules of learner-centred practice but not the realization rules (section 2.3.1). However they may also be well aware of the conflict between what they see as desirable, and what is possible within the constraints of their contexts, as Brickhouse and Bodner (1992) describe with a second year science teacher. This relates to earlier discussion of the distinction phenomenographers make between beliefs and intentions, and the constraints which contexts place on behaviour (section 2.2.2).

A question which then arises is: what counts as learning in novice teachers? How do we recognise when learning or growth occurs? Kagan (1992b) proposes that growth consists of greater metacognition, pupil knowledge, awareness of pupil learning, procedural knowledge and problem solving skills. Anderson et al. (2000) suggest two indicators of growth: changes in thinking and the trying out of new approaches, even if unsuccessfully.

Changes in thinking are important even if students are not yet able to enact them in practice, because such changes create the possibility for future development.

Despite their limitations, the stage models together with research on the differences between expert and novice teachers (Berliner, 1992; Hogan, Rabinowitz, & Craven, 2003) have helped to clarify thinking about the goals of teacher education. Their weakness is that they do not adequately take contexts into account, and so in the next section I consider the trajectory of an individual through different contexts.

2.4.4 Trajectories and Recontextualization

In section 1.2.1 I explained that identities have a trajectory through time. In section 2.4.1 I described how the initial conceptions of a student teacher come from her personal history in particular classroom contexts, which means that conceptions also have a trajectory through time. Likewise her knowledge for teaching has a trajectory through time. In other words, the development of a teacher extends in time from well before a teacher education programme starts, and takes place in particular contexts. From a complexivist view, a teacher's individual history and hence her trajectory are unique.

I represent the trajectory of an individual teacher by the horizontal arrow in Figure 10. Hammerness et al. (2005) emphasise that the dimensions of teacher learning (described in section 2.3) take place in a 'learning community'. Essentially a person who becomes a teacher passes through three educational contexts: school, university and then school again. In each of the three contexts, the individual sits under the power of the context, mediating her agency by means of her identity. Thus the context has the power to impact the individual considerably, represented by the down arrows. In educational contexts which are responsive, the individual also influences the context, represented by the dotted up arrows. Once in the role of a teacher in a school, the individual is in a position of power in her own classroom, and so she impacts the context of her classroom and at the same time is impacted by the classroom. Before she becomes a teacher, she practises in this role as a student teacher, but in this context the classrooms she practises in are not her own – they belong to other teachers – and so they have potential to affect her more than be affected by her. So in the course of her trajectory, the balance of the power of the context and the agency of the individual shift.

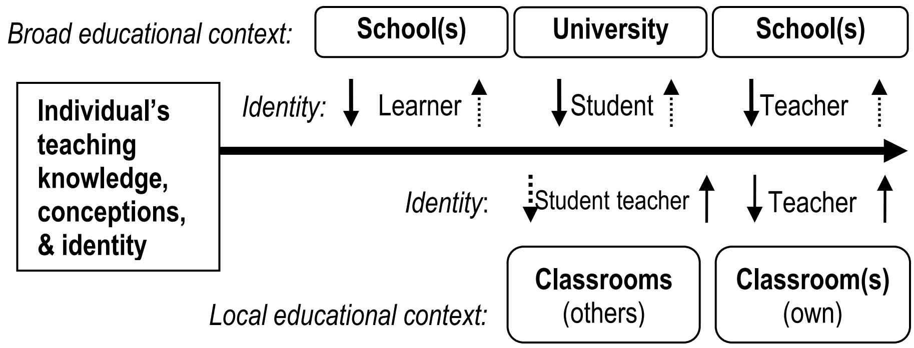

Figure 10: Trajectory of an individual teacher

This means that an individual's conception of teaching and teacher identity are influenced first by her own experiences in science classrooms, then by her experiences in a university teacher education programme such as the B Ed, and then by her experiences as a teacher in particular schools in particular districts in particular provincial Departments of Education. The experiences in each of these three areas are different for different individuals – though they may be similar in some respects – and the combination produces a unique trajectory for each individual. The inputs in teacher education programmes act as forces on these trajectories, affecting the directions they take (Anderson et al., 2000; Samuel, 2003). However, consistent with a complexivist view of education, students in the same programme are affected in different ways. Anderson et al. (2000) show how three students moved in three distinctly different directions in response to the same programme. Fletcher and Luft (2011) found that the impact of fieldwork on beliefs is variable.

The university context in Figure 10 sits sandwiched between two school contexts. According to Bernstein (1996) all education is a recontextualization from the site of practice. So we teach people how to teach, not in the schools where they will ultimately teach, but in universities, with short forays into schools which may be significantly different from the schools in which they will ultimately teach.

Moreover, the problem with professional knowledge is that some of it is tacit (Ensor, 2000; Kagan, 1992a; Schon, 1987). Thus we attempt to convey this tacit knowledge through modelling. For example, when I taught a topic to student teachers, I used some activities which could be suitable for using in classrooms. But students are not the same as junior secondary school learners. This means that an activity which I had in the past used at school level needed to be recontextualised before I gave it to students. And should a teacher later decide to use the activity, she would need to recontextualise it into the context of her particular classroom. So every offering in teacher education suffers a double recontextualisation before it enters a real classroom. Moreover the second recontextualization is not simply a reversal of the first: the classroom from which it originated is different from the classroom in which it will end up (Ensor & Galant, 2005). Furthermore, while the lecturer performed the first recontextualization, the teacher is expected to perform the second recontextualization. The double recontextualisation makes it more difficult for student teachers to achieve the realization rules of the pedagogies presented in teacher education.

Some activities were created by me specifically for my students – I had never aired them in a secondary school classroom. In this case the first recontextualization was an imaginary one. The paradox is that the more experienced I became as a teacher educator, the more often this happened as the distance between me and my experience in real secondary school science classrooms increased.

In contrast, knowledge acquired by teachers before and after university is acquired in real secondary schools. Since no recontextualisation is necessary, teachers may find this knowledge is easier to work with than the offerings in their teacher education. This is related to Prosser and Trigwell's constitutionalist model (Figure 6, p. 30) which implies that the prior experiences which are salient in a particular situation are related to a person's perceptions of the current situation. In a school context, other experiences of school contexts are more likely to be salient than university experiences.

One could argue that if each individual has a unique trajectory, then there could potentially be infinitely many conceptions. However phenomenography works from the premise that there are a limited number of ways of experiencing or conceiving a phenomenon. I note that the complex model of Figure 6 was constructed by phenomenographers who recognise each individual's situation as unique but nonetheless make the assumption that there exist only a limited number of qualitatively different ways of experiencing a phenomenon. So while each individual teacher has a unique trajectory, I take the phenomenographic view that there are a limited number of qualitatively different ways in which the phenomenon of science teaching is experienced by early career science teachers in the South African context.

2.5 What Should Happen in Teacher Education?

Two critical problems emerge from sections 2.3 and 2.4. First, what teachers need to learn is complex and multifaceted – it comprises various bodies of knowledge, as well as conceptions/beliefs about teaching and teacher identity. Second, the learning of this is not straightforward: they cannot simply be told. A third problem arises from the premise that there is not one single best way to teach, as discussed in section 2.2.5. This prompts the question, what should happen in teacher education programmes? The problem is that teacher education does not yet have a well-defined pedagogy. However in this section I will consider what the experts have to say about what should happen in teacher education.

Bullock (2009) points out that good subject teachers are often employed as teacher educators, with the assumption that it is easy to transfer knowing how to teach a subject to knowing how to teach others to teach that subject. This was my own experience as a teacher educator (see section 1.4.3). Competence in subject teaching is presumed to indicate competence in teaching teachers. But a look at the problems of learning explored in sections 2.4.1 and 2.4.4 makes it clear that the teaching of teachers presents particular challenges. Bullock notes that teacher educators also have the problem of an 'apprenticeship of observation' – they draw on their own experiences of being a student teacher, even if these experiences were sub-optimal.

Palmer claims that "good teaching comes from the identity and integrity of the teacher" (1997, p. 16), which implies that a key aspect of teacher education is the development of the teacher identity of each student teacher. Taking identity as central is consistent with regarding education as a complex system, since individual agency is key in a complex system, and identity facilitates the mediation of agency (section 1.2.1). Increasing a teacher's agency by helping her develop her identity as a teacher thus makes sense as a perturbation in teacher education likely to have a productive outcome. Rodgers and Scott (2008) describe teacher education programmes both past and present which treat identity development as central. Metacognition or reflection is central to this process, with autobiography often used as a starting point, since this makes teachers aware of their initial conceptions and identities, as well as the origins of their conceptions and identities (Darling-Hammond et al., 2005). Other metacognitive strategies are personal journals, blogs, portfolios in which teachers construct themselves as a particular kinds of teachers, and discussions about lessons observed or taught (Luehmann, 2007). Robinson (1999) found that South African students wanted personal development strategies included in their teacher education programme.

However Rodgers and Scott (2008) caution, drawing on Kegan's developmental stages of adults, that not everyone may have reached the developmental stage necessary to be able to do this identity work. Teachers need to have reached a stage where they are aware of their own agency in authoring their identities. They also point out that "on the one hand, independence and self-authoring are desired; yet there is an unspoken expectation that students will tow the party line" (p. 750) and conform to the teaching ideal held by the programme in which they find themselves. This implies that, consistent with the discussion of section 2.2.5, a teacher education programme which takes identity development as central should be flexible in regard to what counts as good teaching. This is a challenge particularly where students are assessed on their teaching practicums according to certain standards. In many cases these standards are national – Graven (2000) and Parker (2006) both identify the particular identities expected of mathematics teachers by South African mathematics curricula, and Jansen (2003) points more broadly to the identity demands which policy makes on South African teachers.

Apart from identity work, teachers need a good foundation of knowledge (Hammerness et al., 2005). Teachers need the seven domains of knowledge identified by Shulman. For science teachers, the first of these is science SMK, the teaching and learning of which is well researched (see section 2.2.5). The challenge lies in the counterintuitive nature of some science content, but this challenge is well understood. Hence SMK is the least contentious aspect of a teacher education programme. SMK is not only fundamental to teacher knowledge, but also to teacher identity – strong subject knowledge positions teachers as experts in their fields, and thus strengthens their voices in their classrooms and beyond.

In addition teachers need pedagogical knowledge and PCK. PCK is acquired through extended practice, and so beginning teachers typically have low PCK (e.g. E. Lee, Brown, Luft, & Roehrig, 2007). The challenge is to accelerate the development of student teachers' PCK. Students are given some practice through microteaching and teaching practicums. In teaching practicums, student teachers are typically mentored by a supervising teacher and a university tutor, though there are different models of mentoring (Lubben et al., 2011; Maynard & Furlong, 1995; Young, Bullough, Draper, Smith, & Erickson, 2005). In Wenger's (1998) view, identity is also about participation, and so teachers need opportunities to try out new identities in practice. Luehmann (2007) points out that there is risk involved for a student in trying out a new identity. Positioning herself as a different kind of teacher affects both how she sees herself, and how she is seen by others, and she needs a safe space to be able to make mistakes in this process. However teaching practicums inevitably happen in less-than-ideal schools.

Other methods of developing PCK involve getting students to analyse cases of classroom practice, construct portfolios of their work which involve analysis of their work, and engage in inquiry into student understanding (Darling-Hammond et al., 2005). Wood (2000) got student teachers to use phenomenographic methods to find learners understanding of economics concepts. Loughran, Mulhall, and Berry (2008) recommend their Content Representations (described in section 2.3.1) as a good way to help student teachers acquire PCK. Mavhunga and Rollnick (2012) describe the development of PCK in student teachers through specifically targeting PCK for a particular topic in a teaching intervention. Darling-Hammond et al. (2005) emphasise the need to consider student 'readiness' for learning and hence the scaffolding which is required.

Teachers also need three context specific domains of knowledge to inform their decision making: curriculum knowledge, knowledge of learners and knowledge of context. Teacher education programmes cannot predict these, although they can draw student teachers' awareness to contextual issues and the need to understand their contexts.

I have identified particular pedagogies above, but key to the success of a teacher education programmes is the overall coherence of the programme (Darling-Hammond et al., 2005). A book entitled *The missing links in teacher education design* (Hoban, 2005) suggests that this is achieved by essential links which need to be made across a teacher education programme rather than by particular courses. According to this book, conceptual links are achieved in part by assignments and cases which cut across courses. Theory-practice links are achieved by integration of teaching practicums with university courses. Social-cultural links encourage relationships between faculty, students and schools, which points to the importance of community in teacher education. This echoes the learning community in which Hammerness et al. (2005) situate their model of what teachers need to know (section 2.3). The last link is that of identity since "it is the human factor that determines how program principles really work out in practice" (Korthagen, 2005, p. 231). If identity is key to teaching, then it is also key to teaching teachers, and hence teacher educators also benefit from identity work. This is reflected in the move towards self-study of teacher educators (Laboskey, Russell, & Loughran, 2007; Loughran & Russell, 2002).

Teacher learning does not stop at the end of a pre-service programme. First year teachers typically find the demands of teaching daunting, and often feel that their pre-service programmes did not prepare them adequately (Adams & Krockover, 1997b; Flores & Day, 2006; Luft & Cox, 2001). Many exit teaching – in America novice teachers leave the profession at a far greater rate than experienced teachers (Patterson et al., 2003). In South Africa Chuene et al. (1999) found that the majority of the 34 pre-service and novice South African mathematics teachers they worked with would leave teaching if the chance arose. A survey of nearly 300 American teachers found that teachers can cope with one major negative factor, but with more than one factor, they are likely to leave (P. Green, Hamilton, Hampton, & Ridgeway, 2005).

Here mentoring plays an important role. This may happen within a school, either formally or informally, or from outside, with support from a university or department of education. This is similar to what happens during teaching practicums, with a student teacher typically supported from within the school by a supervising teacher, and from without by a university tutor. The efficacy of different models of external mentoring has been explored in America (Chubbuck et al., 2001; Heider, 2005; Luft, 2009). Luft (2009) concludes that mentoring by a subject expert is most effective. However, even with mentoring, the attrition and turnover rate of novice teachers may be high (Patterson et al., 2003).

In summary, teacher education programmes are likely to be most effective where they help students develop their identities as teachers and develop a strong knowledge base. This is likely to be achieved best through a variety of pedagogies, including practice teaching and reflection, as well as through overall programme coherence, implemented by teacher educators who are self-aware, and complemented by subsequent mentoring of beginning teachers. However these are merely design principles – the translation of these principles into a meaningful and effective curriculum is a mammoth task, a task which, in my own experience, involves playing off competing demands and resource constraints. And none of these design principles predict success – what teachers do in classrooms depends also on the context of the classroom, and the individual history and agency of the teacher.

Thus it is appropriate to explore the experiences of early career teachers in South African classroom contexts. Better understanding of their realities and what they found useful in teacher education should inform South African B Ed curricula. As indicated in the introduction to this thesis, this is an area which needs research, and which this research project contributes to.

2.6 Conclusion

I started this chapter by asking five questions. In the course of this chapter I have addressed these questions, though I recognise that my answers are partial – there will always be more to be said in response to such questions. In answering the five questions I have attempted to come to a better understanding of the complexity of teaching and learning to teach. My first question asked about the relationship between teacher education and learner outcomes. I argued that education is a complex system, where the structure emerges from the actions of individuals, and the system adapts to its context. A complexivist view of education takes into account both the agency of the individual, and her past and present contexts. Take-up of the offerings in a teacher education programme is affected by individual histories and personalities. Thus there is no simple relationship between what happens in teacher education and what learners ultimately learn. Nonetheless it is worth seeking perturbations in teacher education which are likely to have productive though unpredictable outcomes.

My second question was: what is teaching? I looked at the conceptions of teaching held by teachers which research has uncovered, typically ranging from teacher-centred to learner-centred conceptions. In contrast researchers have converged on the idea of teaching as transformation of SMK into forms accessible to learners. However I argued that the notion of good science teaching is both contested and context dependent. My third question followed up by asking what teachers need to know in order to teach. I explored the knowledges, including SMK and PCK, which teachers need, but argued that this knowledge is subordinate to their conceptions of teaching and their teacher identities, which are also essential aspects of their 'knowing' to teach.

The fourth question asked how teachers learn to teach, and in response I first explored the challenges in learning to teach, and found that these are significant. I then explored some models which postulate that teachers go through different stages in learning to teach, although these models have limitations. My last question explored principles for designing teacher education programmes: the need to take teacher identity seriously, the need to provide a good foundation of knowledge through a variety of pedagogies, and the need for overall programme coherence and personal commitment by the lecturers involved.

I have argued that three constructs are central to how teachers teach: conceptions of teaching, identity as teacher and teacher knowledge. My research project explores the first two constructs, and looks at the subject matter content of lessons, which is related to the third construct. Conceptions comprise beliefs about teaching as well as intentions for teaching – there is typically a disjuncture between the two as a result of the constraints of a particular context. Teacher identity can be expressed as the 'kind of teacher' a teacher sees herself as, and allows a teacher to mediate her agency within the constraints inherent in a context. Teacher knowledge comprises different domains, including SMK and PCK, and is subordinate to conceptions and identity insofar as both a teacher's take-up of knowledge and the saliency of that knowledge are shaped by how teachers see teaching and themselves. These three constructs have a trajectory through time as an individual moves through different contexts. Although constituted in contexts and influenced by those contexts, they have resilience as the self negotiates different contexts.

In the course of this chapter, four challenges associated with the work of teacher education have emerged. The first is that education is a complex system – one cannot simply put the desired inputs into teacher education and get the desired outputs in schools. The second is that there is not a universally agreed upon definition of good teaching – what counts as good is contested and context dependent. The third is that teachers need more than knowledge to teach, they need enabling conceptions and identities. Finally individual histories fundamentally affect the way student teachers make sense of and appropriate their initial training. My research questions recognise these four challenges as follows. In regard to the first challenge, the complexity of education, I did not seek causal relationships between inputs in teacher education and teachers' conceptions and classroom practices. Rather, the teachers' narratives give a view on what individual teachers found helpful in learning to teach. Moreover I recognised that what happens in classrooms is not constructed only by the teacher, but also by the learners and both are affected by the broader school context. In regard to the second challenge, I did not have a standard of ‘good science teaching’ against which I assessed classroom practice, though obviously my own subjectivity (described in section 1.4.4) came into play, a point I will explore further in the next chapter. In regard to the third challenge, I investigated teachers’ conceptions of teaching and their identities. In regard to the final challenge, I investigated individual histories by means of teachers’ narratives.

I have also shown that my research questions address gaps in the published research literature. My first and second research questions address the shortage of research into what happens in South African classroom contexts, referred to in the opening paragraphs of this thesis. My second research question addresses the gap in science education research and education research more broadly in regard to the subject matter content of lessons. My third research question addresses the paucity of research describing different teachers’ discourse identities and also responds to calls to find out why South Africans become teachers. My fourth research questions addresses the lack of research into South African secondary teachers conceptions of teaching. In the next chapter I explore the methodology by which I investigated these research questions.

Chapter 3: Methodology

With the challenges described in the last chapter as backdrop, I turn to my research design. In Chapter 1 I located my research as qualitative in the interpretive genre, using narrative inquiry and phenomenography, with two research instruments, classroom observation and interviews. The purpose of this chapter is to describe my methodology in detail and provide the rationale for the research design. I first provide my rationale for the research instruments which I used, then describe the sample, outline the data collected, and address the ethics of the research project. Integral to my methodology is the way in which I have addressed the validity of the research, so I explore some concepts relating to research rigour. Then, consistent with a narrative approach, I tell the story of one day of observation and use that story as a reference point for critiquing my instruments. Finally I consider the validity of the analysis of the chapters which follow.

3.1 Rationale for the Research Instruments

My first two research questions explored the classroom practices of early career science teachers, looking at the form of the activities (first question) and the quality of the science content of their lessons (second question). The instrument used extensively to find out what happens in classrooms is classroom observation, both in South Africa (e.g. Adler & Reed, 2002; Rogan, 2004; Rollnick et al., 2012; N. Taylor & Vinjevold, 1999) and elsewhere (e.g. Lawrenz, Huffman, & Appeldoorn, 2002; Luft, 1999; Newton, Driver, & Osborne, 1999) and thus it seemed the obvious instrument to use. I give the rationale for the particular classroom observation instrument which I used in sections 3.7.3 and 3.7.4.

As noted in Chapter 1, my first two research questions were intended to be wide-angle lenses, taking in the breadth of the repertoire of the teachers' practices. Therefore I wanted to see multiple lessons taught by each teacher, across different grades and topics. Observation of a full school day on a timetable day where the teacher taught different grades would have met this requirement. However because of my concerns about classroom reactivity, i.e. how what happens in the classroom changes as a result of an observer (elaborated in section 3.7.1), I felt that one day of observation was insufficient. At the same time I was mindful of the scope of a doctoral thesis and did not want to generate more data than I could do justice to within the scope of such a project. More days of observation per teacher reduced the number of teachers I could include in the sample. Taking the advice of more experienced colleagues, I decided on two non-consecutive days of observation. Non-consecutive days gave me a wider lens, as no lessons were follow-on lessons of lessons I had seen previously.

With regard to the timing of the visits, I wanted to observe lessons once teachers and learners were well established in their normal classroom routines, again because of my concerns with classroom reactivity. Thus I did not want to observe teachers too close to the start of the academic year. I also did not want to observe lessons just before examination periods, when the focus would be on the impending examinations. At the same time, the timing of the visits needed to fit in with the demands of my academic job and the availability of the teachers. The timing of the visits as it worked out in practice with these constraints is given in section 3.3.

In order to answer my last two research questions, about the teacher's professional identities and conceptions of teaching, I used narrative inquiry and phenomenography respectively. By far the most commonly used instrument in both these research approaches is interviewing (Åkerlind, 2005; Riessman, 2008), and so it made sense to use interviews. I give the rationale for both the content and the nature of the interviews in section 3.8.

An alternative to interviews would have been to get the teachers to respond to questionnaires. My rationale for choosing interviews over questionnaires is as follows. Questionnaires would have amounted to yet another piece of paperwork for teachers who already find administrative demands burdensome. In contrast teachers typically get few opportunities to talk in depth about their work and generally enjoy doing so. In addition I recognised the pressures under which teachers work, and that my research made demands on their time. Interviews give more information per unit time than questionnaires, so were a more efficient use of teachers' precious time. So the choice of interview had ethical underpinnings – I felt it was kinder to teachers. Moreover interviews produced richer data than questionnaires are likely to have, and allowed for further probing of teachers' answers. One could argue that questionnaires would give teachers time to think but I achieved this in part by multiple interviews and by warning the teachers about one major question I would be asking them (see section 3.8.2).

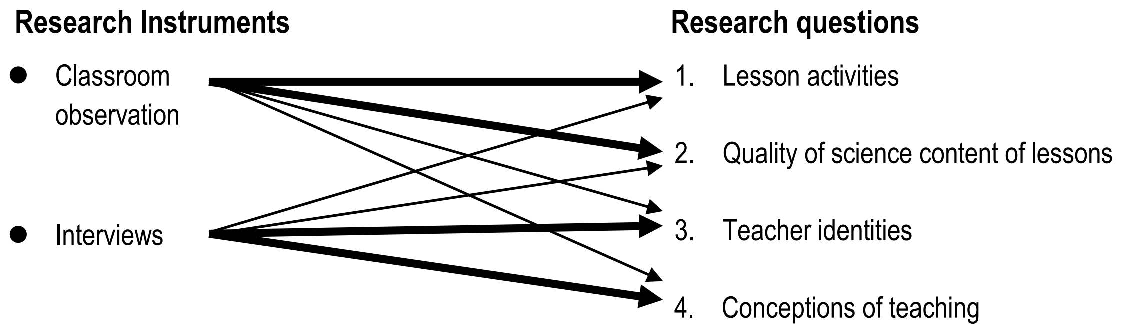

Figure 11: Relationship between research instruments and research questions

I have argued that classroom observation was the logical instrument to use for my first two research questions, and interviews were the logical instrument to use for my last two research questions. However both instruments addressed all four questions, as shown in Figure 11, with observation foregrounded in addressing my first and second questions and interviews foregrounded in addressing my third and fourth questions. The interviews retrospectively informed the observation as they gave me the teacher's perspective on what I observed. The observation informed the interviews as it gave me a context for better understanding what a teacher said in interviews and was a shared experience from which we both could draw to ground our discussion. This dialectical relationship between the observation and the interviews was my intention from the start, and enriched the research design.

3.2 Population and Sample

As explained in Chapter 1, the population of this study was past students of mine: qualified, early career physical science teachers with a four year teaching qualification from the University of the Witwatersrand. In this section I will define the terms of this population and then introduce the sample. By 'qualified' I intended graduates of the B Ed degree or its predecessor, the HDE, who qualified with secondary physical science as a teaching major, and mathematics as a sub-major (or in the case of some of the HDE students, as a second major). By 'physical science teachers' I mean secondary teachers teaching the school subjects Physical Sciences and / or Natural Sciences. This means I excluded teachers who were not teaching science. However, I included teachers who were also teaching a second subject provided that science was their main subject.

What do I mean by ‘early career’? I chose not to call these early career teachers ‘novice’ teachers, since:

> complexity science renders problematic those discourses that focus on peripheries, fringes, border spaces, novices and other notions that suggest that complex forms might have clear centers, boundaries and origins. (B. Davis & Simmt, 2003, p. 143).

In other words, I did not position early career teachers on the periphery of a community of practice (Lave & Wenger, 1991) but rather allowed that they could be significantly impacting the complex school communities in which they are situated. I felt ‘early career’ was a label which signalled their relatively short teaching careers without casting aspersions on their competency.

I wanted teachers who had found their feet in teaching. First year teachers are typically in survival mode (see section 2.4.3), and so their identities as teachers can be expected to only stabilise thereafter. Hence I wanted teachers who were at least in the second half of their second year of teaching, which in terms of the period of data collection meant teachers who graduated in 2008 or earlier. How long is one an early career teacher? I needed to define an upper limit to this label. One way to define the upper limit would have been to look only at science teachers with a B Ed degree, i.e. those who graduated in 2006 or later. However this population was too small: only fourteen teachers graduated from the University of the Witwatersrand with a B Ed majoring in physical science during the period 2006 – 2008, and of these at least half were not teaching science in South Africa – some were teaching mathematics, some had moved out of teaching and one was teaching in England – and I was unable to contact all of those who were teaching science. Another logical cut-off would have been those teachers who had been taught all their physics and science teaching methodology by me, i.e. those who graduated 2005 or later, which only added two suitable and contactable teachers to the population. Such teachers had under five years of experience. With five years of experience, a teacher is eligible for promotion in the South African system, so five years is a logical cut-off point.

Table 2 gives details of the eight science teachers who participated. All names are pseudonyms, chosen for convenience to start with the letters A – H. In the end the sample comprised five teachers from the population described above who were willing to participate and had principals who were agreeable (Mr Abrams, Mr Baloyi, Ms Emeni, Ms Gray and Mr Hlope) as well as two teachers who graduated in 2004 (Ms Cole and Ms

Fikela) and a teacher who had only a sub-major in physical science (Mr Dube). Mr Dube was included by mistake – he had started his degree intending to do a physical science major and I forgot that he had switched[10]. I only realised my mistake on my second visit with him. However I found his contribution to the data very useful, as my analysis will show, and I would have found it ethically difficult to discard the data after he had given me willing and enthusiastic access to his classroom.

Table 2: Sample and Overview of Data

	Teaching experience as at my 2nd visit (years)	Teaching Qual.	Dates of observed lessons	Lessons observed: grade x no. of lessons (+repeats)	Typical no. of learners present in observed lessons	Type of school teacher is in	Own secondary schooling
Mr Abrams	1,9	B Ed (Science) BScHons	2/9/2010 14/10/2010	8 x 3 (+1) 9 x 3 10 x 1	33	Multi-cultural	Multi-cultural
Mr Baloyi	4,9	HDE (Science)	29/10/2009 12/10/2010	8 x 2 (+3) 10 x 2 11 x 2 12 x 1	35	Township	Township
Ms Cole	5,7	HDE (Maths & Science)	10/8/2010 19/8/2010	8 x 2 9 x 2 10 x 2	20	Private	Multi-cultural
Mr Dube	4,8	HDE (Maths)	3/11/2009 22/9/2010	10 x 2 11 x 2 (+1)	20-36	Township	Township
Ms Emeni	4,7	HDE (Science) BScHons	12/8/2010 16/8/2010	11 x 2 12 x 2	21	Inter-vention	Rural
Ms Fikela	6,4	HDE (Maths & Science)	5/5/2011 10/5/2011	9 x 5(+2)	22	Inter-vention	Township
Ms Gray	2,9	B Ed (Science)	16/5/2011 14/10/2011	10 x 2 (+1) 11 x 2 (+1)	13-20	Multi-cultural	Private
Mr Hlope	4,3	B Ed (Science)	3/3/2011 7/3/2011	9 x 3 (+4) 10 x 3 (+2)	40	Township	Rural

I added two teachers who graduated in 2004 in order to increase the size of the sample: I purposively selected Ms Cole and Ms Fikela because they had both done some creative teaching as student teachers and I was curious to see how they had developed further as

[10] The reason he made the switch is elaborated in section 6.2.5.

teachers. Both Ms Cole and Ms Fikela had less than five years of experience, when I originally intended to visit them, but they had more than this by the time I actually saw them. For example, I originally planned to see Ms Fikela two years before I saw her, but my own work pressure meant this did not happen. Then I organised to see her about a year later at a different school, but the day before my scheduled visit, her principal cancelled, as the school was in crisis and closed down soon after. Thus it was only the following year that I saw her. By this time she had six years' experience, but I felt it would be ethically wrong to drop her from my sample after she had expressed enthusiastic anticipation of participating. Some teachers felt privileged to be included in my research, so retracting the 'privilege' after committing to it would have been unethical.

To what extent did my actual sample fit my intention of 'early career teachers'? Despite being near the end of his second year of teaching, Mr Abrams' teacher identity had not yet stabilised in the way that I hoped, as will be evident in Chapter 7, although there were factors apart from the duration of his teaching experience contributing to this. This suggests that my decision to not use teachers with less than 1.5 years of experience was a good one. At the other end of the scale, despite her 5.7 years of experience Ms Cole saw herself as still having lots to learn, so experienced herself as an early career teacher. In contrast Ms Fikela was already looking ahead to having other teachers learn from her, which indicates she experienced herself as beyond this category. This suggests that my intended upper limit of five years of experience was not unreasonable.

The sample taught in four distinctly different types of schools, which I have termed multicultural, township, intervention and private. Multicultural schools are well-resourced and well-functioning schools, which were privileged white schools under apartheid. The term 'multicultural' reflects the demographics of the learners and to a lesser extent the teachers who are often white in the majority. The school culture has not shifted to the same extent as the demographics – the entrenched traditions still reflect the school's origins. Multicultural schools are state schools, but parents pay considerable fees which provide additional teachers and resources. In contrast, township schools are black schools (both learners and teachers) which were deliberately neglected under apartheid and which continue to function sub-optimally (see section 1.4.1). They are state funded, and typically provide school lunches to some learners. Intervention schools use donor funding to give a good educational opportunity to disadvantaged youths who would otherwise probably be attending a township school. Private schools are elite, well-resourced institutions, typically with white learners in the majority. These are not the only types of schools in the South African education spectrum, but are the types relevant to this study. The vast majority of schools in South African are township or rural schools.

The sample received their own secondary education in diverse schools: Ms Emeni and Mr Hlope both attended rural schools; Mr Baloyi, Mr Dube and Ms Fikela attended township schools; Mr Abrams and Ms Cole attended multicultural schools; and Ms Gray attended a private school. This means that Mr Abrams, Mr Baloyi and Mr Dube taught in the kind of schools they themselves attended, but the others did not. Ms Cole attended and started teaching in a state multicultural school but moved to a private school two years before I visited her. Ms Fikela had taught in an international school (teaching a British curriculum), then spent most of a year in a small private school which as mentioned earlier closed while she was there, and so she moved to an intervention school the year I saw her. The rest of the teachers had remained in the same schools they started teaching.

3.3 Overview of Data

Table 2 also gives an overview of the data collected. The data was collected during the period October 2009 – October 2011. In regard to my intention to collect data once teachers and learners were well established in their normal classroom routines, all data was collected from May onwards[11], except in Mr Hlope's case where I collected data in March since he had taught all the same classes the previous year. This means that all teachers had spent at least four months with their classes before I observed them. Half of the data was collected during August and September 2010, with the last three teachers observed in 2011. The last day of data observation (with Ms Cole) happened much later than originally planned because of unexpected events in her personal life. The first two days of data (with Mr Baloyi and Mr Dube) were collected closer to examinations than originally planned. This was because I collected some data in a hurry in 2009, as I thought I might need some data for a symposium I was part of and I already had ethics clearance. Although I did not use the data for the symposium, this experience was very useful, as I will explain in section 3.7.3.

[11] The school year starts in mid-January.

Together with the teachers, I selected two non-consecutive days where I would see teaching across different grades. This meant I saw at least one lesson, but usually two lessons, taught to each grade the teacher taught. Seeing different grades also meant I saw different disciplines (physics, chemistry, life science, earth science) and different topics within those disciplines. This meant that I got a view of the breadth of each teacher's practice, as hoped for. The majority of the lessons happened to be physics, but I also saw a number of chemistry lessons and in the junior grades a few biology lessons and one earth science lesson. Overall I saw 57 lessons, distributed across grades 8 – 12. The periods ranged in length from 30 – 45 minutes. Some lessons used double periods but have been counted as single lessons. In fifteen of these lessons, the teacher gave a lesson I had already seen given to a different class, which I have termed 'repeat' lessons, though no lesson is ever truly a repeat because of the contributions of learners as well as the changes a teacher makes in response both to different learners and to her reflection on the previous lesson. The repeat lessons are shown in brackets in Table 2. Of course the first time I happened to see a particular lesson may have been a 'repeat' lesson for the teacher – she may have taught the lesson on a previous day. I excluded the first two of Mr Hlope's lessons from the data analysis, because the first day I saw him, his school closed early unexpectedly as there was no water, and I then saw him on another two full days. In addition to the lessons listed, I spent a total of 40 – 140 minutes interviewing each teacher.

3.4 Ethics

Ethics clearance for this study was granted by the Ethics Committee in Education of the Faculty of Humanities (protocol number 2009ECE60; see Appendix B). According to a former chair of this committee (David Bensusan), there are two principles which underpin ethical research. The first is that the research should not cause harm to the research subjects in any way. The second is that the privacy of the individual should be protected.

3.4.1 Ethical Standards

These two principles are interpreted into various standards of practice by the ethics committee, and so I will discuss three standards which applied to my research. The first is the standard of 'informed consent' expressed as follows in the University of the Witwatersrand "Code of ethics for research on human subjects (non-medical)"

> The aims and nature of the investigation should be communicated as fully as possible to all subjects/informants, so that they may make an informed decision about whether or not to participate in the study. It should be made explicit that

> participation is voluntary and that the subjects/informants may withdraw from the study at any time. It should also be made explicit that choosing not to participate holds no adverse consequences for subjects/informants.

In other words, informed consent involves three aspects: understanding of the research, choice to participate and choice to withdraw after initially consenting to participation. Although the focus of my research was teachers, learners were also in my field of view – they were literally in the field of view of the camera. Thus I gave both teachers and learners information letters, which included all three of these aspects (Appendices C and D[12]). The teachers received the letters by email before agreeing to the research. The learners were given the letters on the first day I observed a lesson in which they were present.

The second standard of the Education Ethics Committee is that any interviewing, or audio or video recording needs to be agreed to in writing by the participants. This meant that each teacher signed three letters of consent (Appendix E), since the teacher was interviewed with an audio recording, and observed with a video recording. The learners needed to sign letters of consent for the video-recording (Appendix C). The Education ethics sub-committee at the time also required letters of consent from parents of learners under fourteen years, with those learners required to sign letters of assent rather than consent. However I visited the teachers who taught grade eight in August or later in the year, when at least two thirds of a class of grade eight learners would have been fourteen years, and the remainder at most four months from turning fourteen[13]. I felt that it would be unfair and hence unethical to embarrass younger learners by singling them out, and so did not get their parents' consent. The criterion of age is fairly arbitrary when dealing with learners who are in the same grade, and anyhow the Education ethics committee revised this age during the course of my research. Getting consent from parents would also have required me to visit schools before doing the research, which would have created a problem in regard to absentees, since there may then have been learners present for the

[12] These letters are not dated because they were given on different dates to the different teachers and their learners.

[13] In South Africa, children start school in the year they turn seven, which means that they turn fourteen in grade eight if they pass every year. However if they do not demonstrate school readiness, then they may start school a year later. Often children born towards the end of the year are held back in this way.

first day's observation who were not present when I explained the research and asked for their permission.

The third standard is that a researcher needs to be clear up front about issues of confidentiality, and this was addressed in the letters of information. In these letters, I made it clear that pseudonyms would be used, but I reserved the right to use exemplary clips from the video recordings, as I explained in the letters of information to teachers (Appendix D) and learners (Appendix C). This addressed the Education ethics sub-committee's view at the time that video or audio recording is not invasive, but can be problematic in terms of what happens to the material afterwards.

In addition to meeting these three standards, I obtained written permission from the Gauteng Department of Education, and verbal permission from the principals of the schools I worked in. Although the latter was not a requirement of the Education ethics committee or the Gauteng Department of Education, it was appropriate to respect the jurisdiction of principals over their schools.

The above discussion makes it appear that ethical issues are straightforward: stick to the principles and standards of practice, and the researcher will be fine. However I discovered there are ethical tensions which operate in practice and "that ethical principles are not absolute, generally speaking, […], but must be interpreted in the light of the research context and of other values at stake" (Cohen et al., 2000, p. 56). I will explore such tensions in regard to classroom observation in the next section. There are also tensions inherent in the principle of privacy insofar as I will be given credit for my research by name, but the teachers who helped me, at personal inconvenience, will not. Thus what appears as a good principle contains an unquestioned power relationship, where my status as a university lecturer guarantees that my intellectual property is protected, but the teachers' intellectual property is not (Odora-Hoppers, 2002). I committed to confidentiality at the start of my research, so will not change this situation, but I note here that it is not the only route I could have gone. A colleague has chosen instead, in consultation with her research subjects who are secondary school learners, to use their actual names in reporting their responses (Khupe, 2011).

The no-harm principle is not as straightforward as it may appear. Naturally the intention of my research was for benefit, but the intention was to benefit teacher education – by better understanding the experience and practice of early career teachers – rather than benefitting the teachers in any way. I hoped that the teachers involved would benefit from the opportunity to reflect on their practice (Lyons, 1998) and from 'narrative learning' – learning from life by narrating it (Goodson, Biesta, & Adair, 2010) – but this was not the intention of the research. Instead, the teachers experienced the discomfort of having the imposition of an observer in their classroom. For one teacher, Mr Hlope, this discomfort was intense: he experienced nervousness with my first visit to the extent of his mouth drying out so that he found speaking difficult (see section 4.1.2). I could do nothing except apologise for this afterwards. However, despite this discomfort, I note that Mr Hlope was one of the teachers who particularly expressed gratitude for my visits.

My research did benefit one school, where Mr Baloyi chose to pass on the pack of interview transcripts and lesson narratives (mentioned in section 3.5.2) to his principal. The principal read through the lesson narratives, which were purely descriptive and did not contain any evaluation or comment, and as a result took measures in his school both to cut down on the number of interruptions during lesson time and the noise level during lesson time. Mr Baloyi reported that these measures had indeed impacted positively on his teaching.

In this section I have argued that my research met the ethical standards of the community in which I practised my research. This was achieved not only by the necessary paperwork at the beginning, but also by the way in which I carried out my research and reported on it, respecting the dignity of research subjects throughout the process of research, including data collection, analysis and presentation of results (Cohen et al., 2000; Maxwell, 1996). I will add to this discussion in the next section when I describe the ethical dilemmas in classroom observation I encountered on the ground. The interviews and analysis did not confront me with such ethical dilemmas and so I will not specifically consider the ethics of interviews or analysis, though I carried the principles of no harm and privacy through to the end of the research process.

3.4.2 Ethical Tensions in Classroom Observation

On my first day of data collection, I used the information letter and letter of consent for learners which I had submitted to the ethics committee, and came to three important realizations. Firstly the language of the letters was inappropriate for junior secondary learners, especially learners whose mother tongue is not English – I was giving them a letter they could not easily access, which was not ethical at all. The letter was also far too long for learners to be able to read quickly. Third, I was reminded how long it can take junior learners to do something as simple as write their names twice (in the body of the letter and at the end), sign and write the date. Fourth, I realised that giving each learner two pieces of paper created some confusion, and that it would be better to give them one piece of paper with both letters. It was only in the embodied setting of the classroom that I came to these realizations – I was not able to imagine the situation sufficiently vividly beforehand. As a result, I revised the letters, leaving the content essentially unchanged, but simplifying the language and shortening both the information letter and the consent letter (Appendix C). I also removed the superfluous writing of learners' names at the end under their signatures, so that they would only have to write their names once. And I reduced the two letters onto one page. All of the above means that I did not follow my commitment to the Education ethics committee 'to the letter', but the essence was unchanged.

The time it took learners to complete the letters of consent highlights an ethical issue: that of the time taken to explain, hand out and collect letters of consent. I have an ethical discomfort with the teaching time which was swallowed by my research. While I think that it was important that learners were told what the research was about and asked permission, I am not convinced that the process of them signing a form made the research more ethical. I felt as though the whole paper exercise was there to protect me rather than the learners, with the learners being disadvantaged through lost learning time. I addressed this concern by trying to get the ethics 'done' as quickly as possible at the beginning of the first lesson with each class. But this meant the learners did not really have time to read the letters – instead I said "the letter on the left explains what I have already said to you." So most learners ended up in the position of signing something they had not actually read, which is in itself an ethical dilemma. However both of Ms Emeni's classes insisted on reading the full letter and form before they signed – I got the impression that someone had given them the good advice never to sign something they hadn't read.

An alternative would have been to use the time which I spent talking to learners to read the letter to them. However my initial introduction was important for me to establish a rapport with the class, as I will explain in section 3.7.2. Reading without eye-contact would not have had the same effect. In an ideal world, I would have liked to stop the clock, explain my presence, read the letter and the form aloud, and give learners ample time to complete the forms. But in the real world the clock keeps ticking, and the distribution, reading and filling in of forms takes up teaching time. To use precious teaching time for research is unethical, particularly in township schools where teaching time is already severely eroded in various ways (Bayona & Sadiki, 1999; Clark & Linder, 2006).

Related to ticking clocks, a teacher is used to periods of a certain length, and so develops a feel for what it is possible to do in a single lesson. Although I warned the teachers in advance that I would need to take some time at the beginning of a lesson, it happened regularly that teachers did not complete what they anticipated they would within a lesson, at a time when they were being observed and so naturally wanted to demonstrate successful lessons. So in effect my exercise in ethical behaviour effectively interfered unethically with teachers' planning and performance.

Apart from the time it took, the process was flawed with respect to latecomers and absentees. Latecomers did not hear my explanation. They were then either handed a form by their peers – and typically signed without knowledge of what they were signing – or they did not receive a form. Latecomers are often an issue in the first period of the day and after break in township classes where they stream in long after the start of a lesson. But even in the situation where there were few latecomers, the bottom line is that I cannot claim that their experience of my research met ethical standards. I also did not get permission from learners who were absent on my first day of observation, because I chose to not disturb their class's next observed lesson by asking who was not present previously. Again this was a trade-off between competing ethical considerations: the signing of letters versus the teaching time it took. However I did ensure that I always had spare consent forms with me on the second day lest I was asked for such. In any event, many learners did not in fact feature in the videos, as the camera was not sufficiently wide angle to take in the whole class.

In addition to my situated realizations regarding the inappropriate letters of information and consent, I had two other insights on my first day of data collection. I realised that it was appropriate that I not only ask learners' permission to videotape, but that I also ask their permission to be present in their class. Thus I framed my introduction in these terms. I also realised that in practice, asking if anyone objected was unfair and unethical – peer pressure makes it difficult for learners to stand out from the crowd by saying no. Rather I needed to ask learners to put their hands up if they were willing to help me. Of course, getting learners to put their hands up also involves a measure of peer pressure, but at least this situation is one in which to comply with the majority requires an action, rather than the other way around.

However, I did not always remember to ask learners to put their hands up. So although I always started by asking their permission, I did not always give them a chance to express it other than in the signing of the letters of consent, by which time it was even more difficult for them to go against the flow and refuse to sign a letter. But at no point did any learner express objection – instead learners generally welcomed me, and there was a sense in some cases of their being privileged to have a visitor. In this regard another ethical issue came to light: the ethics of watching some classes and not others. Mr Dube explained:

> Those who happened to see you today were like boasting to those that you didn't see today. And then I was fighting with the grade elevens during lunch, they were like saying, "Sir, last year we didn't get to see Ma'am and this year we are not going to see her again." I said that "we are actually working with the timetable, I'm sorry guys, you'll meet her one day." But the influence of you being here, it make them – the reason why we say to them "do science", because you motivate them. If a science lecturer comes here, to them it's like Jesus is coming here.

This response reflects the rarity of white visitors in township schools. In summary, I aspired to research which was ethical towards all involved, but came to understand that ethical behaviour in classroom observation is not straightforward and can involve trade-offs between different ethical ideals.

3.5 Research Rigour

Before describing my methodology in detail, I want to construct a framework for evaluating the rigour of my research design. Scientists in a positivist paradigm argue for research rigour through the constructs of validity and reliability. A study has validity if the experimental design is aligned with the research questions and the research instruments do in fact measure what they purport to. For example the relationship between two variables can be investigated if all other variables are kept constant – thus control of variables is used to argue for the validity of a research design – and measurements are also taken over a sufficient range of values to ascertain the nature of the relationship. Reliability is about the repeatability of the results of an investigation and is achieved by repeating measurements to demonstrate consistency in the measurements. Such a framework works where Newtonian causality operates, but is not suitable where behaviour is unpredictable such as in the social sciences. Nonetheless there is a need for research rigour to establish the credibility of social sciences research.

There are a variety of concepts and strategies which social scientists use to approach the challenge of rigour. Confusingly, they sometimes use different terms to refer to the same concept or strategy, or the same term to refer to different concepts or strategies. The distinction between validity and reliability is also not clear-cut, for example repeated observations over a period of time can be constructed as reliability or as validity through time triangulation (Cohen et al., 2000). Many do not refer to reliability at all, which is the approach I will use, since conceptions, identities and classroom practice change over time.

However there is consensus that validity is about the trustworthiness of the research. Maxwell (1996) and Polkinghorne (2007) contend that trustworthiness is not established through particular strategies but rather through the argument that the researcher makes, which may draw on particular strategies. An argument relies on evidence as well as the rejection of counterclaims which are threats to validity (Toulmin, 1958). Maxwell (1996) suggests starting by considering threats to validity, which is the approach I will use.

In the natural sciences, validity and reliability are established in the research design, although discrepant events may appear in the data which need to be accounted for or ignored. However in the social sciences, the trustworthiness needs to be considered both in the design and the analysis. In the design the trustworthiness of the *data* needs to be considered, whereas in the analysis the trustworthiness of the *analysis* of the data needs to be considered.

I will start my argument for validity by considering threats to validity, then I will give strategies to address these threats, and hence I will make particular claims for validity – or for sufficient validity, since validity is never absolute (Lincoln & Guba, 1985; Polkinghorne, 2007). In this chapter I will do this for both the data collection and data analysis phase. For the data collection I will consider the validity of the data from each of the two instruments used, classroom observation and interviews. In so doing I will provide the rationale for the form these two instruments took.

3.5.1 Threats to Validity

Maxwell (1996) argues that the two main threats to validity in the social sciences are ‘reactivity’ and ‘researcher bias’. Reactivity is the “influence of the researcher on the setting or individuals studied” (p. 91) whereas researcher bias arises because a researcher comes to the research with preconceptions and values through which the data is viewed. I am choosing to use the term researcher subjectivity rather than researcher bias because ‘bias’ connotes a weakness on the part of the researcher, whereas I view subjectivity not as a weakness but as a reality which needs to be taken into account (Peshkin, 1988). Reactivity is a threat to the validity of classroom observation, and so I explore reactivity in regard to classroom observation in section 3.7.1. Researcher subjectivity is a threat to both my instruments of data collection as well as to my analysis, and so I discuss strategies for addressing researcher subjectivity in the next section.

As a result of these threats, a study may not measure what it purports to. Brown and Dowling (1998) argue that ‘construct validity’ is central: that the measured constructs should be valid measures of the corresponding theoretical constructs. Merriam and Simpson (1984) call this internal validity. In this study, there are three theoretical constructs: normal classroom practice, conceptions of science teaching, and teacher identities. I will consider the construct validity of normal classroom practice in sections 3.7.2 and 3.7.3, and that of conceptions and narratives in section 3.9. In addition to classroom reactivity and researcher subjectivity, I will consider other threats and corresponding validities where I feel they are relevant. In so doing, I will not attempt to be exhaustive on the plethora of terms used for validity in an interpretive paradigm, but will argue that this study has sufficient validity.

3.5.2 Strategies for Addressing Researcher Subjectivity

There is consensus that it is not possible to eliminate researcher subjectivity (Maxwell, 1996; Peshkin, 1988) but there are different ways of dealing with it, as I will show. In an interpretive paradigm, the approach to researcher subjectivity is to recognise it, make it explicit, and take it into account in the analysis. Lather (1986) suggests a vigorous reflexivity throughout the research process. Peshkin (1988) argues that since we cannot achieve objectivity in social sciences research, we need to acknowledge and explicitly identify our subjectivities, which I have done in Chapter 1. In this way I bring to my research an awareness of the subjective lens through which I view my data, and communicate my perspectives to my audience. During the collection of data, I followed Peshkin's recommendation and watched out for:

> the warm spots and the cool spots, the emergence of positive and negative feelings, the experiences that I wanted more of or wanted to avoid, and when I felt moved to act in roles beyond those necessary to fulfil my research needs. (p. 18).

For me a particular cool spot was inaccurate content presented in lessons. This met Peshkin's criteria of making me feel moved to act beyond my research role – my urge was to point the inaccuracies out to teachers after their lessons so that their learners would not be disadvantaged. This cool spot has roots in my desire to give learners quality science education and in years of giving feedback to student teachers on the quality of their lessons. It also points to my failure as a teacher educator to help students develop alternative conceptions into scientific conceptions. Having Peshkin's metaphor of a cool spot helped me to recognise what was happening.

One way of minimising researcher subjectivity is to use multiple researchers, so that one can check for intercoder or interjudge reliability in analysis. The challenge for the PhD student is that a doctoral thesis is by definition a one-person research project. Some claim that the notion of intercoder reliability draws from positivistic roots, and so is not appropriate in the interpretive tradition in which I have located my research. Sandberg goes as far as to argue that "interjudge reliability is an unreliable way of establishing reliability of phenomenographic results" (Sandberg, 1996, p. 140). Instead researchers should be able to present their conclusions as credible and justified – validity is not about being the only possible interpretation, but about being a valid interpretation (Maxwell, 1996). This approach is used by phenomenographers (Åkerlind, 2005) and narrative researchers (Polkinghorne, 2007) so sits well with my research. My thought on this is that intercoder strategies do not eliminate subjectivity, they merely bring different subjectivities to bear on the data, and may in fact render subjectivity invisible where the multiple researchers have similar subjectivities, thus giving a false impression of objectivity.

Table 3: Feedback on analysis

Chapter	Topic	Papers presented	Other
4	Classroom activities	• SAARMSTE Conference (January 2011)	• Presented a Wits School of Education research seminar (April 2011)
5	Quality of Lesson Content	• Marang PhD weekend paper (May 2011)	• Initial thoughts presented in Wits School of Education research seminar on classroom activities (April 2011). • Extended conversations with each of colleagues working in similar areas (Nov-Dec 2011) • Paper written 2012, with feedback from UCT colleagues
6	Identity	• Marang PhD weekend paper (August 2011) • SAARMSTE Conference (January 2012)	• Received feedback on draft SAARMSTE paper at a UCT Writing Retreat
7	Conceptions	• Marang PhD weekend paper (October 2011)	

Another strategy for addressing researcher subjectivity is feedback (Maxwell, 1996) or peer debriefing (Lincoln & Guba, 1985) for which I will use the term ‘peer feedback’ to distinguish it clearly from member checks, which I will also discuss in this section. I was fortunate to be in a position to get extensive peer feedback on my research. I presented every stage of my research, both design and analysis, to a critical community, which included fellow PhD students, my supervisors and other experienced researchers. This happened in two forums, quarterly PhD weekends organised by the Wits Marang Centre for Maths and Science Education in which I was located, and annual conferences of the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE). In both forums I wrote papers, presented them and received critical feedback. The feedback on my analysis is summarised in Table 3 which shows that I presented papers on all of my analysis chapters, and received feedback in other forms as well. Obviously I also received additional feedback from my supervisors once I turned these papers into chapters.

The PhD weekends included a formal ten minute response from a fellow PhD student whom I nominated in advance, as well as twenty minutes of comment from the floor. This meant that the feedback was substantial and helpful, both in giving me ideas of ways to take my work forward and showing me ways in which my explication of my work was deficient. For example, feedback on my original research proposal showed me that it was flawed insofar as it focused on a pet project of mine and hence likely to lead to unduly positive feedback from past students wanting to please me. Thus I widened the gaze of my project considerably, which led to a far stronger research design, with more defensible outcomes. In addition, after each PhD weekend paper, I met with my supervisor, for him to give further comment, and for us to decide jointly on the way forward. The conference feedback was less substantial, ten minutes of discussion from the floor, but was helpful insofar as the audience extended beyond the Marang research community. Also the extended abstracts for the papers were blind reviewed before the conferences. In addition, I had conversations and exchanged ideas and literature with colleagues working on similar research projects. This was particularly helpful with regard to the quality of the content of science lessons, since there was little previous research to guide me (see section 2.2.6)

Member checks, which involve giving the output of the research back to the research subjects for comment, are another form of feedback used to address researcher subjectivity (Lincoln & Guba, 1985; Maxwell, 1996). I exposed my data to member checks by giving each teacher a full set of her data: a spiral-bound pack of all interview transcripts, lesson narratives, classroom description(s) and a DVD with recordings of all interviews and the lessons in which whole class teaching predominated. However while I invited comments, I did not insist on them, recognising the considerable time demands on most of the teachers I worked with – I felt they had already generously given of their time to me. This is a case where the ethics of 'no harm' (discussed in the next section) won out against the validity of a member check. No teachers came back to me with criticisms of the data, but I am not claiming this fact as evidence of their satisfaction with the data.

Triangulation is another strategy used to deal with researcher subjectivity. Usually this means using different methods to get different forms of data which align, which achieves pragmatic validity according to Sandberg (2000). Cohen et al. (2000) also speak of time, space, theoretical, and investigator triangulation. The alignment of the data is used to argue for validity. This strategy has roots in the positivistic tradition. But I argue that this strategy is not appropriate for my research project since as mentioned in section 2.4.3 there is often a gap between what teachers do and what they *say* they do. So I contend that a lack of a match between classroom observation and interviews does not invalidate data.

Rather I chose to explore the disjunctures and the issues which they revealed (see section 5.1 for an example). However classroom observation did contribute to the validity of my analysis of interview transcripts, since it gave me a reference point for what teachers said. Likewise the interviews contributed to the validity of my classroom observation, since I was able to get the teacher's view on the lesson (see section 3.7.2).

I have started the argument for the validity of my research by considering two threats, and exploring strategies for addressing one of these threats. I will continue this argument in the course of this chapter by holding up the lens of research rigour to each of my instruments – classroom observation and interviews – and to my analysis. I next tell the story of a day of data collection. The story depicts the texture and messiness of data collection, and provides a focal point for considering the validity of the research.

3.6 A Day with Mr Dube

My alarm clock got me out of bed. I stood in front of my cupboard and debated what to wear. I wanted to wear something which would not signal me as an important person; at the same time I did not want to dress inappropriately casually for the township school in which I would spend my day. Eventually I decided on black jeans and a loose rayon top.

As I drove towards Soweto, I was grateful to be going in the opposite direction to much of the morning traffic. But I had not bargained on extensive roadworks on the way. When I got close to the school I wasn't sure just where it was, so I stopped and picked up a couple of teenagers in the right uniform, and asked them to direct me. One of them made polite conversation, "Ma'am is it your first time in Soweto?" I answered that it was the fourth time I was visiting their school. They responded with gentle surprise.

At the school, I parked inside. Thanks to the roadworks it was now after 8h00, the official starting time of first period. I poked my head into the staff-room – there were a number of teachers there, but not the one I was visiting. So I asked a learner if he knew where Mr Dube was. He responded brightly and escorted me to the teacher who we met on his way from his office to 11A's classroom. Mr Dube explained that he had had to wait for security gates to be unlocked before he could collect chalk and a chalkboard duster from his office. He also had a couple of textbooks and a calculator with him. Then Mr Dube collected a box from the staffroom, containing photocopying he did the previous day after school.

We headed to 11A's classroom. More than half of the old-fashioned double desks were occupied with waiting learners. Mr Dube greeted them and then said "As you can see we have a visitor, but I will leave her to introduce herself." The class looked at me, and I could sense their wariness. I greeted them with a smile, "*San'bonani*" and they responded warmly – my vernacular greeting had broken the ice. I continued "My name is Dale Taylor and I am a researcher from Wits University. I am interested in what happens in science classrooms. Your teacher has kindly agreed to help me with my research. I'm also asking you to help me – the way you can help me is by allowing me to sit in the back of your classroom." I smiled again and I looked around, noticing excitement on the faces of some of the girls. "I have a tiny video camera which I will set up. But I'm afraid I'm not going to turn you into movie stars." This drew a laugh. "I want to use the video to remind me afterwards what happened. There is a small chance I may want to use a video clip to show student teachers and other researchers. If I do this then I will first show the clip to your teacher and we will agree that it doesn't make anyone look stupid. Who's willing to help me with my research?" I put up my hand to indicate that they should do likewise if they were agreeable. I waited. Most of the class responded and put their hands up. Some of them did not put their hands up, but learners near them nudged them, and so they did. "Are you sure?" I said, "because if anyone is not happy to have me here then I will leave now."

I started to hand out the sheet with the information letters and letters of consent (Appendix B). "I need you to sign that you give me permission. This page has a letter which explains what I have just said on the left side, and a form on the right side. Please write your name at the top of the form and sign at the bottom." I repeated the day's date a few times to avoid learners wasting time finding out the date. I told them they could tear off the left side and keep it if they wanted to. While they completed the forms, I headed to the back of the classroom to set up my video camera and launch my laptop. I set up the camera in a corner of the classroom, with its lens set to take in as much of the classroom as possible. The whole front of the classroom was included, since this is where I anticipated the teacher would be. If during the lesson I registered the teacher moving out of range of the camera, I could shift the position of the camera. The limitations of my camera and the small classroom meant that I only got about half the class in the field of view of the camera. While I was fiddling with my kit, more learners arrived, and other learners asked me for forms for them.

I then asked the class to pass their forms to the back of the classroom, and added "The best way you can help me with my research is to pretend I'm not here – you don't need to be on your worst behaviour, you don't need to be on your best behaviour, just be on your normal behaviour." This drew another laugh. "Thanks Mr Dube" I said to indicate to the teacher that he could start the lesson. I switched on the video camera. The teacher started to ask a question, but then three more learners arrived one after another, and he stopped to help them move the large black dustbin which was used to hold the classroom door closed. In the course of the lesson another four learners arrived.

I sat down at one of the back desks, and opened my lesson observation template (Figure 12) on my laptop. I immediately started typing a narrative of the lesson. I knew that I would be able to watch the lesson again on the video, but that I would probably not be able to make out what was written on the board on the video, so I paid particular attention to copying down everything on the board. In order to answer the teacher's questions, the learners were referring to a handout which they had received previously and which I did not have. I would ask Mr Dube for a copy later.

When Mr Dube remonstrated learners for speaking in Zulu, I interrupted to tell him it was not a problem since my comprehension of Zulu in the context of a science lesson is usually adequate. During the lesson I completed most of the sections at the top and end of the template. I also completed a classroom description schedule, noting that "Some of the lower window panes are painted with white PVA – probably all were once – the window looks out onto a small field and a netball court" and "Classroom has 7 posters on back pinboard (e.g. Bill of Rights). There is a timetable close to the door. Lots of graffiti on the facebrick walls."

Lesson Observation

Teacher ; Lesson no	
Grade	
Lesson topic	
Day, Date	
Time	
Length of lesson	
No of boys	
No of girls	
Total Learners	
Venue	
Video no:	
Audio tape no:	
Cleaned up	Date: With video?

Story of Lesson:

AV Resources used	Chalkboard whiteboard OHP DP smartboard
Science Equipment used	
Everyday equipment used	
Texts	Textbooks handouts OHTs
Learner work done on	Notebooks paper (Files)
Languages other than English	Used by teacher learners In whole class / groups
Metaphor	

Figure 12: Lesson observation template

Apart from the late arrivals, there were two other interruptions. Mr Dube later identified for me that the one youngster who interrupted was a COSAS (Congress of South African Students) representative. COSAS was campaigning for the 25 % Continuous Assessment mark to be given to all grade twelves because of the recent protracted teacher strike. The strike had meant that teaching had ceased in all township schools, while it was business as usual in more privileged schools. Being ‘given’ the marks would mean that learners would start their grade twelve examinations with 25 of the 30 marks needed to pass a subject. In the end the only outcome of this campaign was further disruption of teaching and learning.

When the siren went for the end of the double lesson, the teacher and class ignored it and continued with the discussion initiated by a learner who asked a question. The teacher ended the lesson by telling the class representative to collect the handouts the teacher had collected from the staffroom at the start of the day, and told the class to do number 8 for homework. I put my laptop on standby and switched off my video camera. I stuffed my laptop into its bag, and grabbed the tripod with the video camera still attached. Mr Dube offered to help me with my load, but he was already carrying everything he collected before the lesson, so I declined his offer.

We walked together to his car. "I'm really enjoying being in your class" I said. "Really Ma'am?" he replied. He opened his boot to get out what he needed for the next lesson, a grade nine Technology lesson. I asked if I could watch, curious as to what happens in Technology lessons.

After the lesson came the 'short' break[14]. We went up to Mr Dube's office. I encouraged him to do whatever he would normally do during break. I spent break and the next period (another grade nine technology lesson) in his office. I tidied up my narrative descriptions of the lesson I'd just watched and looked with curiosity at the grade nine Technology textbook.

The teacher collected me for the next lesson, a double period with 10B. Then it was the 'long' break, and I encouraged the teacher to join his friends, while I worked in his office. After break, the teacher had his first free period, and so we had a conversation which I audio recorded. I asked questions about the lessons I had observed, and asked him to tell me his story of becoming a teacher. Then we went to 11B's classroom for their lesson. After school, I asked Mr Dube if we could have another twenty minute conversation, and in this conversation, I asked him about 11B's lesson and he continued his story of becoming a teacher. After we finished, we continued talking as we walked down the stairs and I made a mental note to jot down his comments as soon as I reached my car. As I drove out of the school, I saw the sign on the gate of the house opposite: 'chickens, ice-creams, airtimes sold here'.

Later I watched the videos in order to complete the lesson narratives. Although the focus in the narratives was on description, I made comments in square brackets along the way, and also made notes under a heading of 'reflection' – I tried to not lose any insights I had

[14] Recess

as I worked with the data. The videos would not be transcribed. I also wrote a summary of the whole day, detailing the order in which the lessons and conversations happened, and where breaks fitted in. I listened to the audio recordings of our conversations, and decided what needed transcription. I made notes for my transcriber, including names of people and a vocabulary list of science terms with which she might not be familiar. In due course when I received transcriptions, I would listened to the recordings again, and make changes as I saw fit. My data would then be ready for analysis, although in reality the process of analysis had already started with my comments and reflections.

3.7 Classroom Observation

The above story describes a typical day of data collection, and illustrates some of the practicalities of data collection. The story is a narrative composite insofar as 11A had signed letters previously, so I did not need to get them to sign again. Hence the part of the story which describes the way I enacted the ethics requirements has been inserted into a day which is otherwise a description of one actual day of data collection. I chose this day because it illustrates some of the practicalities of teaching in a township school. I will argue for the trustworthiness of the data which emerged from such a day, by considering the threats to validity, and the ways in which my actions in the above story were intended to address them. In so doing I will provide the rationale for the choices which I made. Although the classroom observation and the interviews were interwoven in the course of a day, I will discuss them separately because there are different rationales and validity issues for the two instruments.

3.7.1 Classroom Reactivity Threat

There are two significant threats to the validity of classroom observation: reactivity and researcher subjectivity. I will first unpack each threat and then describe the steps I took to minimise and accommodate it. The obvious way to find out what is happening in classrooms is to spend time in them. However classroom observation is not straightforward. A classroom with a stranger added is to the normal classroom situation as Survivor ‘reality’ television is to true pioneering – it may look good on television, but the presence of the television cameras changes the reality. Although I wanted to be a non-participant observer, the very act of introducing an observer into a classroom changes the dynamic of the classroom: in the metaphor of modern physics, the introduction of the measuring instrument changes the quantity being measured. The observer is an intruder into the space which teacher and learners have co-constructed over the course of time – on the stage of the classroom there are now three roles instead of two, and the third role changes the other two merely by its existence. Thus the first threat to the construct validity of classroom observation is reactivity.

With regard to reactivity, there are two reasons why a teacher's production in the classroom might deviate from typical because of the presence of an observer. Firstly it is human nature to put forward one's best self when being observed – it is a normal part of maintaining self-esteem. This may have affected both the teacher's preparation for the day, and their performance on the day. In the particular situation of my observing past students, this tendency had the potential to be exacerbated by the historical power relations between us, i.e. our historical positioning as student and lecturer. Second, as a teacher myself, I know that the presence of a peer affects what I do insofar as I start to engage in metacognition while teaching, in a way that I do not normally do: as I perceive my peer assessing me, I start to assess myself. This has both positive and negative consequences for my teaching: it makes me self-critical which feeds back positively into my teaching, but it also distracts me somewhat from the immediate task of teaching. So I anticipated that the teachers I worked with could experience the same effect. This effect is likely to be heightened to the extent that the observer is in a position of power over the observed.

I anticipated that the learners would also be affected by the presence of an outside observer, although my relationship to the learners was different from my relationship to their teacher. To the teachers I was a known quantity, someone with whom they had an established relationship. To the learners, I was a stranger. To the extent that they perceived me to be in a position of power, they may have been intimidated in their normal behaviour, be that participation or disruption. The introduction of a stranger does not have a constant effect which can be factored out: as a teacher educator I sat at the back of student teachers' classrooms where my presence appeared to have no effect on the misbehaviour of learners, and in contrast I sat in the back of classrooms where learners dug their disruptive peers in the ribs, with a glance over their shoulders to remind them of the presence of the stranger.

I have identified three effects which I anticipated my presence would have on classroom dynamics: an effect on teacher effort and preparation; an effect on the teacher while teaching; and an effect on the learners. For both teacher and learners, the effect of the observer was exacerbated by the presence of a video camera – the video camera was in effect a second observer. However I chose to use a video camera even though it contributed to reactivity because it allowed me to revisit lessons and hence improved the descriptive validity of my lesson narratives (discussed in section 3.7.3). In this situation the value of descriptive validity won out over the threat of increased reactivity.

3.7.2 Ways Reactivity was Addressed

Given these effects, how can I argue for construct validity? Firstly, I have noted that the first three of the above effects are exacerbated by power relations. I therefore took steps to construct myself with as little power as possible in the classroom. This was fair and ethical, since I was not in fact in a position of power, but merely an invited guest who was no expert on the questions I was asking in my research – I was not asking questions to which I already knew the answers. My role was not to judge but to understand. However I knew that learners were likely to assume that a visitor was someone important, and so I needed to explicitly detract from this assumption.

I did four things to try to reduce the power with which learners perceived me. The first is I avoided ‘power dressing’ – I paid attention to how I dressed, and deliberately dressed fairly casually in order to detract from an image of myself as an authoritative person in the classroom. The second is I asked teachers not to introduce me as their ‘lecturer’, since I felt this would place me in a position of authority above the teacher, and hence in higher authority over the learners. Instead I asked to be introduced as a researcher who is “trying to understand what happens in science classrooms” or allow me to introduce myself, as Mr Dube chose to. This positioned me as a researcher wanting to discover rather than an authority on science teaching. In so doing I chose to story myself with my identity as researcher rather than my identity as lecturer. I also deliberately included my first name in introducing myself, to signal a smaller gap in status between myself and the learners. Third, I used a vernacular greeting where appropriate and humour to establish a rapport with learners. The line about movie stars worked particularly well with junior classes. This was not something I planned to do before I started data collection, but I realised in the situated setting of a classroom that I could use this approach. Evidence of the rapport I established is the way learners sometimes asked me for help during lessons, though this challenged my position as a non-participant observer. Fourth, I positioned learners as agents with a choice to help me with my research. The pre-observation discussion described in *A day with Mr Dube* was typical. The experience of a colleague (Carola Steinberg) in using classroom observation was that adult learners settled into the presence of an observer far more easily if the observer greeted them, explained her presence and gave them a chance to ask questions. Hence I included these three elements in my pre-observation discussion. Sometimes I forgot to ask a class whether they had questions, but the nature of my initial interaction with them was such that they sometimes did anyhow.

I also positioned the teachers as agents helping me with my research, both in what I said to the learners about the teachers, and also when organising the visit beforehand, in order to reduce the effect of our historical power relationship. I also gave positive but non-leading feedback to teachers in the course of a day to help them relax and not worry about my assessment of them, for example "I'm really enjoying being in your classroom." I tried to make it clear that the research situation was fundamentally different from the 'crit' lessons[15] I observed when they were student teachers. Although I was their past lecturer, I was at least not a stranger to them – we had an existing positive relationship on which to build the research.

In addition to building in measures to ameliorate power issues, there were other aspects of my research design which contributed to reducing the reactivity of the research site. I was explicit to both teachers and learners about what I wanted them to do. I told learners "The best way you can help me with my research is to pretend I'm not here." When I organised my first visit I told the teacher that I wanted to see ordinary days; that I was not expecting a special show. Observing a whole day at a time rather than a single lesson contributed to this aspect – it is easier to 'pull out all the stops' for a single lesson.

The amount of time I spent in each teacher's classroom also meant that teachers got accustomed to my presence in the course of the two days, and hence were less obstructed by the peer-induced metacognition described in the previous section. Indeed, as I will show in section 4.1.2, some of the teachers reported that they forgot about my presence for

[15] 'Crit lesson' is a colloquial term for a lesson taught by a student teacher, observed by a tutor who 'crits' (critiques) the lesson, i.e. judges the lesson against certain standards, and ultimately assigns a mark reifying the quality of the student's teaching.

part of the second day of observation. As mentioned in section 3.1, I also only observed lessons once teachers and learners were established in their normal classroom routines.

While I knew my video camera contributed to reactivity, I hoped the fact that it was unattended reduced this effect, because it is easier to ignore a camera which has no-one behind it. Also the position of the camera – out of the general field of view of learners – helped them to ignore it. My position at the back of the classroom (unless there wasn't space there, as happened in a couple of Mr Hlope's lessons) means that I was also typically out of the field of view of most learners, which helped them to ignore me. However, when learners were engaged in individual or group work, I wandered around to see what they were doing, aware that in doing so I was increasing the reactivity to the extent that sometimes the learners adjusted what they were doing as I approached. I felt that the data which I obtained from walking around was more valuable even with the reactivity taken into account, than data collected without moving would have been. So again the value of descriptive validity won out over the threat of increased reactivity.

Despite these measures to reduce reactivity, I expected my presence to affect the dynamic of the classroom, as an intruder into the space which teacher and learners had co-constructed over the course of time. I thus explored the reactivity in the interview, by asking the teachers afterwards what effect they felt my presence had on themselves and their learners. I report on their responses in section 4.1.

In summary, there were two broad moves I made to maximise the construct validity of classroom observation as a measure of normal classroom practice. The first was to attempt to reduce the effect of my presence on the classroom dynamic, particularly by addressing possible perceived power relations in the eyes of the teacher and the learners. The second was to recognise that the experimental situation – with measuring instrument present – was necessarily different from the normal situation, and thus address this in the interview and analysis. In other words, I took steps to reduce reactivity and to account for it. Overall, I recognise that an observed day is at best an approximation to the theoretical construct. From a Bernsteinian perspective, "the empirical site of educational research is, in this sense, consumed by research and this consumption entails the transformative recontextualization of the site" (A. Brown & Dowling, 1998, p. 164). My recontextualising a site of learning into a site of research changed the nature of the site, and hence the validity of the observed lessons is not absolute.

Even without an observer present, there is uncertainty about the extent to which any particular day serves as a typical day. In the normal course of events, there is variation from one day to the next, caused both by the ebb and flow of the processes of teaching and learning, as well as by external factors which impact on the classroom. In the South African context, these can be significant (Clark & Linder, 2006) such as the possible COSAS strike threatening the peace in Mr Dube’s classroom. Vithal and Valero (2003) argue that conflict and disruption can amount to the norm in the South African context and should not be avoided for situations which seem more conducive for research. However in each case, the second day I observed seemed familiar to me – the way in which lessons proceeded and the ‘feel’ of the classroom reminded me of the first day’s visit. This reassured me that the days I watched were reasonably typical, and hence a fair measure of practice.

3.7.3 The Development of the Observation Instrument

While planning my research, I was deeply concerned about the threat of researcher subjectivity to classroom observation, a point I explore further in section 3.7.4. Hence I felt it was important to use some sort of observation schedule to communicate my intention and subjectivities up-front, and focus my attention productively. In *A day with Mr Dube*, I told the story of one day of data collection – the seventh day overall. By this time the process of data collection was stable. However it would be wrong to convey the impression that every day proceeded like this – instead I learnt about and improved on the process of data collection through the process of data collection. The purpose of this section is to tell the story of the development of my observation instrument. Through this story, I will explain some of the choices which I made, and in so doing provide the rationale for the particular observation instrument which I used. It was only in the process of doing the research that I became sufficiently aware of the issues to make these choices.

As a teacher educator, I had sat in hundreds of lessons, ‘critting’ student teachers by judging them against certain standards, and assigning marks which reified the quality of their teaching. For this research, I wanted to be able to see science classrooms with new eyes: instead of judging lessons, I wanted to learn from them. Recognising that instruments shape observations and open or close different aspects, I wanted to use an instrument which would both made my foci explicit up front, and interrupted my normal practice of classroom observation.

I wanted an instrument which would capture the breadth of the repertoire of teachers, rather than focusing on a particular aspect – I wanted a wide angle lens. I also knew that the content of a lesson is important: that it is not enough to look only at form, but that it is easy to get distracted by form. Some available observation schedules focused on form, for example looking at the nature of teacher and learner activity every thirty seconds (Newton et al., 1999) or five minutes (Lawrenz et al., 2002). Observation schedules which looked at content judged it rather than capturing it, as I will show in section 5.3, whereas I wanted to withhold judgement until analysis. I also found that while many studies use classroom observation, their observation schedules are often not readily available.

I found it helped to ask the question: what is my unit of analysis? In response my co-supervisor suggested working with activities rather than lessons, since a lesson can be made up of discrete or even disjointed activities as teachers work to use timetabled time efficiently. Out of this emerged the observation schedule in Figure 13. Looking at this schedule, it is clear that I was interested in both the content and the form of lessons. The sections on ‘talk’ and ‘teacher interventions’ draw from Mortimer and Scott’s (2003) work on classroom talk. The idea of roles draws from Brousseau’s notion of the didactic contract (mentioned in section 2.1.3), according to which both teacher and learners have expectations of their own and each other’s roles in the classroom. However on my first two days of data collection, I realised that the idea of writing ‘field notes’ on a lesson (the last section of the observation schedule in Figure 13) was too vague and as a result my field notes were inadequate. In addition I realised how slowly I write compared with the efficiency with which I type, hence I resolved to use my laptop in future.

Classroom Observation Schedule
Lesson no: Grade: Topic:
Activity no:

Form: Chalk and talk / Teacher demonstration / Hands-on experiment / Exercises /
Mode: Whole class / Group work / individual /
Object of science constituted: knowledge / skills / values + attitudes; strong / weak boundaries:

Sources of knowledge: teacher / learners / textbook / internet / other electronic / handout (textbook / teacher knowledge) How used? (Authoritative/ dialogic)

Physical resources: science apparatus / models / everyday apparatus / textbook / handout. How used? (Textbook: source of homework exercises / structuring of teaching / practical exercises / source of information for learners)

Talk: Dialogic / authoritative; interactive / non-interactive; teacher-learner / learner-learner; scientifically accurate language / everyday language / mixed code)

Teacher interventions: shaping ideas, selecting ideas, marking key ideas, sharing ideas, checking student understanding, and reviewing

Use of learner ideas (preconceptions; everyday intuitive ideas; alternative conceptions revealed in questions; open-ended questions; learner input disrupts lesson plan; learner journals; learner-learner interactions)

Nature of tasks: (plug + chug / open-ended / Herron's level of inquiry) how used?

Teacher role Present information / Manipulate apparatus / answer questions /facilitate

Learner role Listen; answer questions; record /Observe, Manipulate apparatus/

Assessment:

Field notes: Critical incidents / moments which do not fit above / other field notes / A metaphor for the activity?

Figure 13: First observation schedule

My second attempt at a classroom observation instrument was an existing classroom observation schedule which was developed and used in a study of teacher take-up of in-service training in mathematics, science and english (Adler & Reed, 2002). This schedule seemed appropriate for a number of reasons. Firstly, it was developed and used in a South African context, and so takes cognizance of local issues, for example the availability and use of resources, and the use of multiple languages. Second, the researchers were also interested in teacher take-up of training – although the training was in-service instead of pre-service. Third, the study in which it was used was extensive, using multiple researchers observing 25 teachers, and so this observation schedule has been adequately tested and validated. This schedule contains a checklist of classroom resources, and rubrics for evaluating the use of group work, resources, language, questions, explanations and learner ideas. It also involves writing the story of the lesson as it unfolds – effectively using a narrative approach, which seemed appropriate in the context of my study.

However after using this schedule for two days of observation, I abandoned the rubrics. I found that many options simply didn't work for the lessons I watched – they seemed designed for mathematics lessons. Also I found it difficult to reflect on and evaluate the lessons while they were still in progress – one cannot be sure until the end of a lesson that a particular approach has not been used. In the study in which this observation schedule was originally used, only one lesson was observed at a time, so it was possible for the observer to spend some time after the lesson completing the rubrics. In contrast in my study I typically went straight on to watching another lesson so did not have time.

However, I found the telling of the story of each lesson as it unfolded both powerful and manageable. A focus on description meant that I could suspend judgement, and so I found that this method gave me the 'new eyes' I was looking for. The purpose of the narrative of the lesson was rich description, rather than evaluation of the lesson, or focusing on a particular aspect of the lesson. I also recorded all writing on the board. When teachers used the board extensively, I told the story in a two column table, with the right hand column giving the board work, and the left column describing the concurrent action. I added to the narrative when I watched the video of the lesson afterwards. I kept a modified version of the resources checklist which I completed every lesson, but I relocated the questions pertaining to the classroom space into a 'classroom description' schedule which only needed to be completed once per venue. In the end this second observation schedule gave me a powerful instrument in the form of the lesson narratives, and helped me to pay attention to some details which I may otherwise have overlooked. A similar narrative approach was used by Rowland, Huckstep, and Thwaites (2005) who wrote what they called a 'descriptive synopsis' of each mathematics lesson they observed, but this was written after the lesson with reference to field notes and only occasionally a videotape.

In due course I went back and wrote lesson narratives for the first four days of data collection, working from the videos, the old observation schedules and my field notes, such as they were. In some ways the early data collection was messy, but this messiness can be seen as reflexivity in data collection (Lather, 1986) – allowing my experiences in collecting data to inform further data collection. I learnt a lot about myself as a researcher from the first few days of data collection which improved the way I went about data collection. I also started analysing the observation data before I had finished collecting it, as recommended by Kvale (1996), which contributed to my improvement as an observer and reassured me that my approach was indeed 'fit for purpose'. Does the fact that I improved over time lessen the validity of my earlier data? I think not – there were measures in place from the first day of data collection to address site reactivity.

3.7.4 Researcher Subjectivity

In the last section I gave my rationale for the observation instrument I used, by locating it in relation to other approaches and by looking at the ways in which it addressed problems I encountered in practice. This section continues that rationale, by looking at how the observation instrument addressed the major threat which researcher subjectivity poses to classroom observation. While reactivity affects what actually happens in the classroom, researcher subjectivity affects what the researcher *notices* of what happens – the observer is a particular measuring instrument. A lesson is a complex event involving a number of actors engaged in parallel activities, and hence classroom observation is not a straightforward exercise. Because of my subjectivity (described in section 1.4.4), I paid more attention to certain details, and less attention to other details. Breen (2001) demonstrates how different people make contradictory observations after watching the same video, which he explains using enactivism, a theory of learning which derives from complexity theory (see section 2.1.3). Each person responds to a situation based on her unique biological make-up and history. He concludes that:

> the results obtained and reported are more likely to tell us a great deal more about the researcher and his/her historical predispositions than they do about the researched target. (p. 6).

Thus another observer is likely to reach different conclusions about the same lessons. All observation is theory laden, and hence it is naive to hope to objectively view lessons.

The narrative approach which I used addressed the threat of researcher subjectivity by producing rich data. Maxwell (1996) sees rich data as contributing to what he calls 'descriptive' validity, which also addresses the threat of inadequate capturing of data. Descriptive validity is about both the quality and quantity of the data – a large quantity of poor quality data would not lead to descriptive validity. The narrative approach informed the quality of the data by assisting me in fulfilling my role as an observer rather than a judge, since judgement was appropriately delayed to analysis. The narrative approach also provided sufficiently detailed data.

The video contributed to the richness of the data by allowing me to revisit the lesson and fill in more details on the lesson narratives afterwards, though the camera had a slightly different view of the lesson from me. However the video was not without its limitations: as mentioned (section 3.6), it did not capture all learners, though some laboratories had sufficient space behind learners that I could capture a greater proportion of the class. The soundtrack captured most of what the teacher said clearly, but not all learner contributions, and for group work the soundtrack tended to pick up only the overall classroom hum. Thus it was difficult to add more to my description of group work.

Apart from rich data, another way to address researcher subjectivity is to be transparent about the approach used, allowing a reader to make judgements about the quality of the data. Hence my description above addresses researcher subjectivity, not by reducing it but by making the methodology coming out of my particular subjectivities explicit. As an additional contribution to transparency, I will now describe where my attention lay during lessons. When the teacher was talking, my focus was mostly on the teacher. Overall what was observed most easily was that which was in the public domain of the classroom, i.e. whole class discussions – thus these are privileged over other interactions and documented in most detail. When learners worked in groups or individually, I walked around but this only gave me a sample of what was happening and slowed down my rate of observation as I needed to walk back to my laptop to note what I had observed. Whether watching teacher or learners, the reality was that when I typed, my eyes were drawn to the screen of my laptop, and so sound was prejudiced over sight. The very act of recording my observation thus rendered me a less astute observer.

A question worth asking in regard to my subjectivity is, to what extent was my experience of the lesson comparable to that of the learners? With regard to content knowledge, I generally knew more than the learners because of my physics background, but in some cases this was not true, for example lessons on biology and some of the chemistry which is new in the curriculum. In these cases, I was better able to ‘receive’ the content as received by learners. One way in which my experience of the lesson sometimes differed from learners is that I did not always have a copy of the worksheet or textbook they were using during the lesson, but I usually got a copy afterwards, and used it when watching the video.

Thus far I have mentioned rich data and transparency as ways to address the threat of researcher subjectivity. A third measure was to talk to the teacher about the lessons, sometimes asking questions I jotted down while watching the lessons. This was a member check – it brought the research subject's point of view to the observation, and in some cases interrupted my assumptions, thus challenging my subjectivity. I will give some examples of such questions when I describe the content of the interviews (section 3.8.2). Another member check was provided by giving the lesson narratives to the teachers, although, as mentioned in section 3.5.2, this did not lead to any feedback.

3.8 Interviews

Having given the rationale for my approach to classroom observation, I now turn to my other instrument, the interview. In the context of phenomenography, Booth (1992) argues that 'methodological validity' arises from the sound use of the phenomenographic method. I will argue for methodological validity by considering the two main threats to interviews – poor quality interview content and poor quality capture of the interviews – and the ways in which I have addressed those threats. With regards to the content, both the way in which the interviews were conducted and the way in which the questions were asked have bearing on the validity, so I will consider these two aspects separately. In so doing I give my rationale for both the nature and the content of the interviews.

3.8.1 The Nature of the Interviews

Kvale (2006) argues that there are significant power relationships at work in interviews, and criticises qualitative researchers for failing to take these into account. Kvale recommends that transparency is one way to address power issues, so that readers can judge the possible effects of power play for themselves. Hence in this section I will describe how I addressed power issues in the nature of the interviews.

As mentioned, I was very aware of the reality of a historical power relationship between myself and my past students, and so was concerned about the nature of the interviews.

Early in my 2010 data collection, I came across the idea of interviewing as a conversation and this resonated with me. I enjoy finding out about other people's lives: in social gatherings, I try to get people to talk about their passion and I discover fascinating windows onto other worlds as a result. Framing the interviews as conversations helped me to draw on my strength in this regard. I think referring to our discussions as conversations rather than interviews also helped the teachers to relax and not be intimated by the interrogation of a formal interview. And in truth our dialogues were closer in spirit to informal conversations than to structured interviews.

The notion of a conversation sits well with narrative research. In narrative research, the role of interviewer and interviewee are changed to that of listener and narrator (Chase, 2005). This involves a deliberate shift in power – a shift in who controls the interview. The researcher needs to allow the narrator to tell the stories she chooses (Chase, 2005; Connelly & Clandinin, 1990). This means that the interview goes in directions which the researcher does not anticipate, a point I will return to in the next section.

Although our historical relationship counted against validity because of the asymmetrical power of that relationship (discussed in section 3.7.1), I contend that it also counted towards validity, insofar as the conversations were between two people who knew each other and who had an established and generally positive relationship. In addition the teachers were willing subjects who were enthusiastic about participating in the research.

Another aspect of power is the control I had over a teacher's time in the course of a school day. On the first day of data collection, I made the mistake of spending break time interviewing the teacher, as a result of which we were both exhausted by the end of the day. I realised that I needed instead to let teachers take their breaks as they normally would, and use 'free' periods or time after school hours for interviews. I had no right as researcher to take control of a teacher's whole day.

3.8.2 The Content of the Interviews

Having given my rationale for the nature of the interviews, I now give my rationale for the content of the interviews. In this section I will describe the content of the interviews, and then in the following section I will critique related validity issues. In the previous section I explained how I framed the interviews as conversations. This does not mean that the content of the conversations was random. Before I started data collection, I drew up an interview schedule of the questions I wanted to ask. But I did not look at this formal schedule during an interview – it became instead an internalised roadmap, where the order in which we traversed the roads did not matter. In conversation, teachers often travelled down roads in my map without being specifically directed by a question. In addition I often jotted down specific questions while observing lessons – either questions about a particular lesson or other questions which were triggered in that context – and referred to those questions in the course of our conversations. In preference to providing my original interview schedule, I am providing examples of some of the questions I asked, since they give a better idea of what the interviews actually looked like in practice – see Figure 14 and Figure 15.

My information letter for teachers included the following paragraph, which I hoped would reduce apprehension which teachers might have felt about the prospect of being interviewed:

> Participation will involve allowing me into your classroom for two school days, which would include conversations with you about the lessons and this question: **Please will you tell me the story of what has made you the unique science teacher you are today**. You can give this question some thought beforehand**.** The other questions will relate to the lessons I observe. I will audio record these conversations, and transcribe them.

As this paragraph indicates, there were two foci to the conversations: the observed lessons and the teacher's narrative of becoming a teacher. These often happened in different conversations. Before exploring these foci, I typically started the first conversation with a teacher by asking for details of her experience – what subjects and grades she had taught. This was easy to answer, and helped to put her at ease.

With regard to observed lessons, Figure 14 gives the series of questions I asked Ms Gray about two of her lessons. The first was an introduction to chemistry which she taught to two classes in succession, and the second was a lesson about electrostatics. I asked the teacher first to describe what happened, even though I was present in the classroom and had my own knowledge of what happened. This question helped orientate the teacher to a lesson which may have happened a few periods previously. But the main purpose of this question was to get a window on the teacher's perspective (a second order perspective) and uncover conceptions of teaching – revealed in the focus and discourse of the response.

This approach was suggested in conversation by Mike Prosser who has done extensive phenomenographic research into conceptions of teaching (Prosser & Trigwell, 1999). Teachers' beliefs are often tacit and are constituted in particular contexts, which means they are difficult to access directly through interview questions which invite generalizations, such as "what is your conception of teaching?" Moreover, general questions are more likely to lead to 'textbook' answers, drawn from the jargon of the current curriculum, for example 'learner-centred'.

Grade Ten Introduction to Chemistry

1. Just a few little questions first then we'll get into the content of the lesson. You gave a diary to the boy at the back, what was that story, I'm just curious?
2. And then I wanted to know why in the previous class there was a boy on his own at the front?
3. And then you reminded every class of the test that's in a week's time, how often do you remind them? / For how long beforehand? / Why do you do that?
4. If we could start by you describing what happened in those lessons and then tell me what the purpose is for each bit of the lesson.
5. And then you got them to write some stuff down from the overhead, do you want to talk about that? / And getting them to copy it down instead of giving them a handout?
6. And then the activity after that?
7. And you got them to refer to their work books, to find information, do you want to talk about that?
8. And when you create your overhead transparencies, how do you go about deciding what you put on them?
9. Why did the second class go "aaah!" when you said that they're going to do a mind-map?
10. What difficulties do you find that the grade tens have with this section of work, the basic chemistry?
11. You used the terms macroscopic and microscopic, where does that understanding come from? / How do you know what they've done in grade eight and nine?
12. Where does that strategy, of taking what they randomly say and working with that, where does that come from?
13. That's all I had coming out of those lessons, except for the questions about how you think my being there affected them and affected you?

Grade Ten Electrostatics Lesson

1. Do you want to give me a brief description of what happened in that grade ten electrostatics lesson?
2. What do you think my being here, what effect do you think that had on you and on the boys?
3. You're going to get them to hand in that assignment?
4. And then, when we were walking up, after the lesson, you said, you'll never give them an answer, and they hate you for it. So would you like to just talk about that a bit more.

Figure 14: Interviewer's questions on lessons

The intention with a phenomenographic interview is to approach the phenomenon under scrutiny from different angles, until the phenomenon has been 'saturated' i.e. the interviewer is reasonably sure that they have apprehended the interviewee's conception of the phenomenon (Akerlind, 2005). This happened through discussion of multiple lessons and in addition the narratives gave a window on conceptions of science teaching. I also often asked the purpose of an activity, or what the teacher thought learners benefited from the lesson. Sometimes I asked where a particular strategy came from, particularly for unusual approaches or where I recognised strategies from my own practice. In addition I asked how my presence affected the teacher and learners in various lessons – this was to address classroom reactivity (see section 3.7.2). In an ideal world, it may have been possible to interview a teacher after each observed lesson, but *A day with Mr Dube* illustrates how the interviews were shoehorned into the spaces in a teacher's day. Thus these questions were not asked of all lessons because we did not always end the day with a conversation, i.e. there were lessons which happened after our last conversation for the day. I felt it was unfair to ask on my second visit about lessons which had happened a week or more previously.

I invited a teacher's narrative of becoming a science teacher by asking a question along the lines of "Please will you tell me the story of what has made you the unique science teacher you are today?" The choice of inviting stories (narrative thought) rather than generalisations (Bruner's (1996) logical-scientific thought) in an interview is a deliberate one – it means inviting descriptions of particular episodes rather than generalisations. This is a natural way for people to explain themselves but people may assume in the context of an interview that the interviewer wants generalisations and so stories need to be explicitly invited in an interview (Chase, 2005). I have done so by using the word 'story'. Chase (2005) found that a similar question was surprisingly productive: she asked school superintendents about their career histories. After the initial open-ended question, I used more specific prompts, asking the teacher what was significant for them in the B Ed, and which teachers had influenced them both in the schools they have taught and on their teaching practicums. Figure 15 gives the series of questions I asked Ms Gray. Although it is difficult to see without her responses, the questions often followed logically from what she said.

1. Then I wanted to pick up on the question that I asked you about what do you think it is that's made you the unique teacher you are today? I thought we could chat about that now.
   So where do you think that orientation of yours comes from? Why don't you just go with the flow and do what they want?
2. So what else do you think is distinctive about the teacher that you are? Or what else has influenced you in the way you go about things?
   So what you've benefited from doing that module was being able to produce materials? / In that module you also did a concept map and you did that content representation, the CoRe, and you did an outline of how you would use those materials. Were any of those things useful? / So some of them were but then you realised they didn't work so well? Expand that a bit more. Give me some examples. / So are there gaps now in the notes, or activities or what?
3. Oh, really. Do you prefer it [chemistry] to physics? / Why is that?
4. And maths and science, which do you prefer?
   And what is it specifically about the maths, or the science, that makes the science nicer? / Can you pinpoint why it is that you enjoy it?
5. And your decision to go into teaching, where does that come from?
   So what did you want to do? / Why didn't he want you to go into pharmacy? / And why did you think pharmacy would be a good idea for you? / What? / Why? / Why is that? / And why is he doing that? [digression into talking about current teaching situation]
6. But I want to go back, you said at school you didn't like the way you were taught. Were there any exceptions to that?
   Did you have different teachers for physics and chemistry?/ So tell me a little bit more about your chemistry teacher. / And then the way you were taught chemistry at Wits, did that fit with that?
7. You say that boys want to be in your class, from when did that start, from your first year, from your second year?
   Does the HOD teach matric? / Why do you feel that?
8. Were any of your teaching experiences, your teaching pracs, significant for you?
   Who did you have? / Pictures of Mother Teresa? I can't imagine how that would work. / And did you do quite a bit of prac work at [school name] then? / And when did you do that prac in?
9. [specific questions about two particular projects I did with student teachers]
10. Anything else that you see that's distinctive of what you do or that had an influence on how you teach today?

Figure 15: Interviewer's questions on narrative of becoming a teacher

The classroom observation gave a context for the conversations and helped me understand what the teachers said, as well as providing specific instances where I could ask 'Where did you get that idea?' However, teachers can't necessarily identify where their ideas come from, as this extract shows.

Researcher	And then you work in a very sophisticated way with their contributions, in that discussion that you had after they drew the mind-map. Where does that strategy, of taking what they randomly say and working with that, where does that come from?
Ms Gray	I never thought about it actually. It's not something I've thought about.

While my organic approach led to authentic and interesting conversations, it did mean that I failed to ask important questions of particular teachers. So after I had finished with the first five teachers, I analysed which questions I had asked them. Where there were gaps, I then checked to see whether those questions had been addressed in conversation somewhere. Where there were still gaps, I made a note of questions I wanted to ask, and I asked these in a third visit with each of these five teachers. In this visit, I asked the remaining questions, but did not do any further observation. I also used this visit to give them their packs of data (described in section 3.5.2). I found that I did not need to follow up the last three teachers with additional questions, as I had become better at following my internal interview roadmap.

3.8.3 Validity of Interview Data

In the last section I gave the rationale for the content of the interviews. I now consider threats to the quality of the interview data, apart from the threat of power relations which I dealt with in section 3.7.2. The first such threat is that the researcher may not have sufficient understanding of the topics covered in the interview in order to engage productively in the interview and analysis. In this study, I had good science content knowledge and knowledge about issues in science education, as well as knowledge of the South African context, i.e. the curriculum, the school system, and the history of education. My understanding of these areas came from my training and my experience both as a physical science teacher and as a teacher educator in South Africa. As described in section 1.4.3, I had spent twelve years teaching in a secondary school, and then as a teacher educator spent a total of seven three week periods in secondary science classrooms, either observing student teachers teach, or with an alternative teaching practicum, in which a team of students and I spent three weeks presenting a science outreach programme at a different township school each day. This meant that I had visited well over a hundred local schools.

In addition, I gained understanding of the specific contexts of the teachers in this study through observation of their lessons. Clandinin and Connelly (2000) note that a narrative researcher should be in a context long to be intimate enough with the context to be able to take some of the same things for granted as the participants in the research. I suggest this was the case, given my background described above, as well as the days I spent observing the teachers. Thus I argue that I had sufficient understanding that this threat was not relevant. This leads to what Booth (1992) calls 'content validity', the term I will use, and what Sandberg refers to as "establishing a community of interpretation" (2000, p. 14) which contributes to 'internal communicative validity'. In addition, my other data – observation of lessons – contributed to content validity insofar as my interpretation of what they said was aided by my observation of them teaching.

However this knowledge contributes to the threat of researcher subjectivity, which can mean that an interview is "primarily an interviewer's own creation" (Polkinghorne, 2007, p. 482). The narrative research approach of researcher as listener helps to ameliorate researcher subjectivity and has resonances with Heron's (1981) view of the research subject as co-researcher. Phenomenographers talk of bracketing the researcher's knowledge so that the conceptions which result from analysis are indeed found in the sample, and not simply in the head of the researcher. However it is not always clear how this is achieved, though Ashworth (1999) describes the practicalities of bracketing in his study of student conceptions of cheating. I see the explicit identifying of my subjectivity (section 1.4.4) as a precursor to bracketing: I needed to know what my judgements were before I could bracket them. In the interview situation I drew on my knowledge to make sense of what the interviewee was saying, but was also open to other ways of understanding. In this sense I drew on my knowledge but made an effort to bracket my judgements. For example, I was aware of bracketing when I commented to Mr Dube on the fact that he did not refer at all to notes when teaching, which in my unstated opinion detracted from the quality of his lessons. But I picked up pride in his body language when I mentioned this, and by picking up on this, was able to come to a significant insight: that his learners would see him as not knowing his subject if he referred to notes while teaching.

Another threat to interview data is poor interviewing technique. If interviewees are 'put on the spot' and given insufficient time for deeper reflection, this may lead to unconsidered responses. Polkinghorne (2007) and Lather (1986) both suggest using multiple interviews, as I did. As mentioned in the previous section, I also gave teachers the question about their development as teachers before I visited them, to allow them time to think about it. Kvale suggests that the interviewer should actively try to understand the interviewee's meaning so that "considerable parts of the analysis are pushed forward into the interview situation itself" (1996, p. 277). I read Kvale shortly before the 2010 data collection started and so carried this thought with me, choosing to try to understand the teacher in the moment and not allowing myself to think "I'll make sense of that when I listen to the tape." This meant

I asked productive follow-up questions. This approach sits well with phenomenography's goal of uncovering meaning in an interview. The phenomenographer Akerlind (2005) suggests extended use of the question 'why?' instead of assuming shared meaning, and I can see in the transcripts that I took her advice, sometimes asking a string of 'why' questions. In watching the video of my first interview with Mr Dube in 2009 (I used my video camera because I did not yet have a voice recorder), I realised I worked hard for understanding, and I saw that I supported this effort with encouraging body language and facial expressions. Apart from taking the position of listener, bracketing my knowledge and pushing for meaning, I was also wary of asking leading questions. When I watched the video of my interview with Mr Dube I was satisfied by the way I succeeded in interrogating meaning without directing the teacher.

While my existing relationship and shared history with the teachers was of benefit in the interview situation, there was one way in which it was a threat, in respect of aspects of the B Ed in which I was directly involved. I recognised before I started data collection that, based on our relationship and history, as well as cultural norms, the teachers may have wanted to please me in reporting on such aspects. I thus started with general questions which allowed the teachers to frame any benefits of their teaching qualification in whichever way they saw fit. This strategy worked well – the teachers appeared to have had no problem in identifying other lecturers who had influenced them without referring to me.

I have addressed five threats to the quality of the data in interviews: asymmetrical power relationships, insufficient researcher knowledge, researcher subjectivity, poor interviewing technique, and interviewees wanting to please the interviewer. The final threat is inadequate or inaccurate capture of the data, which is addressed in the next section.

3.8.4 Transcription

Transcripts are useful representations of conversations, but they are not exact representations. Verbatim transcription is impossible – there is always translation involved in moving from the spoken medium to the written medium, and there are choices which the transcriber makes in this translation. The purpose of this section is to argue for the validity of the transcripts of my interview data. I am choosing to call this 'transcript validity'; other suitable terms are descriptive validity (Maxwell, 1996) or referential adequacy (Lincoln & Guba, 1985). O'Connell and Kowal (2005) claim that while there are a number of transcription conventions in common use, transcript validity is not well established:

> The crucial role of the transcriber as the user of a notational system in the very process of transcribing, and the role of the reader who is the consumer of the notational system have still not been adequately studied. This neglect also entails a lack of concern about reliability and validity in the use of the notational systems, both on the part of the transcriber and on the part of the transcript reader. (p. 3 of online version).

Given this lack, I will argue for the validity of the transcripts by explicating the decisions made in transcription and the rationale behind these decisions. In doing so I will argue that the decisions made in transcription rendered the transcripts 'fit for purpose' – they communicate the intention of the speaker to the reader. This is appropriate because the focus of the research was the ideas communicated rather than discourse analysis.

Most of the transcription of conversations between the teachers I worked with and me was done by a professional transcriber. I also did a small amount of transcription early on, which gave me a better understanding of the process of transcription and the decisions one makes in transcription. A critical prerequisite for transcript validity is good quality recordings. My transcriber indicated that the recordings were of good to excellent quality. However three teachers were sometimes unclear in their speech and so difficult to hear, despite the quality of the recording.

Since my transcriber does not have a background in science education, I listened to the recordings beforehand and gave her a list of science jargon which came up in each recording, as well as any names of people. Once I received her transcription back, I listened carefully at least twice to every recording while following its transcript and made changes where I saw fit, which I will describe later in this section. Where my transcriber was not sure of a word or phrase, she indicated such clearly in her transcription. These occasions fell into two categories: either jargon which she could not be expected to know and which I had not included on the list I gave her, or words which were unclear, because of for example Mr Abrams' laughter while talking, or unclear speech, particularly with Ms Cole, Mr Baloyi and Mr Hlope, or a burst of background noise. For the former category – and for some occasions where my transcriber misheard jargon – I was able to correct the transcript. For the latter, if I also could not make out clearly what was said, I indicated such in the final transcription.

One way to argue for the trustworthiness of transcription is through inter-transcriber reliability. This can be done through having two people transcribe independently and then compare their transcriptions. This was not done here, but I contend that the fact that two people worked on the transcripts increased the transcription validity. Furthermore, where we differed, this was not an indication of lack of inter-transcriber reliability but rather reflected our different backgrounds: I knew both the necessary science and the classroom context, and had actually participated in the transcribed conversation, so had access to knowledge which my transcriber did not.

The decisions made in transcription adhered to O'Connell and Kowal's (2005) seven principles for transcription, as I will demonstrate. O'Connell and Kowal's first principle is parsimony:

> Only those components of spoken discourse that are to be analysed should be transcribed, and only what makes analyses intelligible should be presented in transcripts for the reader. (p. 12).

The following transcription decisions were made in this regard. Words such as 'um' and 'uh' which did not add to the meaning were omitted, as well as other 'fill in' words. For example Mr Hlope used 'you see now' regularly and Ms Cole used 'you know', 'like' and also 'so.' at the end of a sentence. My transcriber and I fairly consistently left out these words or phrases where they interfered with rather than aided meaning. However we left some pet phrases, such as Ms Cole's 'and that sort of thing'. Second, I tend to verbalise affirmation instead of just nodding my head, so we omitted my 'yes', 'okay, 'right' and other affirmations. Finally we omitted repeated words where the teacher repeated themselves as they formulated what they were saying. Similarly where a teacher corrected themselves, only the correction was included. These decisions addressed the reality that the spoken word is often messier than the written word, and rendered transcripts which are easily intelligible. Since the transcripts were not only used for analysis but also in reporting on the research, this last point is important.

O'Connell and Kowal's principles of 'conventionality' and 'lexical integrity' promote punctuation as conventionally used in writing, rather than using a special system of punctuation and other symbols for representing intonation. Related to this, we used what transcribers refer to as ‘standard orthography’ – spelling as found in a dictionary. Thus ‘gonna’ became ‘going to’, ‘wanna’ became ‘want to’ and ‘coz’ became ‘because’. I felt the teachers themselves would write it that way, despite how they said it. However where my transcriber alternated between using ‘yeah’ and ‘yes’ for the Afrikaans ‘ja’ often used by South Africans, I changed this to the original ‘ja’. We used the teachers’ original grammar, rather than presuming to correct grammar.

All of the above deals with the words used in transcription. I turn now to the other aspects of transcription. Laughter was described in words, consistent with O’Connell and Kowal’s principle of ‘description’. The choice to not use a symbol system to represent intonation means that conventional punctuation has to work hard to convey the intonation and rhythm of the original spoken word and support the meaning of the written word. Whereas actual words are fairly straightforward to record, there is considerable interpretation and construction in punctuation. Mostly I agreed with my transcriber’s punctuation, but there were two changes I made consistently. Firstly I included inverted commas for reported speech, which made it clearer in the transcript – as it typically was in the recording because many teachers used a different voice to imitate others’ speech. Second, my transcriber used ‘...’ both for a pause and for someone interrupting themselves, so I changed the transcripts to indicate an interruption with ‘–’ and pauses as ‘[pause]’ thus removing the ambiguity. This accords with O’Connell and Kowal’s principle of ‘one-to-one correspondence’ of symbols.

O’Connell and Kowal’s remaining principles are ‘objectivity’ and ‘separation’ whose consequence is that any comments on the transcript should not be confused with the transcript itself. In my research these were not included in transcripts but rather inserted as annotations in the data analysis programme (nVivo).

I have demonstrated how the transcription of the interview data measures up to the standards set by O’Connell and Kowal. While theirs is not the only way to go about transcription, it was suitable for the purposes of my research, as it led to good readability of the transcripts and conveyed meaning clearly. Both the decisions made in transcription and my transparency regarding the decisions made in transcription contribute to the validity of the transcripts. In addition there was generally good agreement between myself and my transcriber over the transcription, and the differences which existed were mostly a consequence of our different backgrounds. In effect transcription was the first stage of data analysis, and I oversaw this process in detail. In the next section I consider the validity of the rest of the analysis, but first I consider two other aspects of the transcripts.

I changed people's names on the transcripts, not to add to transcription validity but because of ethical considerations. I left learners' first names because I felt that use of their names would not disclose the school involved, because of the large number of learners involved in this study. Also their names were sometimes used in the observed lessons, and so it was helpful to be able to tie them together. However I referred to other teachers as e.g. '[senior science teacher]', since it would be possible to identify a school from the teachers' names.

Recorded conversations are privileged over other conversations, for example conversations which happened as I walked with teachers between classes, as happened in *A day with Mr Dube*. One way I dealt with this was by keeping field notes about interesting points which came out of these conversations, but the actual words of the teachers were lost in the moment. Another tactic I used was to try to pick up such conversations later, when my voice recorder was active. However this was mostly not very successful – the conversation situated in a particular moment in space and time could not be reconstructed in another moment. For example, on one occasion Mr Abrams said something in passing about the difference between mathematics and science teaching before he went to break. At the end of break, I tried to pick up this conversation, but the later conversation did not have the same sense as the earlier conversation. Experiences such as these meant I sometimes left the recorder going through details which didn't need transcription – in case the conversation digressed into something worth transcribing. Recognising a degree of arbitrariness as to *which* conversations were recorded, I chose to not transcribe details for which I felt the teacher's voice did not add to the data, for example details about which classes she taught, but these details were all captured in other ways.

3.9 Validity of Analysis

The ultimate purpose of attention to validity is to provide results which are trustworthy. The next four chapters present the analysis and results of my research. The way in which I report on the analysis and present the results will contribute to the validity of the analysis. But in this section, I want to consider validity issues which cut across the different analyses. Researcher subjectivity is a threat to the validity of analysis and I mentioned in section 3.5.2 that I had the benefit of extensive peer feedback to address this threat.

A second strategy to address researcher subjectivity is to use validated methods of analysis. I used QSR nVivo 8 to manage my data and to code the interview data. I used a phenomenographic analysis for conceptions of teaching science (Chapter 7). Richardson (1999) argues that a phenomenographic analysis uses the same approach as grounded theory (Strauss & Corbin, 1990). Both approaches derive their validity from allowing categories to emerge from the data, rather than having preconceived categories imposed by the researcher – hence minimising researcher subjectivity. As mentioned in section 3.8.3, phenomenographers talk of bracketing their own ideas, both in interviewing and in analysis. I describe how I did this in analysis in section 7.1. Some phenomenographers use intercoder reliability checks or what they call 'dialogic reliability checks', but:

> A common alternative to these particular forms of reliability checks is for the research to make their interpretive steps clear to readers by fully detailing the steps, and presenting examples that illustrate them (Åkerlind, 2005, p. 332).

I do this for my phenomenographic analysis (Chapter 7).

In addition to phenomenography, I used narrative inquiry (Chapter 6) which is also an established methodology (Chase, 2005; Polkinghorne, 1995). I used a grounded analysis (Strauss & Corbin, 1990) for my analysis of the activities in lessons and compared my results to similar frameworks (Chapter 4). In the relevant chapters I give details of these analyses but here I make a claim for interpretive validity (Maxwell, 1996) as a result of the well validated methods I used. However, my analysis of the content of lessons did not have a well-established methodology to draw on, since content of lessons has been something of a blind spot in research (section 2.2.6). Hence I explicate my approach to lesson content clearly.

The second major threat to data analysis is that there may be a gap between the measured constructs and the corresponding theoretical constructs, thus detracting from construct validity. The constructs this applies to are conceptions, identities and narratives. It is a fundamental tenet of phenomenography that conceptions can be uncovered through appropriate interviewing and analysis. Thus one could argue that construct validity is an assumption of phenomenography arising from the epistemology of phenomenography. A similar argument can be used as regards narrative: a narrative is the story told in the interview situation. However, Polkinghorne warns that there is a "disjunction between a person's actual experienced meaning and his or her storied description" (2007, p. 480) in an interview due to the limitations of language, of reflection and of the interview situation. The limitations of language are heightened where the narrator is not using a first language, which applied to the majority of my sample, though they all spoke English very comfortably.

Another reason for a gap between the measured constructs and the theoretical constructs is the contribution of the researcher. The researcher contributes to the construction of conceptions, identities and narratives in the dialogic interview situation, as well as in analysis since the analysis goes beyond description to theory building, particularly with conceptions. I tried to narrow the gap between the theoretical and measured constructs through methodological validity in the interviews, as described in section 3.8.3. The way in which I have performed my analysis of conceptions, identities and narratives also contributes to construct validity, and is reported in Chapters 6 and 7.

I mentioned in section 3.7.3 that I started analysing the observation data before I had finished collecting, and the same was true for the interview data. This means that data was treated unevenly: earlier data contributed more to theory building and later data more to confirmation. The extent of this varies for the different analyses. This may have detracted from the validity of the data analysis. However such reflexive practice strengthened my methodology overall – an example of which is the way in which my observation instrument improved (section 3.7.3).

Phenomenographers talk about pragmatic validity and communicative validity, terms coined by Kvale (Åkerlind, 2005). Pragmatic validity is the usefulness of the research, for which I make no claim, though I hope it will feed productively into pre-service science teacher education and education more broadly. Communicative validity in analysis is achieved if the research is communicated in a way which makes sense to and is accepted as plausible by the intended audience. Member checks can be used for 'internal' communicative validity (Booth, 1992), also called face validity (Lather, 1986). However, Lather warns against "reducing explanation to the intentions of social actors" (1986, p. 262). From a critical theory perspective, teachers may be unaware of how their perceptions are limited by dogma imposed on them (Lather, 1986) – for example Outcomes Based Education or Continuous Assessment – which they may accept without realising how they are oppressed by it. From this perspective, the 'triangulation' gap between theory and practice mentioned in section 3.5.2 is appropriate. Thus while analysis needs to take into account teachers' responses to it, it should not be limited by it. Hence I gave each teacher a summary of her journey into science teaching, thus providing the opportunity for a member check, but did not expose my analyses of conceptions and classroom practice to member checks.

The final stage of analysis is the reporting where 'external' communicative validity is sought. This has to do with the way the results of the research are reported, such that "teachers and others in the field should be able to recognise the results which are described" (Booth, 1992) with these results supported by evidence and finding their place in the context of the research field as a whole. This resonates with Polkinghorne's comment in the context of narrative research that "validity is a function of intersubjective judgment. A statement's validity rests on a consensus within a community of speakers" (Polkinghorne, 2007, p. 474). I attempt communicative validity in the way I report my research, by detailing how I arrived at my results for all analyses, and using the participants' own words in reporting the conceptions, identities and narratives.

I strove for validity in my data analysis by paying attention to the threat of researcher subjectivity and the threats which undermine construct validity and communicative validity. Ultimately the judgement about the degree of trustworthiness of my research lies with the reader, and cannot be made on the basis of what I have reported in this section, but rather on the reports of the analyses themselves in the next four chapters.

3.10 Conclusion

This chapter started with the rationale for my choice of research instruments, a description of the sample and an overview of the data. I explained how the ethical principles of 'no harm' and privacy were fundamental to my research although I encountered ethical dilemmas in classroom observation. In section 3.5 I said that I would make an argument for the validity of my research by considering threats to validity and strategies to address these threats. That argument has framed the rest of the chapter, and is summarised in Table 4 which shows the threats to validity, the related types of validity and the strategies which I used for each stage of the research. My list of threats, the strategies to address those threats and the resultant types of validity is not exhaustive. I made choices in constructing my validity framework: I could have constructed it differently and indeed did experiment with different options. In the end I consider my validity argument to be appropriate for my epistemology and methodology.

In this chapter I considered my two research instruments separately though in reality they were interleaved in the course of a day of data collection, as *A Day with Mr Dube* (section 3.6) illustrated, and worked together to help me learn from the research. With regard to classroom observation, I gave my rationale for the ways I reduced and measured classroom reactivity. I then gave the rationale for my observation schedule, by comparing it to other approaches, exploring the ways in which it addressed problems I encountered in practice and showing how it addressed the threat of researcher subjectivity. With regard to the interviews, I gave my rationale for the nature, content and transcription of the interviews. Having given the rationale for both the choice and form of both my research instruments and my argument for the trustworthiness of my data and my analysis of that data, I am now in a position to present that analysis with some degree of confidence in the next four chapters.

Table 4: Validity Framework

	Threats	Types of validity	Strategies
Data collection: Classroom observation	Classroom Reactivity (sections 3.7.1-3.7.2)	Construct validity (observed lessons are a valid measure of normal classroom practice)	• Reduced reactivity: • Reduced power relationships o between researcher and teacher o between researcher and learners (through dress, introduction, positioning of learners as agents with choice) • Was explicit to teacher (before visiting) and learners (at start of lesson) about wanting to see 'normal' practice. • Multiple observations (two days), not too early in year • Left video camera unattended • Positioned video camera and myself out of field of view of learners
			• Understood reactivity: Asked teacher about effect of observer o On teacher o On learners
	Researcher subjectivity (section 3.7.3)	Descriptive validity (description of lessons is adequate and valid)	• Rich descriptive data • Descriptive approach rather than judgemental approach. • Copied down all board work. • Re-watched lesson with video • Transparency of process of observation • Member checks • Discussion of lesson with teacher afterwards • Gave lesson narratives to teachers • Reflexivity & transparency in development of observation instrument
Data collection: interviews	Asymmetrical power relations (section 3.8.1)	Methodological validity – nature of interviews	• Transparency: described nature of interviews • Framed interviews as conversations • Application of narrative interview method: positioned teacher as storyteller • Did not take over teacher's whole day
	Lack of knowledge (section 3.8.3)	Content validity	• My background in physics, my experience as a secondary science teacher and as a lecturer in the programme which the teachers studied.
	Researcher subjectivity (section 3.8.3)	Methodological validity – content of interviews	• Narrative interview method: positioned teacher as storyteller • Phenomenographic interview method: bracketed my judgements • Sought meaning in interview • Avoided leading questions
	Poor quality data (section 3.8.3)	Ditto	• Multiple interviews. • Gave teachers question about development as a teacher in advance.
	Inaccuracy or incompleteness of capturing data (section 3.8.4)	Transcript validity	• Used professional transcriber • Used good voice recorder to capture interviews • Researcher checked transcripts (inter-transcriber reliability) • Adhered to a transcription convention suited to the research • Made transcription decisions explicit • Gave transcripts to teachers (opportunity for member check)
Analysis (section 3.9)	Researcher subjectivity	Interpretive validity	• Peer feedback: presented papers on my analysis • Used established methods of analysis: phenomenography, narrative analysis, grounded analysis.
	Gap between measured and theoretical constructs	Construct validity of conceptions and narratives	• Recognised that conceptions and narratives are co-constructed in interview and further constructed in analysis.
	Inadequate reporting	Communicative validity	• Gave each teacher a summary of her journey into science teaching (opportunity for member check) • Described process of analysis • Used participants own words in reporting

Chapter 4: Lesson Activities

What happens in the classrooms of my past students? As described in the last chapter, I spent two full school days observing the lessons of each of the eight teachers I worked with and wrote a narrative description of each lesson. I also had conversations with the teachers about their lessons. The lesson narratives and transcripts of the conversations are the data for this chapter and the next. I use two different lenses on this data: in this chapter I consider the form of the lessons and in the next chapter I consider the content. These are not the only lenses I could have brought to bear on this data, but they gave me the wide-angle perspective on teachers' practice which I wanted. The research question which this chapter addresses is: What is the form of the activities in early career Physical Science teachers' lessons? In the first part of this chapter, I report on the reactivity of the research site. This applies to the validity of both this chapter and the next. Thereafter I analyse the form of the lessons.

4.1 The Effect of the Observer

I explained in the last chapter my concern about how the trustworthiness of classroom observation data is threatened by the reactivity of the research site. I described how I both reduced the reactivity of the classroom and accounted for it by asking teachers how they felt my presence affected themselves and their learners (section 3.7.2). In this section I first look at how these teachers felt my presence affected their learners, and then how it affected them. In both cases I organise the responses' from least effect to most effect. For practical reasons, I did not ask the teachers about all of the observed lessons, for example some lessons happened at the end of the school day and I did not talk to the teacher again.

4.1.1 Effect on Learners

Ms Fikela, Mr Baloyi, Ms Emeni and Mr Dube felt that my presence had no effect on the behaviour of their learners. Ms Fikela's intervention school often has visitors, so she commented "our kids are so used to having visitors around, it's become such a norm to them, so they don't really act up." Mr Baloyi had expected that his learners might change their behaviour for me, but reported "It could have had an effect for the first five minutes or so of the lesson, thereafter they just forget that you're here."

Mr Hlope and Ms Cole noticed that my presence silenced a few learners. Mr Hlope reported that some of his learners who would normally give answers didn't, because they were afraid of being wrong in front of me. Ms Cole's first impression was that my presence had no effect on the behaviour of a class as a whole, but on reflection she noted that in her grade ten class:

> there were two girls that are usually very on top of everything and would volunteer, and even when I asked the one girl, she gave me some weird answer, it was very out of character for her. So I think it did make a few kids quite shy.

Ms Gray, Mr Abrams and Mr Hlope reported that learners sometimes behaved better because of my presence – this was a different kind of silencing. On my first visit, Ms Gray reported that my presence may have affected a group of three boys at the front who were more focused on their work than usual, but this may also have been because she emphasised that the section she was teaching was important. Apart from these three boys, she reported that my presence had no effect on her learners. However on my second visit, Ms Gray described her classes as rowdier than normal, which she attributed to other factors – the grade twelves' last day of lessons and the imminent announcement of the new head boy. Mr Abrams felt that my presence had minimal effect during the three lessons involving practical work, but that in the two of the 'chalk and talk' lessons, learners were "more reserved" and trying to behave better, for example he noted after a grade eight lesson on my first visit:

> Agh obviously they do notice that somebody's here, so they always say, "Sir, today we have to be at our best behaviour" [laughs]. So they like all behave, you know. So [laughs] it has an effect in terms of the type of interaction that we have.

Mr Hlope noted for a grade nine class:

> But for you being there now, it instilled a lot of discipline on them. They did realise that something serious is happening, they need to behave. More especially when they see the video they thought, maybe our parents is going to be shown this and all this, and then they were so scared.

In this case it was not only my presence but also the camera which had an effect. My explanation to the learners about how the video would be used did not explicitly guarantee them that their parents would not see it, and even if it had, they may not have trusted me. Mr Hlope repeatedly said that I and my camera's presence instilled discipline in his classes.

Mr Dube noted that my presence had an impact on the language of the classroom – he and his learners "mostly use half Zulu, half English" but a greater than normal portion of the lessons were conducted in English for my benefit – working on the assumption that a white observer would not follow Zulu. Initially Mr Hlope also did not speak as much Zulu as he normally would to his grade nines, but after I encouraged him to talk as he would normally do, he did. Thus my presence negatively impacted the communication of bilingual classrooms, a third kind of silencing. On occasion I tried to remediate this by calling out during a lesson to learners to speak Zulu when it was clear they were speaking English for my benefit but struggling to express themselves. I described an example of this in *A Day with Mr Dube* (section 3.6).

Mr Dube felt that, while his learners did not behave differently, they felt privileged to have me visit. I mentioned in section 3.4.2 that the class who did not see me felt left out because "If a science lecturer comes here, to them it's like Jesus is coming here." Mr Dube may have projected his own sense of being privileged at having me visit onto his learners, but there was evidence insofar as the unobserved class expressed their disappointment to him. Similarly Mr Hlope remarked:

> And the other thing is, you being white, you know our learners how they are, yoh, they were like, *uvakasha umlungu* [a white person is visiting] and all these things, then they feel very important. You know, they still have that mentality.

He explained "we were brought up thinking that white people are […] more knowledgeable and responsible." I was surprised by these comments, but they reflect the rarity of white visitors in township schools, and the way race remains a significant marker in an otherwise all-black environment. I note here that Mr Baloyi also teaches in a township school, but some of the staff and learners are 'black' while others are 'coloured'[16], and so the presence of someone of a different colour was less marked.

In summary, according to the teachers my presence as an observer had a widely varying effect on learners: from no observable effect to a marked effect. My presence had both positive and negative silencing consequences: it inhibited bad behaviour but it also inhibited learners' contributions to the lesson. In addition it inhibited communication in classrooms which are usual bilingual. Overall it proved most difficult for learners to ignore my presence in Mr Dube and Mr Hlope's classrooms, in part because they assumed

[16] Mixed race.

I was important because of my skin colour. I note here that what I have reported is not how the learners experienced my presence, but rather how the teachers experienced their learners' behaviour in my presence. It would be interesting to know how the learners perceived my presence to have affected them and their teachers, but that was beyond the scope of this project.

The teachers' accounts accord with my experience. My own sense is that learners responded well to my opening address: I was able to quickly establish a rapport with them and they seemed to take seriously my injunction to pretend that I was not there (see section 3.7.2), helped by having myself and my video camera mostly out of their field of vision. However in the small classrooms in which Mr Dube and Mr Hlope taught, I sat amongst the learners and not behind them, often sharing a double desk with a learner. Here I felt my presence as an intruder most keenly, and was aware of learners being self-conscious in my presence.

4.1.2 Effect on Teachers

In the last section I reported on the effect of the observer on the learners. The other contribution to classroom reactivity is the effect of the observer on the teachers, which is the subject of this section. Only Mr Baloyi and Ms Gray reported being unaffected by my presence. When I asked Mr Baloyi what influence my presence had on his lesson he responded:

> I don't think it had an influence as such. Just that the first time that you were here, it felt like crit lesson again on School Experience [teaching practicum] but after a couple of minutes within the lesson, I sort of forgot that you were here.

Ms Gray said "To be honest, I just forgot [laughs]. I know that's bad but I haven't changed anything." Every time I asked her about my effect, she said that she had carried on as normal.

Three teachers reported that they forgot about my presence some of the time. Having initially felt "maybe intimidated", Mr Abrams reported that he was able to ignore me during a prac lesson because "I always have fun at the pracs." During the second day I visited, Ms Emeni presented content which she found difficult and which demanded her attention, thus taking her attention off me:

> today with the content that I was doing, I kind of forgot that you were sitting at the back of my classroom, because I'm struggling to get that message across.

Ms Fikela also commented on the second day "I was not conscious now that there's a camera, I forgot about it." However on my first day. Ms Fikela said:

> in the beginning I was like, I forget, I'm being observed, for example, I'll put my hands on my waist and I'm like, [Ms Fikela], you're being observed, you must move your hands off your waist, that type of a thing, and then - but later on as the lesson progresses you forget about it, and it just goes. […]. I'm used to having people watching me also, but just in the beginning, you're cautious that someone is watching you.

Ms Cole reported that she felt "more nervous" and Mr Hlope experienced nervousness to the extent of his mouth drying out on the first day I visited, making it difficult for him to speak. He was worried that he would say something incorrect, remembering that when I had been his tutor for teaching practicums in first year, I corrected him after a lesson for calling the chloride ion a 'chlorine' ion. He was worried that I would interrupt the lesson and point out a mistake:

> just think for a minute if you were to say, "[Mr Hlope], it's actually not this, it is this one", what will happen to them? You know what, there will be chaos! Because you said it yourself, and they will be sure that because you are saying this, that's correct, because the fact that you're white you're always carrying the correct information.

Again my skin colour exacerbated the problem. I note here that I had never interrupted a lesson and criticised him in front of learners when he was a student teacher, so this fear was not well founded.

A couple of teachers reported engaging in the kind of metacognition which I had anticipated (see section 3.7.1), as this exchange illustrates:

Researcher:	And how did you find having me here, did it affect you?
Ms Emeni:	It's difficult! [laughter] It is still difficult, but, well.
Researcher:	Did you feel it changed how you were in the classroom?
Ms Emeni:	*Ja*[17], because now I have to listen to myself. [laughter]
Researcher:	And what do you find when you listen to yourself?
Ms Emeni:	All the mistakes that I make. Calling the screen the object, but well it is. Those kinds of things, then I do hear them coming out of me, okay, so this is what I actually do.

Similarly Mr Abrams reported "usually when I speak I just let go, so for you being here I have to also sort of like think on my thoughts and what I've actually said." In particular,

[17] 'Ja' is the Afrikaans word for 'yes'.

the teachers were concerned about their physics in this on-the-spot reflection. Ms Emeni added to the exchange above, "And at the back of my head I don't want anyone to ask me a question that I couldn't answer [laughs]." This is understandable given that I was once their physics lecturer.

The above reports what teachers felt and thought with my presence. The other dimension of my effect is how they changed what they did because of my presence. Where they felt nervous their behaviour is likely to have changed, as Ms Cole explained, "I'm usually more relaxed. I usually joke around a lot more." Mr Hlope said he took longer going over homework than he would normally – he wanted to do it properly for the video.

I have discussed here how teachers responded to my question about how they felt my presence affected them. But what about other effects which they did not mention? To what extent did they put on a 'special show' for me? For most of them it was obvious that they simply carried with whatever they were busy with – the lessons followed on from the previous day, as I could judge from learners' books or from references to the previous day in the lesson. There were two exceptions, namely the teachers who felt privileged to have me visit: Mr Hlope and Mr Dube. It seemed that Mr Hlope did more practical work than average, although it was clear from his learners' responses that they are not unused to seeing apparatus – that he does any practical work at all is exceptional given the constraints of his context, a point I will return to in section 8.4.2. I also realised that Mr Dube chose his favourite content for some of the lessons I saw. But this did not shift his typical modus operandi, and so I still got a good insight into the way in which he organises his classroom.

In summary, my effect on the teachers ranged dramatically from some who found me easy to forget to Mr Hlope who had difficulty speaking. It seems the presence of the observer had more impact on the teachers than on the learners, though the measures were different, with the teachers self reporting and the effect on learners judged by their teachers. Overall it seems my visits had minimal effect on Mr Baloyi, Ms Emeni, Ms Fikela, Ms Gray and their classes. But Mr Abrams, Ms Cole, Mr Dube and Mr Hlope all felt the impact of my presence, and some of their learners did too. I am satisfied that I took classroom reactivity into account adequately in my research design. From an ethical perspective, I was glad I asked the teachers about their experience of having me present, because it gave me the opportunity to apologise for the discomfort which some of them experienced as a consequence of my research project.

4.2 Analysis of Activities

Having reported on the reactivity of the observed lessons, I now turn to the analysis of the form of the lessons. I started by writing a brief summary of each lesson of the first five teachers, based on the detailed lesson narratives, and then looked for different ways to group together the lessons, using a grounded approach (Strauss & Corbin, 1990). Out of this process, there emerged thirteen possible types of activity. Table 5 gives a description of what each type of activity looks like. The activities in Table 5 are organised in terms of two dimensions: the purpose of the teacher and the mode of engagement of the teacher and learners. I will first elaborate these two dimensions, and then show where the lessons which I observed fit into Table 5.

Initially I worked with the data from only five of the teachers. This is because I was still busy with data collection but wanted to know whether the data I was collecting was usable – whether it could in fact be analysed! This was born of my concern with the trustworthiness of classroom observation, and the difficulty I had had in finding a suitable classroom observation tool, described in section 3.7.3 where I also noted that starting the analysis early is recommended (Kvale, 1996). Later I turned the framework which emerged from this data onto the lessons of the remaining three teachers (Ms Fikela, Ms Gray and Mr Hlope), and this served as a check for my framework.

4.2.1 Teaching Purposes

From the data it emerged that the activities in the observed lessons could be grouped according to four teaching purposes: firstly introducing learners to new content in the form of general principles; secondly applying the general principles to specific situations by having learners do exercises which then leads to thirdly giving feedback on those exercises; and fourthly revision. Under the banner of revision, any of the first three purposes could be enacted: re-teaching, exercises and marking of those exercises. These purposes often form a teaching sequence:

Introduction of general principles → application → feedback (→ revision)

This teaching sequence can be enacted in a single lesson or over a series of lessons. This sequence works deductively from general principles to specific examples, in contrast to an inductive inquiry-based approach.

Table 5: Types of activities

Purpose: / Mode of engagement:	**Introduction of general principles**	**Application**	**Feedback**	**Revision**
Exposition (whole class)	*Source of knowledge: teacher* Teacher talks and dictates / writes from head *Source: text* Teacher/ learner reads text and Teacher elaborates. Learners listen and possibly annotate text or fill in gaps.	Teacher works through example on board	Teacher reads answers and learners mark their work	Teacher re-teaches
Q&A (whole class / groups / individual)	*Source: text / learners* Teacher asks questions, and marks significant answers by writing on board. Learners answer from their own knowledge or by finding answers in a text.	Learners answer questions in text in groups or individually. Teacher responds to learner queries	Teacher gets Learners to answer questions (either by reading their answers or writing on the board)	Learners answer straightforward questions. Teacher responds to learner queries
Conversation (whole class / groups)	*Source: texts, teacher and/or learners.* Whole class discussion	Learners work on a demanding problem in small groups	Learners take turns at board, building on and debating a solution.	Learners work on a demanding problem in small groups

The first two of these activities resonate with two of the six teaching purposes identified by Mortimer and Scott (2003) in their analysis of talk in science classrooms: introduction of general principles is Mortimer and Scott's 'the scientific story', and application is Mortimer and Scott's 'guiding students to work with scientific meanings'. Mortimer and Scott also include 'opening up' and 'working with student views' which are subsumed in my classification as part of the process of 'introduction of general principles'. But Mortimer and Scott do not consider the need for closure on tasks given to learners. Achieving closure through feedback can be boring, as Ms Cole expressed: "I hate marking, it's my worst."

In the introduction of general principles, there are a variety of sources of science knowledge which may be drawn on. Traditionally the teacher and the textbook are the dominant sources of knowledge in a science classroom. Handouts may take the place of the textbook or the teacher: they take the place of the textbook if they are drawn from textbooks or other print sources, and they take the place of the teacher when authored by the teacher. But the learners are also sources of knowledge which a teacher may draw on or ignore.

4.2.2 Modes of Engagement

Three distinctly different modes of engagement emerged in the lessons. I have termed these: exposition, question and answer, and conversation. I will explore what these looked like in lessons where the purpose was the introduction of general principles, i.e. the first column in Table 5. These modes used the possible sources of information (teacher, learners and texts) in different ways.

Exposition involves a delivery of information. On some occasions the source of information was the teacher, who spoke without notes, and either dictated or wrote on a board or overhead projector for learners to copy down. Alternatively a text (a handout or a workbook) was used as the primary source of information, with either the teacher or a nominated learner reading aloud. The learners filled in gaps or annotated the notes in some way under the teacher's instruction (e.g. "highlight that word").

In question and answer (Q&A), learners answered a series of questions, either drawing on their own knowledge or information given in a text. For example, Mr Dube had previously given his grade elevens a handout on torque, and then in the lesson asked a series of questions. His learners sought answers in the text, and Mr Dube then summarised the main points on the chalkboard. Mr Baloyi gave his grade eight learners a handout with questions on the solar system, and access to a variety of books. Generally the questions tended to be closed questions, i.e. questions where the teacher has a particular answer in mind. But open questions were also used, for example Ms Gray used open questions in a grade ten introductory chemistry lesson, and worked in a sophisticated way with the responses she got from learners, asking follow-up questions. I note that it is possible to classify questions more finely than as open or closed, for example Boaler and Brodie (2004) identified nine types of teacher questions in mathematics lessons, but this would require transcripts of the lessons, which I did not have because rather than looking in detail at a few lessons I wanted a wide-angle lens on teachers' practice.

The third mode of engagement was that of conversation. Although interactive like the Q&A mode, in a conversation all parties ask questions whereas in Q&A the teacher asks the questions and the learners answer. The learners can influence the direction of a conversation whereas the teacher drives a Q&A interaction on a pre-directed route. In Q&A, the teacher judges the correctness of answers, whereas in conversations, learners judge each other, often because the teacher deliberately suspends judgement. In Q&A, the learners mostly interact with the teacher, whereas in a conversation, the learners interact with each other, turning to look at each other, and responding to each other without the teacher interjecting, although the teacher often chairs the taking of turns. The teacher promotes this interaction by redirecting learner questions to the whole class. This notion of conversations within classrooms is popular with complexity theorists (B. Davis, Sumara, & Luce-Kapler, 2000; B. Davis & Sumara, 1997).

The conversations arose in different ways with different teachers. Mr Baloyi deliberately set up some of his lessons as conversations. For example, his grade eights had recently made themselves ‘discussion glasses’, an idea of Mr Baloyi’s based on de Bono’s (1985) ‘thinking hats’[18]. The grade eights used their discussion glasses in a debate on whether to build a nuclear power station. They had no prior knowledge of nuclear power, and so were required to use the textbooks and other books available in the classroom to find information.

In Ms Cole’s lessons, the conversations arose spontaneously during lessons. For example, this is an extract from the narrative of a grade nine lesson about average speed (also dealt with in section 5.7.5). The extract starts with Q&A, which is then interrupted by a girl who says she does not understand, and points to the fact that there are two dials on the dashboard of a car. A conversation ensues.

> *[Q&A:]*
> The teacher gets one girl to read the worksheet aloud. After a few sentences the teacher interrupts to talk about speed, and asks girls what they can remember about speed. The girls participate enthusiastically. The teacher chairs, indicating which girls with hands up can talk. One girl says “d-s-t triangle”, and the teacher reacts with surprise, and asks who has and who has not done the ‘triangle’.

[18] De Bono’s six ‘thinking hats’ are six different ways of thinking which can be used as tools in group work.

The teacher says “Where do we see speed, when you're moving around the world in your everyday lives?”

Someone volunteers “In a car.”

The teacher continues “When you’re driving in a car, how do you experience speed?” A girl refers to “something in the front” and the teacher tells them it's called an odometer, “Do you guys ever watch that when your mom’s driving?”

[Conversation:]

One girl says she does not understand, “because there's two.”

The teacher asks someone to explain, and one girl says “It calculates the speed that you’re going at” and describes the dial.

Another three girls describe the rev counter, talking about “engine power” and “revolutions per minute”, which the teacher explains as “how hard the engine is working” and says it “doesn’t distinctly relate to speed.”

Another girl asks “Does it have anything to do with torque?”

The teacher asks “Do you know what that is?” The girl says something about “turning force.”

The teacher says “Let’s go back to odometer and you guys said it’s measured in km/hour.” Then she asks them about road signs, and they talk about speed limit signs. The girls give different values of speed limits.

A girl asks how traffic cops measure speed, and the teacher throws the question back at the class. One girl volunteers “Don’t they have those gun things?” The class laughs and she continues her description. The teacher reminds them “one at a time” and asks other girls for more details. One girl suggests it has to do with radar.

One girl refers to “the olden days” and describes two tapes on the road. Teacher says “that’s a very important point you made” and explains. She asks “What two measurements would they have in that case?” The class choruses in response. “So then can you see how they would work out the speed, those of you who’ve done the triangle?”

The teacher asks “How do those new guns work?” A girl suggests they take a picture, and the teacher points out that that “is afterwards, once they know you’re speeding.” Teacher then gives an explanation of ‘radar guns’ and concludes “Depending on how quickly the signal is returned back to the gun, they can measure how fast that car was going.”

In this excerpt, both the teacher and the learners influenced the direction of the conversation. The teacher’s initial question was open, and the conversation about the speed of cars ensued because of the answer to this question, with the teacher asking follow-up questions. The girls introduced the ‘rev’ counter, torque, and speed traps into the conversation. The teacher influenced the direction of the conversation by choosing to build on some contributions, such as speed traps, and not others, such as torque. She recognised speed traps as useful for building the big idea of the lesson (speed) and commented afterwards:

> oh, I liked what the one girl brought up about the speed trapping. And she spoke about the olden days when they used to use the two lines apart. And I thought that was good because it brought up distance and time. She basically described the whole concept [of speed], so I liked that.

The girls listened to each other as well as to their teacher, although their responses to each other were often mediated by the teacher, with the teacher repeating their questions to the class. Interestingly this conversation happened with a class which the teacher identified as less able, so conversations of this nature are not limited to more able learners.

In contrast conversations in Mr Dube's lessons happened during time set aside at the end of a lesson in which he invited questions. His learners anticipated this, and so always had thoughtful questions prepared, such as "Where does the salt in the sea come from?" after a lesson on the hydrosphere, and "Is it possible to relate the principle of moment and the principle of the law of momentum?" after a lesson on torque.

A distinctive element of the conversations was that learners brought information which surprised their teachers, for example Ms Cole's grade eights explained density in terms of how tightly particles are packed, even though she had not used a particle model in talking about density. Complexity theorists refer to this as occasioning – allowing things to "'fall together' in complex and unexpected ways" (B. Davis et al., 2000, p. 144).

Questions were also asked by learners in other forms of engagement – in fact learners freely asked questions with all the teachers. However the nature of the questions was different. Questions asked in exposition lessons tended to be concerned with the accuracy of the notes which learners recorded. For example, in a lesson in which Mr Abrams drew a diagram of hydrolysis and talked about the structure of the atom, the sequence of questions asked by learners was:

> Is it 'a node' or 'anode'?
> Is that a heading?
> Are we writing that down?
> Doesn't protons have a formula?
> What is the mass measured in?
> What's the heading?

This series of questions suggests that the teaching purposes of the teacher should not be confused with the purposes as perceived by learners, in this case: to take notes. It also illustrates how learners contribute to the emergent action in the classroom both by the questions they ask, and the questions they *don't* ask – in this example the questions hardly engage with the actual content of the lesson. I will return to this point in section 5.5.2.

The examples given above are all taken from lessons where the teaching purpose was the introduction of general principles. The three modes of engagement were also evident in the other classroom activities. For example, feedback on tasks which the learners had done could be achieved by the teacher reading out the answers (exposition), by the teacher reading the questions and getting learners to answer, either orally or on the chalkboard (Q&A), or by a conversation in which learners argued with each other about a solution, with the teacher delaying judgement.

4.2.3 Classification of Lessons

Table 6 shows the classification of the 41 lessons which were not repeat lessons, in terms of the activities which they included. Note that a lesson could include more than one activity, and so some lessons occur more than once in Table 6. Double periods are counted as one lesson. I have not included repeated lessons, i.e. lessons where I saw the same content taught by the same teacher to other classes, although no lesson was ever a pure repeat because of the contribution of the learners. I note here that I saw different numbers of lessons with different teachers: from only four with Ms Emeni to twelve with Mr Hlope. This was because Ms Emeni also taught mathematics, and the lesson periods in her school were much longer than those in Mr Hlope's school. In addition I visited Mr Hlope on three days, because on the first day the school closed at first break because there was no water. However I have not included the lessons from this first day (H1 and H2) in my analysis. Two lessons did not fit into the table: a lesson where learners had time in the computer centre to work on their reports on a practical investigation into thermal properties which they had done at home (C2) and a lesson where learners planned investigative science projects in small groups (F3).

What does Table 6 reveal about the teachers' practices? With all the teachers I observed lessons whose purpose was the introduction of general principles, and all except Mr Hlope had lessons which involved the application of those principles. I saw lessons where teachers gave feedback to their learners on work the learners had done with all the teachers except Mr Dube and Ms Gray. If I had observed more lessons, I may have seen application and feedback activities with the other teachers. Only three teachers engaged in activities whose purpose was revision, although I noted in section 4.2.1 that activities whose purpose was revision resembled activities with one of the first three purposes.

Table 6: Classification of lessons by activity

Key: A1 indicates the first lesson of Mr Abrams' which I observed; A2 was his second lesson and so on.
Lessons in bold print involved practical work – either demonstrations or hands-on activities.

Purpose: / Mode of engagement:	**Introduction of general principles**	**Application**	**Feedback**	**Revision**	**OVER-ALL**
Exposition	A1, A5, **A7**, A8 (Source: teacher) A6, A8 (Source: text) C1, C4 (Source: text) E4 (Source: text)	A8	A5, A6, C1, E2, E4	A4	A C E
Q&A	B2, D1, D3, **D5**, E3 F4, F6 G1, G2, G5 H3, **H6**, H9, **H10**	A6, **A7**, C1, **C3, C6**, E2 **G4**	A6, C1, C4, C5 F2 H4, H8, **H9**	C1, C5	A B C D E F G H
Conversation	**B1**, B4, C1, C4, **C6,** D1, D3 F2, F7 G2	**A2,** B5, B7, D2, E1, E4 F3	B5, B7, E1, E4	B3, B6	A B C D E F G
OVERALL	A,B,C,D,E,F,G,H	A,B,C,D,E,F,G	A,B,C,E,F,H	A,B,C	

With regard to the mode of engagement, only Mr Abrams, Ms Cole and Ms Emeni engaged in exposition. This was Mr Abrams' preferred mode of engagement whereas Ms Cole and Ms Emeni used it less and were more versatile in their repertoire. Q&A is a more learner-centred mode of engagement and was used extensively by all of the teachers. All of the teachers except Mr Hlope had conversations take place in their classrooms during my two days of observation. That I did not observe conversations happening in Mr Hlope's lessons does not mean they did not happen at all in his practice – I noted in section 4.1 that both Mr Hlope and his learners were affected adversely by my presence in the classroom.

Another aspect of the teachers' repertoires is their use of practical work. The teaching of the sciences is distinguished from other academic subjects by the use of equipment. This may be formal science apparatus (such as test-tubes and multimeters) or everyday equipment (such as elastic bands and sellotape). Lessons involving practical work are indicated in bold print in Table 6. Five of the observed lessons involved learners working with apparatus: grade eight lessons where learners measured mass and volume to find densities (C3 and C6); a grade eight kidney 'dissection' which involved learners drawing a kidney which had been cut in half for them (A2); a grade ten lesson where learners explored electroscopes with instructions on a worksheet (G4); a grade nine lesson where learners used stencils to draw molecules (H9); and a grade ten lesson in which learners used 'microelectricity' kits (H6).

A further four lessons involved demonstrations. For a grade eight change of phase demonstration the teacher heated ice on a Bunsen burner (A8). In a grade ten lesson, the class was required to arrange physical models of the atom (Dalton, Thompson etc.) in chronological order (B1). For a grade ten illustration of displacement and distance, one learner walked along two sides of a netball court while another walked across the diagonal (D5). A learner blew through a straw into lime water to demonstrate the test for carbon dioxide in a grade ten lesson (H10).

In total, nine of the 41 lessons in Table 6 included practical work – nearly a quarter of the lessons observed. This is an impressive proportion, though I note that Mr Dube's demonstration was included for my benefit and Mr Hlope seems to have included a higher than normal proportion of practical work. Nonetheless it was impressive to see any practical work at all being done in Mr Dube and Mr Hlope's contexts: they did not have their own classrooms and moved instead between classrooms 'owned' by classes.

4.2.4 Comparison with Other Studies

How do these results compare with other studies? Newton et al. (1999) also investigated activities in secondary science lessons. They observed 34 secondary science lessons in London across a range of grades and topics, though it seems that each lesson was taught by a different teacher. They used an observation schedule which marked off what was happening every thirty seconds in terms of class organisation, learner activity and learner-teacher interactions. They found that all but two lessons followed the same pattern: the teacher started with an introduction with reference to previous work, and gave instructions for an activity which learners then did. At the end the lesson was wrapped up in some way. I note here that since they only watched one lesson per teacher, teachers are likely to have enacted their conceptions of a good science lesson, based on the pertinent British curriculum, and left the 'marking' till another lesson – the only instruction Newton et al. gave was that they did not want to see a revision lesson. Newton et al.'s typology of lessons divides lessons into practical and 'non-practical' lessons. The non-practical lessons are classified as either 'teacher presentation' or 'text-based lesson' except for two lessons, one of which took place on computers and the other in a library. They identified five different types of practical lesson, but they did not see demonstrations being used.

How does Newton et al.'s analysis compare with mine? Their analysis ignores content, whereas I saw the teacher's purpose with regard to content as central. However, they were not interested in the content of lessons but rather were looking for opportunities for argumentation. Their distinction between 'teacher presentation' and 'text-based lesson' parallels my identification of the source of knowledge in an introductory lesson, though they do not seem to consider that learners can also be a source of knowledge. Newton et al. saw the use of apparatus as key to their classification, whereas I saw apparatus being used for different teaching purposes and in different modes of engagement, as reflected in Table 6. That practical work can serves different purposes was not recognised by Newton et al.'s classification of lessons by practical work but is consistent with Berry et al.'s (1999) recognition that different people see different purposes for practical work. Overall my results suggest that I saw a wider range of lessons, although Newton et al. saw variations on practical work which I did not ('circuses' and construction projects).

My three modes of engagement correlate with the 'communicative approaches' identified by Mortimer and Scott (2003). They classified classroom talk as interactive or non-interactive, as well as dialogic or authoritative. In a dialogic approach, "attention is paid to more than one point of view" (p. 33) whereas in an authoritative approach only the voice of science is admitted. These two axes lead to four possibilities, as shown in Table 7. I have added the three modes of engagement which I observed into this table. I did not observe non-interactive dialogic communication, i.e. communication where the teacher talks about different points of view, without input from the learners.

Table 7: Mortimer and Scott's four classes of Communicative Approaches

	Interactive	**Non-interactive**
Dialogic	*Conversation*	
Authoritative	*Q&A*	*Exposition*

Table 8 compares the three modes of engagement with three other typologies of classroom talk. The first is a framework developed by its authors from the literature, ahead of their research into learner and teacher questioning in science lessons (van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). The second claims to draw on its author's "own international research" (Alexander, 2008, p. 33) and is not specific to science lessons. The third is taken from the observation schedule designed for the Newton et al. (1999) study described above. In some cases I have put two categories together. There is good overlap between these different typologies, which enhances the validity of the typology which emerged from my analysis.

Table 8: Comparison of typologies of classroom talk

Modes of engagement (This project)	**Ways of speaking in science classrooms** (van Zee et al., 2001)	**Kinds of teaching talk** (Alexander, 2008)	**Observation schedule** (Newton et al., 1999)
		Rote [drilling]	
Exposition	Lecture	Expository instruction	Explanation of a scientific idea by teacher Instructions from the teacher
Q&A (Application)	Recitation	Recitation	Question-answer interactions
Q&A (Introduction of general principles)	Guided discussion		
Conversation (whole class)	Student-generated inquiry Discussion	Discussion Dialogue	Deliberative interactions Pupil-generated questions
Conversation (groups)	Peer collaboration [group work]		A formal group discussion

With regard to conversations, Newmann, Marks, and Gamoran (1996) suggest that one of the criteria for a quality lesson should be that “students engage in extended conversational exchanges with the teacher and/or their peers about subject matter in a way that builds an improved and shared understanding of ideas or topics” (p. 289). Alexander (2008) notes that in his observation, conversation is “considerably less common” (p. 34) than the other kinds of teaching talk. That conversations happen regularly in the classrooms of the teachers in my study is encouraging.

4.3 Discussion

My analysis uncovered thirteen types of activity which occurred in the course of 41 lessons which were not repeat lessons. These activities could be characterised both by the teacher’s underlying purpose and the mode of engagement through which that purpose was enacted. Table 6 gives an idea of the repertoires of the teachers – the range of possible activities from which they draw in teaching. Nearly a quarter of the lessons involved practical work, either hands-on activities or demonstrations, which was used for different teaching purposes and with different modes of engagement. Some teachers had definite preferences for a particular mode of engagement: Mr Abrams for exposition, Mr Dube for Q&A, and Mr Baloyi for conversation. But all the teachers drew on a variety of activities in the two days I observed them. This means both that they have a rich repertoire and that two days of observation gave me an idea of the breadth of teachers’ practices, which is what I had hoped for.

I claimed in the introduction to section 4.2 that my analysis was a grounded analysis. But I had expectations when I asked the research question of the kinds of activities I might encounter. Hence I ask here: to what extent did the categories emerge from my own expectations? In my proposal I anticipated four different kinds of activities might arise: ‘chalk and talk’, teacher demonstration, hands-on experiment, and worksheet / exercises. These are similar to Newton et al.’s categories but very different from the categories which did arise. I am thus satisfied at the ‘groundedness’ of my analysis.

However I think a weakness of this analysis is that it looked for patterns, rather than allowing good lessons to stand on their own. For example Ms Fikela worked in a sophisticated way with texts, mediating them to learners by interspersing questions in the reading of the text, which the text then answered. At the same time she worked powerfully with her learners' contributions, even though these contributions were limited, as her learners had only been in the intervention school a few months, and were therefore not fully accustomed to working in this way. A different lens on this data would be to explore individual lessons such as this, where learning was profoundly facilitated, according to my professional judgement.

What is also not evident in the above analysis is that there was a good relationship between all the teachers and their learners, although as I noted in section 4.1.1, Mr Abrams, Ms Gray and Mr Hlope reported that some of their learners behaved somewhat better than normal because of the presence of an observer. These good relationships facilitated the Q&A and conversation modes of engagement. In all the lessons there was a positive atmosphere, except for a lesson where Mr Abrams reprimanded learners for not doing homework after which the class was subdued. Learners were cooperative, and bought in to their teachers' approaches. In particular senior learners understood and performed their roles well, though junior learners sometimes inadvertently subverted their teacher's purpose.

This analysis has simply provided a description of the form of activities in science classrooms. But it is not enough to look only at the form of a science activity: the substance also needs interrogating. Brodie and Pournara (2005) point to mathematics teachers who changed to using the form of group work without any change in the substance of a lesson. Moreover the teaching purposes which I identified are directed at the science content of the lesson, and so the content warrants attention, and hence is the focus of the next chapter.

Chapter 5: The Quality of the Content of Science Lessons

In the last chapter I looked at variation in the form of science lessons. The problem is that this analysis did not address the overall quality of the lessons, because central to the quality of a lesson is the quality of the science made available to learners. I realised that the form of a lesson could be excellent, for example a highly interactive, enthusiastic conversation, yet the lesson weak because of deficient subject matter content. I observed the following problems with lesson content: accuracy, appropriateness and comprehensibility. This led to me to formulate another research question during the course of data collection: what is the quality of the science content made available on the plane of the classroom, in lessons which introduce new content? The purpose of this chapter is to address this research question.

My problem in analysing the content of lessons was that I could not find a suitable analytical tool for critiquing lesson content, and so needed to develop a way to analyse lesson content. I started by identifying the subject matter content of each of the 21 lessons which introduced new physical science content, i.e. the physics and chemistry lessons in the first column of Table 6 (p. 146), and then developed a rubric for assessing the quality of the content. In this chapter, I first distinguish between different types of knowledge, as well as between teacher knowledge and the subject matter content of lessons. Then follows an analysis of the ways in which classroom observation schedules and other frameworks have dealt with subject matter content of lessons. Thereafter I introduce the form in which I represent lesson content, which I call the 'content object', and explain how the content object develops in the course of a lesson. Finally I apply the rubric to the 21 lessons which introduced new physical science content. This is a different view on some of the data of Chapter 4.

Of course the ultimate goal of most lessons is the take-up of content by learners, but this is not something I assessed, since I concerned myself only with that which could be observed in the course of a lesson. Moreover individual learners have different entry points and pathways through the same lesson, and so apprehend the content of a lesson differently. In Marton, Runesson and Tsui's (2004) terms, I am considering the 'enacted object of learning' – what the researcher sees made available for learning – rather than the 'lived object of learning' which learners actually learn. Obviously the mode of delivery of science content is also important in attaining the goal of learning, but the mode is not under consideration here, since this was dealt with in the previous chapter.

5.1 Types of Knowledge

In order to analyse the knowledge presented in a lesson, it is helpful to distinguish between different types of knowledge. Thus in this section I compare various typologies of knowledge, represented in Table 9. The first is that of Biggs (1999), who classifies knowledge as propositional, procedural, conditional or functioning. Propositional or declarative knowledge is 'knowing that'. It is knowledge which can be expressed in propositional statements. Procedural or practical knowledge is 'knowing how', for example laboratory process skills and problem solving skills. Philosophers agree on this distinction, attributing it to Ryle (1945) although they contest whether these two types of knowledge are independent or whether one precedes the other (Fantl, 2008). Biggs argues that in order to use propositional and procedural knowledge, one needs to know under what conditions it is applicable – he terms this 'conditional' knowledge. The combination of the first three types of knowledge gives rise to 'functioning' knowledge – knowledge which is usable. Functioning knowledge is not a separate type of knowledge but the combination of the other three types into knowledge which is useful.

Table 9: Knowledge typologies

Biggs (1999)	Propositional knowledge	Procedural knowledge	Conditional knowledge		
Shulman (1986)	Propositional knowledge (principles, maxims, norms)		Strategic knowledge	Case knowledge (prototypes, precedents, parables)	
Schwab (in Shulman, 1986)	Substantive knowledge				Syntactic knowledge
Sfard (2000a)	Object level rules				Meta- discursive rules
SA Curricula	Knowledge	Skills			

Along with Shulman's (1986) seven categories or domains of teacher knowledge which I described in Chapter 2, Shulman distinguished between three 'forms' of knowledge: propositional knowledge, strategic knowledge and case knowledge . Strategic knowledge aligns with Biggs' conditional knowledge, and case knowledge is knowledge of particular exemplars of the general principles of propositional knowledge. However Shulman's examples of case knowledge suggest that this 'form' of knowledge is more applicable to the domain of PCK than the domain of SMK. Furthermore, Shulman breaks propositional and case knowledge down into a further three 'types' each, for example he breaks propositional knowledge down into principles, maxims and norms. Shulman's examples of maxims are in the domain of general pedagogical knowledge.

When Shulman (1986) talks about SMK, he also makes a distinction between substantive and syntactic knowledge, which he attributes to Schwab. Substantive knowledge is the propositional and procedural knowledge above, and syntactic knowledge is rules for deciding what counts as knowledge in science. Sfard (2000a) makes a similar distinction, calling substantive knowledge 'object level rules' and syntactic knowledge 'meta-discursive rules'. Substantive knowledge is explicit while syntactic knowledge tends to be implicit in the discourse. However, when pedagogies which teach about the Nature of Science or argumentation are employed, then syntactic knowledge becomes explicit. Also if learners ask "how do we know?" they are pushing their teacher for syntactic knowledge.

South African school curricula give "expression to the knowledge, skills and values worth learning in South African schools" (e.g. Department of Basic Education, 2011b). The 'knowledge' is propositional knowledge whereas the 'skills' are procedural knowledge. I see values as beliefs and hence distinct from knowledge (section 2.3), and have thus not included them in Table 9. Values are often implicit in lessons, for example, the value that 'science is good' was implicit in the lessons I observed – none of the teachers took a critical stance on the dominance of western scientific thinking. Here I note that I see no knowledge as neutral – all knowledge is value-laden. Scientific knowledge in particular reflects a hegemonic view of the world, which does not acknowledge the way in which scientific knowledge is privileged over other ways of knowing and is used by those in positions of power to maintain their power. However taking into account how the teaching and learning of scientific knowledge reproduces power was beyond the scope of this study.

What conclusions can be drawn from the above? It is possible to produce complex – and possibly confusing – typologies of knowledge, as Shulman has done. Nonetheless the categories of propositional and procedural knowledge, though not exhaustive, are uncontested as valid 'forms' of content or discipline knowledge, and are explicit where some other categories of knowledge are implicit.

5.2 Lesson Content and a Teacher's SMK

In section 2.2.6 I made the distinction between the subject matter knowledge of a teacher and the subject matter content of a lesson. I emphasise that distinction here by illustrating it with an example from the data. In conversation before a lesson, Mr Abrams' told me about the difference between elements and atoms:

> because we use these words but we actually don't think about the effects that it has. And we're looking at something simple as your elements and atoms, it may look simple but if you go a bit deeper the complexities come in, to say that is there really a difference between an element and an atom? And looking at how you use the two words, because we say **an element consists of atoms**. Then you come to the atom to say, okay, fine, but then if you're saying that as a definition, are you saying that **an element is an atom**? And those are the debates that I would assume would be happening to the learners. And you also see it when you start marking scripts that they interchange words, and you may have thought that I've said this word to mean this but they use it in a different context.

In this extract he expressed the scientifically correct position (that an element is made up of atoms) as well as the confusion that learners often have, and the importance of a teacher using words carefully. In the lesson immediately following this conversation, he dictated the following to his learners:

> In order to determine the characteristic of an **atom**, the atomic number that stresses the amount of positive charges differs from **atom** to **atom**. Therefore each **atom** will contain different numbers of positive charges. The atomic number (which indicates the number of positive charges) gives you the structure of the **atom**. **Elements** from the periodic table are neutral.

Here he confuses the terms 'element' and 'atom', and in the course of the lesson, he did not explain the difference between these terms.

I note here that this was the first lesson of Mr Abrams' which I watched, and after the lesson he told me that he felt "maybe intimidated" by my presence, so that could account for his mistake. However he also reported that my presence precipitated metacognition while teaching: "usually when I speak I just let go, so for you being here I have to also sort of like think on my thoughts and what I've actually said" (see section 4.1.2), but this did not lead him to notice the discrepancy between what he had told me before the lesson and what he said in the lesson. Setting aside the effect of the observer, if I had only observed Mr Abrams' lesson, I could have concluded that he was unaware of the distinction between elements and atoms. The conversation I had with him shows that such a conclusion about his SMK would not have been valid.

5.3 Other Frameworks for Lesson Content

In this section I look at what the literature had to offer me by way of classroom observation schedules and other frameworks for addressing the subject matter content of a lesson. Although many studies use observation schedules, they are not always published with the studies, in part because the validity of classroom observation is generally seen as unproblematic – in contrast to my view described in section 3.7.1. Table 10 gives three American and five South African observation schedules which include the science content of a lesson. I will first give the contexts of these schedules, and then discuss the ways in which they address content. Thereafter I will look at other frameworks for lesson content.

The first three observation schedules are used in the qualification of beginning teachers. Praxis III[19] is required for qualification as a teacher in some American states, and involves lesson observation and interviews by an assessor, which are used to assess nineteen criteria (Educational Testing Service, 1994). The next schedule is used to assess student teachers at the end of each of their seven three week teaching practicums over the course of their four year B Ed degree at the Wits School of Education (Rusznyak, 2011b). Thus this schedule covers more than one lesson. The third schedule is the schedule which the second one replaced, which was designed around the different ‘roles’ expected of a South African teacher.

The next two schedules were designed and used by American researchers. The Classroom Observation Protocol is for mathematics and science lessons, and was used to investigate the effectiveness of an intervention programme. Apparently it was based on at least five earlier schedules and “Items selected were those that had been shown to be predictive of standards-based instruction and positive student outcomes” (Lawrenz et al., 2002). The next one was designed by Newmann et al. (1996) who were concerned that the move to learner-centred pedagogies might mean that the ‘intellectual quality’ of lessons was not considered. They used their schedule to investigate schools which had been restructured.

[19] Praxis II is described in section 2.3.2.

Table 10: Content related items in observation schedules

	SMK of Teacher	Accuracy / Selection	Transformation of Content	Connections in Content	Responses to Learners
Praxis III (Educational Testing Service, 1994) USA certification of teachers			Creating or selecting teaching methods, learning activities, and instructional materials or other resources that are appropriate […]; Making content comprehensible to students.	Demonstrating an understanding of the connections between the content that was learned previously, the current content, and the content that remains to be learned in the future.	providing feedback to students to assist learning
Wits Assessment Form (Rusznyak, 2011) Certification of teachers	*Knowledge and understanding of content:* Demonstrates broad and networked understanding of topics & subject		*Teaching & learning strategies:* Thoughtfully selects, and effectively uses teaching and learning strategies appropriate to content and learners	Demonstrates broad and networked understanding of topics & subject	*Monitoring learning & understanding:* Probes learners' understanding: acts on feedback to address misunderstandings
Old Wits Assessment Form (given in Rusznyak, 2011)	Sound knowledge of content	Selecting and sequencing sufficient, suitable and accurate content	Explaining		
Classroom Observation Protocol (Lawrenz, Huffman, & Appeldoorn, 2002)	The teacher/faculty member displayed an understanding of mathematics/science concepts (e.g., in her/his dialogue with students)		Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so. The lesson promoted strongly coherent conceptual understanding.	Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or to real-world contexts, social issues, and global concerns.	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.
Standards for Authentic Pedagogy and Student Academic Performance (Newmann, Marks, & Gamoran, 1996)			*Higher-order thinking:* Instruction involves students in manipulating information and ideas by synthesizing, generalizing, explaining hypothesizing, or arriving at conclusions that produce new meanings and understandings for them.	*Deep knowledge:* Instruction addresses central ideas of a topic or discipline with enough thoroughness to explore connections and relationships and to produce relatively complex understandings. *Connections to the world beyond the classroom:* Students make connections between substantive knowledge and either public problems or personal experiences	
FDE Classroom Observation Schedule (Adler & Reed, 2002)	*Content knowledge and confidence:* Good knowledge, confident and shows greater understanding of the subject.		*Clarity of explanation of concepts by teacher:* flexible and good explanations	relates to other ideas/ concepts/ topics	*Teacher dealing with learners' conception and misconceptions:* Notices and engages with the learners; conceptions/error and facilitates conception clarity. *How the teacher responds to learners answer:* Responds to both correct and incorrect answers in a manner that encourages further effort.
PEI research project (Harley, 1999)	Has sound knowledge of subject content		Uses appropriate learning/teaching strategies and resources so that learners reach the desired outcomes.		Gives frequent and constructive feedback to learners
PEI: Protep (Jita & Karlsson, 1999)		Relevant science knowledge is selected	Teachers organise learning experiences, within the specific subject matter content of science as defined by the four themes […]	Knowledge of science concepts and principles in practical situations related to daily life are developed and used	Common and specific needs/problems of learners are recognised

The last three schedules are South African. The first was the schedule which I tried using early in my research (see section 3.7.3) which was a schedule used in assessing the impact of in-service teacher education in mathematics, science and English (Adler & Reed, 2002). The last two schedules come out of a large South African conglomeration of research projects, the President's Education Initiative (mentioned in section 2.3.2). One was used to assess ten good teachers, three of whom were physical science teachers (Harley, 1999) and the other was used to assess science teaching in grade one (Jita & Karlsson, 1999).

I have organised Table 10 in terms of different aspects of lesson content, using the actual words from the observation schedules. Some of the observation schedules give rubrics, in which case I have given only the highest level descriptor from the rubric. Where there are blanks in Table 10, the observation schedule in question did not address that criterion. I have argued that teachers' SMK cannot be directly inferred from lessons but a number of the observation schedules include it, with two assuming that the teacher's SMK can be unproblematically inferred from a lesson, and the other three making claims about the SMK demonstrated in a lesson. All of the observation schedules take an interest in the way content is transformed to make it accessible to learners, connections in the knowledge. and with the way the teacher engages with learners' knowledge. However only two are concerned whether the selection of lesson content is suitable, and they require an observer to make professional judgements 'on the fly' without providing evidence of such judgements. Only one schedule mentions accuracy.

Why do most of these observation schedules not make a judgement about the accuracy and selection of the content of a lesson? It seems that either there is a conflation of lesson content with teachers' SMK or else the content is taken for granted. In regard to the first two schedules, one could argue that student teachers are told what content to present, and so they should not be judged for content over which they have no control. However, even with prescribed content, student teachers can make mistakes, and so my opinion is that at least the accuracy of the subject matter content if not the selection should be up for scrutiny. I note

The observation schedules in Table 10 consider both the content and form of lessons, but I have only included the items related to content. There are other observation schedules which are only concerned with form which I have not included in Table 10. For example, Onwu (1999) used an observation schedule in a project in the President's Education Initiative which assessed the extent of use of science equipment by ten grade twelve teachers. Newton et al. (1999) developed an observation schedule for investigating the use of argumentation in science classrooms (mentioned in section 4.2.4). Luft (1999) developed a rubric for investigating the use of inquiry in science lessons.

There are frameworks for looking at lessons which analyse the content of lessons, but which are not expressed in observation schedules. These frameworks reconstruct lessons afterwards, through transcripts and other means, and so allow the researcher to provide evidence of the analysis. For example, one of the dimensions of Mortimer and Scott's analysis of classroom talk is content. They classify the content as either 'everyday' or scientific, and classify scientific content further along two axes: whether it is empirical or theoretical, and whether it is a description, an explanation or a generalization. While this is a valid way of analysing content, it does not comment on the quality of the content.

Rusznyak (2011a) provides a framework which passes judgement on two dimensions of the content of a student teachers' lessons: the quantity and accuracy of the information provided, and the way in which it is conceptually organised so that learners can see the relationships between concepts and the overall structure of the knowledge. In this two dimensional space, she identifies six categories. However her analysis was not of the lessons, but rather of the written 'crits' given by supervising teachers, so still depends on observers' on-the-fly judgements. Her category descriptors slip between lesson content and judgements about the student teacher's SMK. For example one of her lowest level descriptors is "students with inaccuracies in the factual base of their lessons" whereas her top level descriptor is "students with sufficiently flexible and thorough understanding of the lesson topic as to be able to mediate subject matter knowledge in coherent, conceptually sound ways". The former descriptor talks about the content of the lesson whereas the latter describes the SMK of the teacher. Conflation of lesson content with SMK is also seen in the 'knowledge quartet' framework (Rowland et al., 2005) whose explicit intention is to infer a student teacher's mathematics SMK, PCK and beliefs from an observed lesson.

In addition to the above frameworks which consider whole lessons, there are also frameworks which consider aspects of lessons. For example, two frameworks pass judgement on the quality of explanations, which are one part of the content of a lesson. Dagher and Cossman (1992) analysed the explanations given by teachers, and found ten types of explanation. They passed judgement on the quality of the explanations, declaring two of the types to be spurious. Another classification of explanations is Biggs' SOLO Taxonomy (Biggs & Collis, 1982) according to which higher order explanations make more links to evidence. Both the last two frameworks have resonance with the idea of using argumentation in science classrooms.

Variation theory (explained in section 2.2.5) can be used to evaluate the quality of the transformation of a lesson (e.g. Marton & Tsui, 2004; Pang & Marton, 2003) but only in situations where different teachers present the same object of study, because it follows from variation theory that researchers "can only find out how the object of learning is dealt with in the classroom by comparing it with another way of dealing with the same object of learning" (Marton et al., 2004, p. 35). Such an analysis was thus beyond the scope of my study – although my study compared different teachers, the objects of study for those different teachers were different, and so could not be compared. Instead my only frame of reference has been the way I have taught particular content, and I have not taught it under the same curriculum or conditions as the teachers I observed.

What can I conclude from this analysis of the way in which existing frameworks approach the subject matter content of lessons? First, if frameworks mostly don't consider the quality of the subject matter content of a lesson, or conflate it with teachers' SMK, it is no surprise that education research tends to have a blind spot for the subject matter content of lessons (see section 2.2.6), since frameworks necessarily frame what researchers see. Second, frameworks which allow researchers to reconstruct and analyse the content *after* the lesson allow for more considered judgements accompanied by evidence. Such frameworks are provided by variation theory, by Dagher and Cossman (1992) and by Biggs' SOLO Taxonomy. However these frameworks only address the explanations or transformation aspects of the lesson content and so are not suitable tools for addressing the lesson content as a whole.

5.4 Unit of Analysis: The Content Object

Since I could not find an established framework for critiquing the subject matter content of a lesson, I needed to develop my own. In this section I will describe how I captured and represented the subject matter content of a lesson and in section 5.6 I will describe how I assessed the quality thereof. Both these analytical tools emerged in the course of the research as I grappled to find a way to deal to with the subject matter content of lessons. In discussing these tools, I will give examples from the data and position them against other approaches.

Table 11: Content object format

Content Object	
Subject matter content	**Transformation**
Propositional knowledge	
1.	•
2.	•
3.	•
Procedural knowledge	•
4.	•
5.	•

I use the term 'content object' to refer to the subject matter content of a lesson. The content object is the science knowledge which is made available on the plane of the classroom for learner uptake, as seen from the perspective of the researcher. A content object includes both propositional and procedural knowledge, as well as the transformation of that knowledge, and can be represented in the form of Table 11. There are other types of knowledge which I could have included but have not, as elaborated in section 5.1.

I explained my choice of the metaphor 'transformation' for that which teachers do to subject matter knowledge in Chapter 2, and noted that I am using the term differently from Shulman – I am encompassing both planning and instruction in transformation. Transformation is what happens to propositional and procedural knowledge to make it accessible to learners. This includes instructional strategies such as demonstrations, worked examples, different representations, metaphors and learner activities. Transformation may involve making learners aware of their existing knowledge, and helping them to organise it or recognise that it conflicts with scientific ideas. Although the knowledge and its transformation are delimited separately in my expression of the content object, a learner may well not see the distinction, experiencing the transformation as a seamless route to the knowledge.

Knowledge of a discipline is never simply a list of propositional statements, but rather a web of knowledge. The web also has links to other topics in the discipline and to knowledge outside the discipline, such as ‘everyday’ knowledge. Making both the internal and external links explicit is also part of transformation. In addition, within a topic there are critical ‘big ideas’ (Loughran et al., 2004) or ‘threshold concepts’ (Meyer & Land, 2006) which need to be grasped in order to make sense of the topic. The lesson may emphasise these big ideas. The topography of a lesson is a useful metaphor which a colleague (Lee Rusznyak) uses for thinking about the quality of a lesson: the big ideas are the mountain peaks of the lesson with other knowledge arranged spatially around the big ideas. In this metaphor, the links are roads between concepts. In the content object any big ideas are indicated in bold print. I note here that there is not necessarily consensus on which are the big ideas of a topic, and the lesson’s emphasis could be disputed by discipline experts. I put connections under transformation rather than under propositional knowledge because I see the making of links as part of the process of making knowledge accessible to learners. An alternative way to represent a content object would be to attempt to map the topography, for example using a concept map (Novak, 1990).

The term ‘content object’ is used in learning management systems, such as WebCT. In learning management systems, information can be stored in different types of generic containers, for example a web page. A container has a certain structure. Content in a container is called a content object. The same content could be stored in a different container. A content object is an intermediate size structure: it is made up of smaller bits - ‘content fragments’ - and content objects can be assembled into larger objects, such as learning objects (Verbert & Duval, 2004). In a similar way, a lesson is a generic container with a certain structure – it involves a teacher and a group of learners interacting between the ringing of two bells – which can hold different contents. Table 11 is an alternative container which can be used to hold the same content. A lesson is an intermediate size structure: it contains smaller elements while being part of a bigger programme of learning. Thus ‘content object’ seems an appropriate term to borrow to describe the content of a lesson.

I note however that my idea of reifying the content of a lesson into an object came from not from the above but from Patrick's (1992) idea of the 'object of study' which physics teachers constitute for their learners. She did a phenomenographic study which in essence found three different conceptions of physics held by teachers. In her case the object was the entire discipline as constituted in the classroom, whereas I have considered the slices of physics or chemistry constituted in individual lessons. Similarly, as mentioned in the introduction to this chapter, Marton et al. (2004) use the term 'enacted object of learning' for what I have called the content object, and distinguish it from the 'lived object of learning' which is the learning outcome in the learner, and the 'intended object of learning' which was the teacher's intention. So although I have borrowed the term from informatics, I am not the first in science education to think about the content of a lesson as an object constituted in the classroom. Although he has not referred to it as an object, Zain Davis has taken a similar approach, looking critically at "what is constituted as mathematics" (2011, p. 97) in a single grade eight mathematics lesson.

The content object does not represent the whole lesson, only the science content of the lesson. In section 5.7.1 I give an example which shows how the content object relates to the lesson as a whole. Treating content as an object means reifying an object out of classroom action. In so doing I present the content object as a static whole but this was not how it appeared in the classroom, although in some cases much of the content object accumulated on the chalkboard in the course of a lesson, and so was present as a whole by the end of the lesson. Representations in mathematics and science often take temporal objects and represent them as spatial objects such as graphs – it is this ability to perceive in one moment what takes place over time which gives such representations their power (Sfard, 2000b). In the same way, the content object on paper is a spatial representation of a temporal reality.

I identified the content object for each lesson where the teacher's purpose was the introduction of new physical science content. I did not analyse lessons where the teacher's purpose was application, feedback or revision because it is difficult to judge the quality of the content of lessons which are further on in the teaching sequence described in section 4.2.1, i.e. application, feedback or revision, since they reference earlier lessons which I mostly did not observe. I excluded life and earth science lessons because I had neither the necessary content knowledge nor the PCK to evaluate such content objects adequately. In addition the teachers received minimal preparation as earth and life science teachers, and thus I felt it unfair to judge them as teachers based on the subject matter content of lessons in these subjects. I identified the content object by looking at any handouts and at the lesson narratives, which included any writing on the board and whole class spoken interactions. I did not consider discussion which happened in small groups, or the work in learners' books – the latter often mirrored the board writing anyhow. I gave the propositional knowledge in the content object in the order it was given in the lesson. Some examples of the content objects are given in section 5.7.

5.5 Building the Content Object

The content object emerges in a lesson as a result of the contributions of both the teacher and learners. Although typically the teacher contributes the greater share, there are both obvious and subtle ways in which learners contribute. I will first examine the teacher's contribution and then the learners'.

5.5.1 The Teacher's Contribution

In Chapter 2 I described Shulman's (1987) categorisation of seven different domains of knowledge upon which teachers draw: four general domains – general pedagogical knowledge, knowledge of their learners, knowledge of context, and knowledge of educational purposes and values – and three domains of subject specific knowledge: subject matter knowledge (SMK), curriculum knowledge and pedagogical content knowledge (PCK). The teacher's contribution to the content object draws on these last three domains as follows. The propositional and procedural knowledge draw on her SMK. Her selection of propositional and procedural knowledge draws on her knowledge of the curriculum. And the transformation of content draws on her PCK, which, as I explained in section 2.3.1 is built on her SMK.

There is always some translation of the knowledge domain into the observable contribution of the teacher to the content object, as illustrated in Table 12. The content needs to be expressed through the medium of English. So a teacher may have a good conceptual understanding of content, sometimes expressed to me in an interview, but may trip up on the verbalisation of an idea, and say something which is incorrect or misleading, as Mr Abrams did. Similarly a teacher never simply teaches a curriculum, but selects from a curriculum, even if they are not aware of doing so. And the PCK of a teacher is notoriously hard to access, but evidence of PCK emerges in the way in which a teacher designs a lesson. Thus Park and Oliver (2008) have developed a rubric for evidence of PCK in a lesson. For example, a teacher who explores student prior conceptions or pre-empts their alternative conceptions in some way has PCK which includes knowledge of student prior conceptions and alternative conceptions. A teacher with curriculum saliency will make links to other parts of the curriculum as appropriate.

Table 12: Relationship between teacher knowledge domains and the content object

Teacher knowledge (in teacher's head)	**Translation process**	**Content object** (on plane of classroom)
Subject Matter Knowledge (SMK)	Verbalisation	Propositional and procedural knowledge
Curriculum knowledge	Selection of content	
Pedagogical content knowledge (PCK) • knowledge of student prior conceptions and alternative conceptions • knowledge of instructional strategies and materials • knowledge of useful representations and metaphors, • knowledge of difficulties students have in comprehending the content • curricular saliency	Design of lesson	Transformation • exploring student prior conceptions or pre-empting alternative conceptions • instructional strategies (e.g. demonstrations, worked examples) and materials (e.g. worksheets) • representations and metaphors, • emphasis on big ideas or threshold concepts • selection from curriculum which reflects curricular saliency • topography / emphases of lesson • links to other topics in curriculum • links to everyday …

The teacher contributes to the content object both by initiating moves in the lesson and by responding to learners' contributions. In the course of a lesson, learners may give answers which may be based on alternative conceptions. The teacher contributes positively to the content object by noticing and addressing incorrect answers, possibly by further questioning. Chin (2006) identified four different types of feedback given by Singaporean science teachers to learners' contributions – affirmation, correction, focusing and questioning. In a South African study, Maja et al. (1999) identified that teachers in successful schools "used learners answers to identify misconceptions and provide feedback about what they must do to improve their learning" (p. 11 of full report) while teachers in poorly performing schools tended to ignore alternative conceptions. Brodie and Coetzee (2010) analysed five South African mathematics teachers' responses to learners' contributions, and notes that it is easy for teachers to respond to correct answers, but more challenging to respond to errors and partially correct answers. In addition the teacher contributes to the content object by responding to learners' questions, either at the level of the question itself, or by recognising that a question reveals something of a learner's (mis)understanding and addressing this in some way.

This idea of a 'content object' could be applied to a lesson in any discipline. So now I consider the kinds of transformation we could expect to see which are distinctive of the disciplines of physics and chemistry. Chemistry educators recognise that there are three levels of explanation in chemistry: the macroscopic (which can be observed), the microscopic, sometimes called the sub-microscopic (which is the explanation for the macroscopic at the level of particles), and the symbolic (the equations which chemists use to represent chemical processes) (Treagust et al., 2003). A good teacher helps learners work with all three levels and understand the ways in which they relate, for example that the microscopic provides an explanatory model for what can be observed macroscopically and represented symbolically.

Similar levels of representation are present in physics: 'real world phenomena' (the macroscopic level of chemistry), idealised 'physical models' of reality (which serve the same purpose as the microscopic in chemistry but are not microscopic) and 'conceptual models' of these (which serve the same purpose as the symbolic representations of chemistry). In addition the acontextual 'physical theories' which underpin the models are explicit in physics where they tend to be implicit in chemistry (Buffler, Lubben, Ibrahim, & Pillay, 2008). As an example, under low velocity conditions, the 'physical theory' of special relativity reduces to the theory of Newton's laws of motion which underpin different 'physical models' of motion, such as rectilinear motion, circular motion and projectile motion. The 'physical model' of circular motion can be applied to 'real world phenomena' as diverse as planetary motion and the hydrogen atom, but there are idealisations involved, such as treating the motion of planets as circular when it is in fact slightly elliptical and treating the electron as a particle. There exist multiple 'conceptual models' for representing this motion, for example mathematical formulations (such as $a = v^2/r$), graphical representations, diagrams (which represent three dimensional reality on a flat sheet of paper), analogies, and computer 'virtual laboratory' simulations. Thus modern approaches to the teaching of physics include multiple representations of situations (e.g. Knight, 2008).

5.5.2 Learner Contribution to the Content Object

The content object is not due solely to the contribution of the teacher: learners also contribute. The structure of a complex system emerges in a bottom-up direction from the interactions of actors within the system, and adapts over time in response to outside influences or perturbations (section 2.1.3). This emergent characteristic of complex systems implies that the content object emerges in a bottom-up direction from the interactions of actors in the classroom – it is the product both of the teacher's input and the learners' contributions. Although I identified that a complexivist view of education implicates learners' contributions in lessons, before I started this project I could only see how learners contribute to the 'personality' of a class. But through sitting in classrooms I came to appreciate that they also contribute substantially to the quality of the content object of a lesson.

The first way in which learners contribute to the content object is by their answers to their teacher's questions. Brodie and Coetzee (2010) developed a classification scheme for learner responses in a mathematics lesson, based on the correctness of the response. They note "A lesson with many complete responses will look very different from one with many partial responses, and both of these will look different from a lesson with many basic errors" (p. 124). The implication is that learner responses shape a mathematics lesson and its content object.

Learners' answers contribute to both the content of a lesson and its transformation. An example of learner contribution to transformation occurred in a conversation in one of Ms Cole's lessons. Ms Cole wanted her learners to understand density as mass per volume, following some experiments where they had found the densities of different substances. She asked "What do I mean by less and more dense – what am I talking about?" She was looking for a macroscopic understanding, but a learner responded "I think it's to do with how tightly the particles are packed together, how much space there is between them." The teacher had not spoken about the microscopic situation in relation to density nor did she intend to, but this learner's explanation proved to be useful, and the class repeatedly returned to it in the ensuing conversation.

The learners' contributions do not need to be valid for them to contribute positively. They can reveal misconceptions which the teacher then engages productively with, as happens in the following example:

> Mr Hlope gives his class a worksheet which requires them to "in your own words, explain what is meant by" current, resistance and voltage. The learners engage with this task willingly and competently write things in their own words.
>
> Mr Hlope then nominates two or three learners to read their answers for each term. For resistance, one learner reads "It's an insulator that does not allow electricity to flow through."
>
> Mr Hlope repeats this answer, and says "Is resistance an insulator?" He stands with his hand on his chin.
>
> He invites another learner to read his answer: "Resistance is the disallow of charge to flow through a circuit."
>
> The teacher commends this answer, saying that we understand what you mean. He returns to "is a resistor an insulator?"
>
> Some learners call out "yes" tentatively, then others call out "no."
>
> The teacher says "Let's rephrase, does an insulator allow current to flow through it?" The class choruses "no."
>
> The teacher says "when we talk of an insulator, we normally talk of something that completely disallow, that would be an insulator. But if we talk of a resistor, a resistor can be an insulator [means to say conductor?]. If we talk of a resistor in terms of a light bulb, it's not an insulator, it's something that resists the freedom of movement of electric charges. So an insulator completely does not allow charges to pass through."

In this extract, the first learner to respond revealed an alternative conception that a resistor is an insulator. From my experience, this is a fairly common alternative conception, especially in the context where the resisting property of a conductor is being emphasised. Mr Hlope responded by exploring this idea. In doing so, he used the word which another learner introduced, 'disallow'. There were thus two learner-initiated contributions to the content object: the first that a resistor is not an insulator, and the second that whereas an insulator 'disallows' the movement of charges, a resistor allows charges to pass. However, for these 'wrong answers' to contribute positively to the lesson, the teacher needed to engage with them. As noted in the previous section, teachers contribute to the content object by the way they respond to learners' contributions. In the above extract Mr Hlope did not comment on the confusion of the terms resistor and resistance in the first learner's answer, which means that the potential of this learner contribution was not realised.

The second way in which learners contribute to the content object is by the questions they ask, particularly questions which make links between the knowledge of the lesson and other knowledge – for example knowledge from other sections, subjects or everyday experiences. Such questions may prompt further transformation by the teacher. For example a learner asked at the end of a lesson on torque (see section 5.7.2) “is it possible to relate the principle of moment and the principle of the law of momentum?” Here he related the term ‘moment’ which was used in the lesson to the term ‘momentum’ which he had previously encountered in science. Again the teacher’s response is critical to the value which such a learner contribution adds. Mr Dube did not answer this good question but instead, after a bit of discussion, told learners to go home and research whether there is a relationship between the two. However this is not easily researchable so this learner contribution may have been better served by a direct answer from the teacher

Learners also contribute to the quality of the content object by the questions they don’t ask. In particular learner silences weaken the content object when they fail to query when the teacher makes mistakes or nonsensical statements. For example Mr Dube defined displacement as “the rate of change of position.” This is in fact the definition of velocity, not displacement, and did not make sense in the context of the lesson where the displacement had been calculated as the distance between two points. Rate had not been referred to in the lesson. If a learner had asked a question about what ‘rate’ meant, Mr Dube might have realised and corrected his mistake, thus leading to a better quality content object.

Wagner (2009) distinguishes between different types of learner silences. A learner may be silent because they have nothing to say or because they choose to say nothing. In the above example, some of Mr Dube’s learners may not have queried the definition because they do not expect science and school more generally to make sense, but understand their role as memorising words which have limited meaning for them. Others may have chosen to remain silent out of respect to the teacher. I mentioned in section 2.2.5 that respect is central to traditional African culture, and children are expected to respect adults and demonstrate this respect by not questioning what adults say. Clark and Linder (2006) explain learner silences in South Africa as a consequence both of African cultural beliefs about how children should behave and of practices in township and rural schools, where learners learn early in primary school that silence is the best way to stay out of trouble.

Thus learners are silenced by African culture and school culture, but Wagner points out that even in such a situation the learner makes a choice to comply. I note though that all the teachers in this research project had established didactic contracts about the roles of teacher and learners with their classes such that learners asked questions freely. Wagner also points out that speaking up requires a learner to be able to verbalise her thoughts. Whatever the reason for the silence, the content object of Mr Dube's lesson on displacement is likely to have been different if his definition was not met with a learner silence. I note here that teachers can also contribute silences, but in the case of teachers it is usually done for positive effect, creating space for learners' contributions, for example through wait time (van Zee et al., 2001).

Learners also contribute unwittingly to the content object through the history they share with their teacher. How teachers teach is influenced by their experience of their learners in previous lessons. So over time, learners' responses shape the direction their teacher takes. In conversations a number of the teachers expressed their perceptions of the learners in particular classes or in their school in general. For example Ms Cole said after a discussion of speed traps with her grade nines (as part of the lesson described in section 5.7.5):

> they're not very academic, they're not very bright. […] it just turns out that that year group is particularly weak, across all subjects. Like all the teachers complain about them. So I didn't want to get into depth with them. But the grade eights that you just saw now, they're worlds apart, so maybe if the discussion came up with them I'd maybe get more in-depth with them. But I try to just keep it simple for this class.

Here she draws not only on her own experience but also that of other teachers. Mr Hlope described his township learners as slow:

> the kids, they are very slow, and it consume time. Surely you have seen how long does it take just to write, to answer one question. It takes them fifteen minutes to answer one question.

He puts this down to "language barriers" and to their being promoted to the next grade because of age rather than ability. He saw activities in the textbook he was using as inappropriate for his township learners, though he recognised they would be appropriate in a different context.

In summary, learners contribute with their answers and questions to both the content of a lesson and its transformation. They contribute both by the questions they ask, and the questions they don't ask – such learner silences have a negative effect on the content object. Over time their contributions influence the way their teacher teaches them.

5.6 The Quality of the Content Object

I have argued that the content object constituted in a science lesson is central to the overall quality of the lesson, and depends on the contribution of both the learners and the teacher. My first step in analysis was to identify the content object for each physics or chemistry lesson where the main teaching purpose was the introduction of new content, i.e. 21 of the lessons. A content object is a representation of content, but does not assess the quality of the content. I defined a good quality content object as one which gave learners a good opportunity to learn valid and significant science content and skills. To evaluate the quality, I developed the rubric in Table 13. Each dimension has four levels, with level 4 being the highest level. Level 3 is good, with level 4 being exceptional. A content object can be at different levels on different dimensions. In the rest of this section I will unpack this rubric.

I did not start this research project with this rubric. Rather it emerged as I worked with the data. I mentioned in the introduction to this chapter that I observed three issues with the subject matter content of the lessons I observed: accuracy, appropriateness and comprehensibility. I started with five lessons which seemed particularly interesting in terms of these three issues, and I asked three questions of each lesson: Is the content correct? Is the selection of content appropriate? Is the transformation of the content adequate to make it accessible to learners? These three questions ask for an answer of yes or no. Out of the process of asking the questions of the five lessons, I realised that the questions were too simplistic and so I developed the rubric. I explore these five lessons in section 5.6. I further refined the rubric when I assessed the remaining sixteen lessons.

Table 13: Rubric for assessing the quality of a content object

Level	Accuracy	Appropriateness	Transformation
1: problematic	Content fundamentally flawed	Content largely not appropriate	Minimal transformation
2: flawed	Content significantly flawed	Topic appropriate but level inappropriate	Transformation uneven / flawed
3: good	Minor slips or alternative conceptions, peripheral to lesson	Appropriate to grade in terms of topic and depth	Good transformation but with some gaps
4: excellent	No content errors except grade appropriate simplifications	Curricular saliency demonstrated in emphases	Rich transformation, making content of lesson accessible to learners

The first dimension of the rubric is about the accuracy of the subject matter content, i.e. whether the content is scientifically correct. Alternative conceptions which do not concur with the accepted scientific view are not the same as careless statements which either don't make sense or inadvertently encourage alternative conceptions, or minor slips which don't reflect an underlying alternative conception. There are also simplifications where the teacher deliberately chooses to say something which is not strictly true, as a more scientific explanation would not be comprehensible to learners. The accuracy of the content object is affected by learner errors which are not addressed by the teacher. The centrality of errors to the purpose of the lesson needs to be considered before a judgement can be made about the quality of the content object.

The second dimension of the rubric is the appropriateness of the content. Here the curriculum, despite its flaws, is a useful reference point because it is what teachers are mandated to teach. So for each lesson I found the relevant section of the curriculum. However I also took into account flaws in the curriculum, particularly the underspecified grade 8-9 curriculum, in assessing the appropriateness of the content object. Looking at the peculiarities of the curriculum sometimes helped me to understand why teachers sequenced things in particular ways. My judgement of appropriateness was made with reference to the curriculum, but was more than just a judgement about whether the teachers followed the curriculum. Relevance to a curriculum requires more than just reading a particular part of a curriculum: it requires a view of the whole curriculum which sees the part in terms of its importance to the whole. In other words curricular saliency facilitates the selection of appropriate content. I note here that district officials may play a role in mediating the curriculum, by instructing what should be done when, and this may impact on a teacher's curriculum choices. Appropriateness is not only about choice of topic but also about the level at which that topic is explored, and so this is also reflected in the rubric.

The third dimension of the rubric is the extent to which the content is transformed to make it accessible to learners. As indicated in section 5.4, transformation includes instructional strategies and the topography of the lesson. In some cases the transformation was uneven, with elaborate transformation of some content, and glossing over of other significant content. Of course not all content is equally easy to transform: it is harder to transform conceptually challenging content.

Who is responsible for these three different dimensions in a lesson? I noted in section 5.5 that both the learners and teachers contribute to the content object. The accuracy comes from both the teacher's and the learners' contributions, *and* the way they respond to each other. The appropriateness comes from the teacher, since she has access to the curriculum and frames the lesson. The transformation typically comes mostly from the teacher but can come from learners as they give alternative explanations and help their classmates to make sense of the content.

How are the three dimensions of the rubric related to each other? The teacher's contribution to the three dimensions draws on three different domains of teacher knowledge: accuracy draws on SMK, appropriateness draws on curriculum knowledge and the curricular saliency aspect of PCK, and transformation draws on PCK. So the framing of the teacher's contribution to the content object in terms of Shulman's domains of knowledge seems appropriate (section 5.5.1). Both these subject specific domains of teacher knowledge and the questions which I have asked of the content object are hierarchical. To make sense of a curriculum, a teacher needs sound SMK, and PCK is built on foundations of SMK. Similarly, it is not meaningful to ask whether the lesson content is appropriate if the content is not valid, although I found that if the transformation is good, the quality of a lesson survives minor content glitches. Likewise, the transformation of content is not of interest unless the content is correct. But it is possible for a content object to be accurate and appropriate without being transformed, similar to way it is possible for a teacher to have good SMK and curriculum knowledge, but weak PCK.

There is one important aspect which my analysis does not address: the quantity of content in a lesson. I note that this *is* addressed by Rusznyak's (2011a) framework. I have ignored this aspect not because it doesn't matter, but because it was difficult to make comparisons given that the lessons were different lengths (ranging from thirty minutes to double periods of up to eighty minutes).

Table 14 gives my evaluation of the content objects using this rubric. My assessment drew on my own subject matter knowledge and my PCK acquired through over twenty years of teaching introductory physics at secondary and tertiary level, and twelve years of teaching secondary chemistry. While the rubric could theoretically be applied to any subject, I was only in a position to apply it to physical science lessons, and my application of it drew on my science-specific knowledge and experience. Figure 16 represents the information in Table 14 on a graph, plotting the transformation score against the combined accuracy and appropriateness scores. I needed to combine two dimensions in order to plot the graph on two axes, and so I combined the accuracy and appropriateness scores since these are both assessments of the propositional and procedural knowledge of a lesson, i.e. the left side of the content object. The lessons in the top right corner of the graph – demarcated by the dotted lines – are good in all respects.

Table 14: Evaluation of content objects

Lesson	SUBJ	GR	TOPIC	Accuracy	Appropriateness	Transformation
A1	C	8	Hydrolysis & atom	2	2	2
A5	P	9	Pressure	4	2	1
A7	C	8	Phase change	2	3	3
A8	P	9	Pressure intro	3	3	3
B1	C	10	Model of atom	3	4	4
B4	P	8	Nuclear energy	4	3	3
B7	P	11	Mass on slope	2	3	3
C1	P	9	Average speed	3	4	4
C6	P	8	Density	4	3	3
D1	C	10	Hydrosphere	2	1	3
D3	P	11	Torque	4	3	1
D5	P	10	Displacement	1	2	2
E3	P	12	Photoelectric effect	3	3	2
F2	P	9	Friction	3	4	4
F4	C	9	Elements	2	3	3
F6	C	9	Periodic table	3	4	4
G1	C	11	Stoichiometry	3	3	2
G5	C	11	Organic chemistry	3	4	3
H10	C	10?	Gas stoichiometry	3	3	3
H5	P	10C	Circuits	3	3	3
H6	P	10D	Circuits 2	3	3	3

Figure 16 shows that the majority of the teachers demonstrated some good lessons. The graph also shows that all of Mr Dube’s and most of Mr Abrams’ lessons had weaker content objects. Mr Dube was the only teacher who only had three years of physics and chemistry in his teaching qualification, compared with the other teachers who all had four years. This suggests that weaker SMK could account for weaker content objects in his lessons. Mr Abrams had been teaching for less time than the rest of the sample, and so it is possible that inexperience accounts for weaker content objects in some of his lessons.

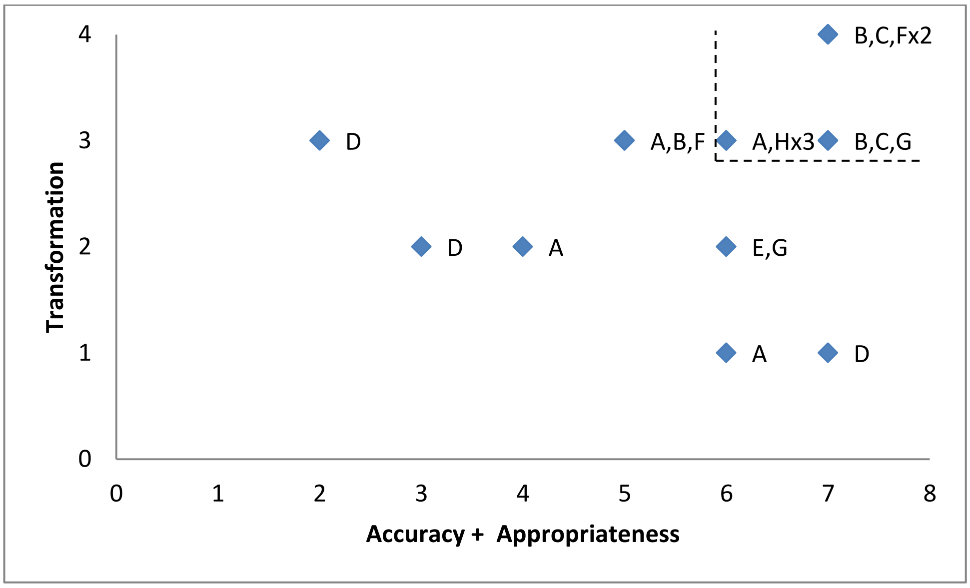

Figure 16: Graph of evaluation of content objects

5.7 Lesson Exemplars

To illustrate my approach to critiquing the subject matter content of lessons, I will now explain my evaluation of five lessons. I cannot present all 21 lessons in this much detail, but have chosen lessons which illustrate the various issues, and which represent the breadth of my data, with one lesson from each grade observed, and three physics lessons and two chemistry lessons. The lessons come from four different teachers – I have chosen to use two lessons from Mr Dube because I found them particularly helpful in developing my understanding of issues with the lesson content. I will present the lessons in order from what I consider to be the least effective lesson to the most effective lesson. The first two lessons were taught by Mr Dube: the first is a grade ten chemistry lesson on the hydrosphere and the second is a grade eleven physics lesson on torque. The next lesson is Ms Emeni's grade twelve physics lesson on the photoelectric effect. The fourth lesson is Mr Abrams' grade eight chemistry lesson on phase change, and the last is Ms Cole's grade nine physics lesson on average speed.

5.7.1 Grade Ten Hydrosphere Lesson (D1)

In order to demonstrate how the content object relates to the lesson as a whole, I will describe Mr Dube's lesson on the hydrosphere in more detail than the other lessons I refer to. The whole lesson is summarised in Figure 17. Figure 18 gives what was written by Mr

Dube on the board over the course of the lesson. Table 15 gives the content object of the lesson as well as the relevant extract from the curriculum document. The phrase in bold print, "Movement of water in plants" was the big idea of the lesson, i.e. the idea which was emphasised in the lesson. The particular points in the curriculum which the lesson addressed are highlighted.

Introduction: The teacher starts the lesson by asking learners to close their eyes while he talks about creation. Then he asks learners to imagine a world without water, and gives them '5 minutes' to draw a picture of this with some notes in groups.
Body: For the rest of the lesson, the teacher asks questions, and engages with the learners' responses, sometimes asking for elaboration, sometimes elaborating himself. The learners participate throughout – putting their hands up to answer questions, wanting to be chosen. Many seem to make an effort to use scientific discourse in their answers. The teacher often repeats his questions, and allows wait time for questions requiring more thought, pausing until there are a number of hands up. He often asks learners for further elaboration. The teacher records certain points, mostly in full sentences, neatly on the board, which most learners copy into their books without being told to do so. The teacher has lots of positive energy, and there is a positive vibe in the classroom. The teacher wears a lab coat but has no notes or other resources. His presentation is fluent, and he is confident and in control throughout. He uses some chorusing, by going up at the end of the sentence or by using the word 'what' in the middle of a sentence.
In the course of the double lesson there are 5 interruptions by teachers and learners from outside the class, 3 of which are directed at the class, but they do not interfere with the flow of the lesson – the teacher is completely unfazed and does not lose his train of thought. There is considerable noise from outside which increases as the lesson progresses, but the teacher can be heard clearly and does not express any irritation with the noise. However he tends to repeat learners' contributions more towards the end of the lesson, perhaps aware they cannot be heard.
Conclusion: The teacher concludes by setting an exercise for homework, and by giving an opportunity for questions, for which the learners are prepared and ask three good questions. The teacher takes these questions seriously – he takes time over them.

Figure 17: Description of the hydrosphere lesson

If there was no water on planet earth

- There would be no life on earth
- All living organisms would die
- There would be no water cycle on earth
- There wouldn't be any seasons on planet earth

There are 3 regions or [?] on earth:
1) atmosphere (air)
2) Lithosphere (land)
3) Hydrosphere (water)

<u>Hydrosphere</u>
<u>Water</u>
Water is the basic unit of
life because without it,
there would be no life on earth.
Its chemical formula is H_2O
<u>Properties of water</u>

- Water is colourless and tasteless.
- Water can be in more than one phase, i.e. it can be a in a liquid phase a gas phase and solid phase

[*diagram showing small plant (like bean seedling), labelled 'plant', with a couple of small circles on leaf labelled 'stoma'*]
Water is absorbed by plants by
means of the roots.
The roots of the plants absorb mineral
salts as well.
When plants absorb water & mineral
salts, they (mineral salts & water) are
transferred to the leaf and stem.
The leaves of the plants consist
of small pores known as stomata.
Their function is to help the plant
to lose water through transpiration.
When water has been lost by plants
through transpiration, Evaporation
takes This is the process where by
liquid changes to gas. Since the
particles of water would be in a gas phase
they lose weight and are therefor
easily transferred to the atmosphere
where by Condensation takes place.
<u>Condensation</u> is the process where by
liquid changes to gas.
[*textbook reference for homework*]

Figure 18: Hydrosphere lesson board work

Table 15: Hydrosphere lesson content object and curriculum

<table>
<tr><th colspan="2">Content Object: D1 – Hydrosphere</th><th rowspan="3">Curriculum</th></tr>
<tr><th>Subject matter content</th><th rowspan="2">Transformation</th></tr>
<tr><th>Propositional knowledge</th></tr>
<tr><td>1. Water is the basic unit of life</td><td>• Without it there would be no life on earth.
• Imagine what earth would be like without water.</td><td rowspan="5"><u>The hydrosphere</u>
Its composition and interaction with other global systems.
Identify the hydrosphere and give an overview of its interaction with the atmosphere, the lithosphere and the biosphere. Water moves through
• air (atmosphere)
• rocks and soil (lithosphere)
• plants and animals
dissolving and depositing, cooling and warming.
(Department of Education, 2006, pp. 50-51)</td></tr>
<tr><td>2. Properties of water (colourless, tasteless, occurs in more than one phase)</td><td>• It can be a in a liquid phase, a gas phase and solid phase</td></tr>
<tr><td>3. Movement of water in plants: absorbed through roots and lost through the stomata.</td><td>• Diagram showing small plant (like bean seedling), labelled ‘plant’, with a couple of small circles on leaf labelled ‘stoma’]
• Detailed explanation written on board, including ‘The function of the stomata is to help the plant to lose water through transpiration’.</td></tr>
<tr><td>4. Particles of water lose weight when they evaporate</td><td>• ‘evaporation’ and ‘condensation’ both used to refer to evaporation</td></tr>
<tr><td>5. Movement of water in the water cycle, with reference to SA’s dams.</td><td>• But this does not mean we should waste water because not all water is suitable for drinking.</td></tr>
<tr><td>6. The salt in the sea comes from mineral salts in the soil</td><td></td><td></td></tr>
</table>

Is the content object accurate? Mr Dube’s statement that “water is the basic unit of life” can be criticised for being confusing, insofar as in physical science, atoms are considered the basic units of all matter, including living matter. In biology, cells are considered the basic units. This confusion was compounded by the fact that the discussion immediately preceding this was about atoms. A better statement of his underlying concept would have been “water is essential for life.”

To say that “The function of the stomata is to help the plant to lose water through transpiration” is not correct – rather the function of the stomata is gaseous exchange (taking in carbon dioxide and releasing oxygen), with transpiration of water an inevitable consequence. Also Mr Dube wrote “The leaves of the plants consist of small pores known as stomata.” But there is more to leaves than stomata, so it would have been more accurate to say that the leaves contain stomata. However this was not a biology lesson, and so these two errors were not central to the lesson, though they may have muddied the water for students who also study biology.

Mr Dube insisted that water loses weight when it evaporates – he stated it twice and also wrote it on the board. Two alternative conceptions which children typically have are that air has no mass and that substances disappear when they evaporate (Kind, 2004). Mr Dube's conception of evaporation appears to have moved beyond these in the direction of the scientific conception but is not yet consistent with the scientific view of evaporation. However this was not a lesson about evaporation, so this inaccuracy was not central to the lesson, though it could be a stumbling block to understanding conservation of matter in physical and chemical processes.

What about the accuracy of learners' contributions to this content object? The valid point that "the salt in the sea comes from mineral salts in the soil" arose because a learner asked in the question time at the end of the lesson where the salt in the sea comes from. In answer to Mr Dube's open question at the beginning of the lesson, a learner suggested that water is responsible for the seasons. Although Mr Dube initially challenged this, he then indicated it as valid by writing it on the board. Along the way another learner stated that "water is one of the phases of matter." This statement reflects a common learner confusion of water and liquid (Kind, 2004), but Mr Dube did not pick up on this. The learners were silent about the incorrect statement written on the board that "Condensation is the process where by liquid changes to gas" even though the same definition was written for evaporation two sentences earlier. Overall I judged the accuracy of the content object to be at level 2: 'significantly flawed'.

Is the content appropriate? The lesson addressed some aspects of the curriculum, which I have highlighted in Table 15. Mr Dube's emphasis on the biology of water transfer in plants reflects a lack of curriculum saliency – a lack of understanding the significance of this section in the context of a physical science course. The movement of water in the lithosphere and animals was called for by the curriculum and may have been addressed in a subsequent lesson, but such continuation was not mentioned in the observed lesson – instead Mr Dube, after mentioning acid rain, said:

> this means that before we use that water, we need to make sure that it's purified, so that we don't actually suffer from bacteria or different viruses, because these lead

> to diseases known as cholera and many others. **So tomorrow this is what we are going to do**, we are going to look at the treatment of water, and what effect human beings have.

Although acid rain is mentioned later in the curriculum, treatment of water is not. Moreover the role which water plays in “dissolving and depositing, cooling and warming” in its movement in air and plants was not addressed in the lesson. The content object includes a description of the direction of movement of water but not the purpose of such movement. Rather the role of the stomata in plants was emphasised in the lesson. The properties of water were included in the content object and marked as significant by being written on the board, even though these are not in the curriculum, and were already known by the learners. In summary, the content object is weakly relevant to the curriculum. Regardless of its relevance to the curriculum, the content object is simplistic for grade ten – it reflects what learners mostly already knew as evidenced in the answers they gave – and does not in any way address difficulties with this topic. Thus I judged it to be at level 1: ‘Content largely not appropriate’.

What transformation of the content took place to make it accessible to learners? Table 15 shows that there was transformation of every aspect of the lesson. The diagram of a plant was helpful, although arrows showing the direction of movement of water in the plant would have made this illustration more powerful. A diagram of the water cycle might also have been helpful. With regard to the topography of the lesson, items 1 - 4 of the content object were written on the board, and the last two only dealt with orally, marking them as less significant. The major emphasis of the lesson was on the movement of water in plants. I assessed the transformation as level 3, ‘good transformation but with some gaps’, recognising however that the transformation was of content which was flawed and inappropriate.

The answers to these three questions give a measure of the overall quality of the content object: the content object is problematic in terms of accuracy and appropriateness. This lesson had the weakest content object of all the lessons which I observed. Contributing factors here are that the teacher qualified with mathematics as his major teaching subject and physical science as his sub-major, and the topic was a new one in the curriculum. In addition Mr Dube did not refer at all to notes while teaching. He explained to me that his learners would see him as not knowing his subject if he did so. The context of this perspective on notes is one where teachers who do not have good SMK are heavily reliant on textbooks while teaching, and thus teachers who are able to teach without referring to books or notes are assumed to have good SMK.

In contrast the form of the lesson, as described in Figure 17, was excellent – an island of positive, enthusiastic engagement in a sea of noise and interruptions. I have chosen this lesson not to show up the teacher but because it so dramatically illustrates the centrality of the content object to the overall quality of the lesson. The form of the lesson is important, but can be completely undermined by a weak content object. One could argue that the form of this lesson had standalone value in encouraging science learners – a lesson with value in terms of 'values and attitudes'. However this depends on the overall mix of science lessons experienced by this class in the course of a year. Many lessons like this would weaken such standalone value.

5.7.2 Grade Eleven Torque Lesson (D3)

I turn now to another lesson given by the same teacher, a lesson on torque. Mr Dube had previously given the learners a photocopy of a textbook introduction to torque. The form of the lesson was very similar to the hydrosphere lesson, but instead of learners drawing on their own knowledge, they sought answers to Mr Dube's questions in the handout. The content object is given in Table 16.

Is the content object accurate and appropriate? The content object contains no errors, although this statement is clumsy "The point of rotation that takes place when a force is exerted on objects is known as the fulcrum." A fulcrum doesn't 'take place', it simply 'is'. The content object is also completely relevant to the curriculum, covering the points highlighted in Table 16 and hence appropriate. I judged the accuracy at the highest level, level 4, and the appropriateness at level 3, 'Appropriate to grade in terms of topic and depth'.

However, there was very little transformation of the science content. At the beginning of the lesson, Mr Dube asked the class whether they had ever wondered why a door handle is where it is, why there are short and long spanners, and whether they were familiar with a seesaw, using the Zulu name. He added that "you will find out today how these things operate." But this transformation was incomplete – Mr Dube did not return to these three

Table 16: Torque lesson content object and curriculum

Content Object: D3 – Moment of force and mechanical advantage Subject matter content Propositional knowledge	Transformation	Curriculum
1. Moment of force is the extent that causes objects to rotate (Turning force) (Torque)	• Have you ever wondered why a door handle is where it is, why there are short and long spanners? Are you familiar with a seesaw? [but this was not related to torque]	**Moment of force, mechanical advantage** • Know that when an object is fixed or supported at one point and a force acts on it a distance away from the support, it tends to make the object turn. • Know that the moment of a force, or torque, is the product of the distance from the support and the component of the force perpendicular to the object. • Calculate the moment of the force, or torque, due to each force when several forces act on the same object using the equation: $\tau = F_{\perp} r$ • Know that for an object to be in equilibrium both the sum of the forces acting on the object and the sum of the moments of the forces must be zero. • Solve problems involving objects in equilibrium. • Describe the terms "load" and "effort" for a lever • Define "mechanical advantage" as the ratio of "load/effort" and calculate the mechanical advantage for simple levers • Apply the concept of mechanical advantage to everyday situations. (Department of Education, 2006, pp. 57-58)
2. The point of rotation that takes place when a force is exerted on objects is known as the fulcrum / pivot		
3. Moment of force depends on the magnitude or size of the force, and it depends on the distance		
4. The force that is acting on the surface of the object needs to be perpendicular to the surface of the object, because if it is parallel, the object will not rotate.		
5. Torque = perpendicular force x distance; $T = F_{\perp} \times r$		
6. Units: $F_{\perp}$ = Newtons (N); r = Metres (m);		
7. Principle of moments: For any object that is in equilibrium the sum of clockwise moment is equal to the sum of clockwise moment is equal to the sum of anticlockwise moment		
8. Equilibrium = the sum of forces that add up to zero; $\Sigma F = 0; \Sigma T = 0$		
9. Torque is a vector quantity.	• because it consists of both magnitude and direction	
10. Mechanical advantage = $\frac{load}{effort}$ = $\frac{distance \text{ moved by effort}}{distance \text{ moved by load}}$	• Mechanical advantage = How much easier the machine makes our work = Ratio of load to effort	
Procedural knowledge		
11. making different quantities the subject of the torque formula in a 3 variable equation.	• extended discussion	
12. 1 m = 100 cm	• Class asked to convert centimetres to meters	

good examples in the course of the lesson. However there was transformation of mathematical concepts: extended discussion on making different quantities the subject of the torque formula, and on how to convert centimetres to meters. Both of these mathematical processes should not have required explanation at grade eleven level, although the learners made far more of a meal of them than they should have, thus contributing to the diversions. None of the rest of the statements in the content object wasunpacked, though they certainly needed to be. In addition, as clearly expressed in the curriculum, learners should have done calculations using the equations and principles. Hence I put the transformation at level 1 ‘minimal transformation’. The learner contribution to this limited transformation was a silence – they did not ask their teacher to explain or give examples. Overall, the torque lesson is another example of a lesson with good form but a weak content object. However, in contrast to the hydrosphere lesson, the weakness of the content object was purely a result of lack of transformation. As a result I judged the content object to have little meaning for the learners

5.7.3 Grade Twelve Photoelectric Effect Lesson (E3)

The next lesson I want to present is a lesson of Ms Emeni’s which introduced the photoelectric effect. Ms Emeni explained the concepts and wrote them on an overhead transparency. She insisted that her learners not write while she explained, saying she would give them time later to write. She then asked learners to repeat her explanation to each other in pairs. The learners responded immediately, and managed to rehearse the explanation well.

The content object of this lesson (Table 17) is mostly correct and completely relevant to the curriculum, but low in transformation. With regard to accuracy, the only criticism which can be made is that the photoelectric effect is evidence not of the *dual* nature of light but of the *particle* nature of light which, together with evidence for the *wave* nature of light, constitutes evidence for the dual nature. Thus I put both the accuracy and the appropriateness at level 3.

With regard to transformation, the lesson cried out for a diagram of a photon hitting the surface of a metal and an electron leaving, but Ms Emeni did not use any diagrams – the explanation was entirely in words and symbols. Such a diagram would have given learners a spatial representation of a temporal reality, and hence a visual peg on which to hang the verbal explanation. Ms Emeni repeated point 4 of the content object, but at no stage did she unpack this claim, and the learners also failed to question the meaning of this claim, or the term ‘quantum’ which was needed to make sense of point 1. Ms Emeni did however look at the three situations of the energy of the incoming photon being less than, equal to and greater than the work function of the metal. Overall I judged the transformation as level 2, ‘transformation uneven / flawed’. The overall quality of the lesson was compromised as a result.

Table 17: Photoelectric effect content object and curriculum

<table>
<tr><th colspan="2">Content Object: E3 – The Photoelectric Effect</th><th rowspan="3">Curriculum</th></tr>
<tr><th>Subject matter content</th><th rowspan="2">Transformation</th></tr>
<tr><th>Propositional knowledge</th></tr>
<tr><td>1. Quantum theory is used to explain the photoelectric effect.</td><td></td><td rowspan="7"><u>Photoelectric effect</u>.
• Describe the photoelectric effect as the process that occurs when light shines on a metal and it ejects an electron
• Give the significance of the photo-electric effect:
• it establishes the quantum theory
• it illustrates the particle nature of light
(Department of Education, 2006, p. 99)</td></tr>
<tr><td>2. When a photon of light strikes an electron in the metal surface, all of the energy is transferred to the electrons. After this the photon no longer exists. $E=hf$</td><td></td></tr>
<tr><td>3. The minimum amount of energy required to remove an electron from the surface of a metal is known as the work function (W_0) of the metal.</td><td>• The metal exerts an attractive force on the electron. Therefore, the electron requires energy to break free from this attraction.
• Three situations of the energy of the incoming photon being less than, equal to and greater than the work function of the metal.</td></tr>
<tr><td>4. The minimum frequency required to cause the emission of an electron is known as the threshold frequency (f_0). $W_0 = hf_0$</td><td></td></tr>
<tr><td>5. The energy of the emitted electron is given by: $Hf – W_0 = ½ mv^2$</td><td>• Learners given problem to do which used this equation</td></tr>
<tr><td>6. The emitted electrons are called photoelectrons.</td><td></td></tr>
<tr><td>7. The photoelectric effect is evidence of the dual nature of light.</td><td></td></tr>
</table>

5.7.4 Grade Eight Phase Change Lesson (A7)

The fourth lesson I look at is Mr Abrams’ lesson on phase change. He heated ice until it melted and then boiled. During this process, he talked about how flame colour is related to temperature, and described what was happening at a microscopic level. While this happened, the girls answered a worksheet with nine questions about the observations and a ‘fill in the gap’ explanation. Mr Abrams also dictated three sentences. In the course of the lesson, Mr Abrams read the thermometer out loud (at 30°, 19°, 34°, and 94°) and gave the girls opportunities to look at it. The girls enjoyed this lesson – there was a happy vibe throughout, except the moment they were reprimanded for taking a long time to settle. The content object is given in Table 18.

Is the content accurate? That depends on how one interprets the term ‘bonds’. If the term applies to the intramolecular bonds between the carbon and oxygen atoms in a molecule of water, then it is incorrect to say that bonds are broken and in fact this is a common alternative conception held by learners. Instead what happens is that the intermolecular forces between different molecules are overcome. However in water the intermolecular forces are called ‘hydrogen bonds’ and so it is correct to say that these hydrogen bonds are broken. Mr Abrams said nothing to contradict this interpretation. Of course the learners have not yet heard about hydrogen bonds, nor will they for a few years. There was no evidence in the lesson of how they interpreted the term ‘bonds’. However Mr Abrams’ use of ‘bonds’ can be criticised for facilitating the development of a typical alternative conception. In addition, the temperature of the ice/water mixture while melting was taking place should have been 0 degrees, not 19 degrees. Teachers are faced with a dilemma when the practical situation does not yield the expected result, and I admire Mr Abrams’ decision to be honest about the thermometer reading, but would have liked to see him modulate this in some way, for example, pointing out that we expect ice to melt at zero degrees Celsius, and questioning the performance of the thermometer. I thus judged the accuracy at level 2, ‘significantly flawed’.

Table 18: Phase change lesson content object and curriculum

<table>
<tr><th colspan="2">Content Object: A7 – Melting</th><th rowspan="3">Curriculum</th></tr>
<tr><th>Subject matter content</th><th rowspan="2">Transformation</th></tr>
<tr><th>Propositional knowledge</th></tr>
<tr><td>1. In the solid phase particles are tightly packed together, and there are strong bonds between the particles</td><td></td><td rowspan="3">A particle model of matter can explain physical changes of substances such as melting, evaporation, condensation, solidification, diffusion and heating by conduction. (Department of Education, 2002, p. 74)</td></tr>
<tr><td>2. When heat energy is applied, this energy may cause the particles to have weaker bonds. When the solid changes to a gaseous phase, the bonds of the particles will break, and therefore when the bonds are broken, the particles will start to move as now there will be more spaces because of the broken bonds.</td><td>• Demonstration of ice melting on Bunsen burner. Meanwhile teacher talked about what was happening, and learners completed worksheet, adding some dictation to worksheet.</td></tr>
<tr><td>3. As the ice melts, the temperature remains constant at 19 degrees Celsius.</td><td>• Teacher read thermometer placed in melting ice.</td></tr>
</table>

The content is completely relevant to the curriculum (level 3), and is a good transformation (level 3) of the curriculum content. With regard to the three levels of representation used in chemistry, in this lesson, there was an effective macroscopic demonstration, with an accompanying microscopic explanation which was accessible to the learners. The symbolic level was not used, as is typical at grade eight level, although a word equation (water(*s*) $\rightarrow$ water(*l*)) would have enhanced the explanation, and made it clear that the water particles remain water and do not break up into hydrogen and oxygen, a common alternative conception (Kind, 2004). Overall the lesson provided accessible and suitable content to learners, though with potential for facilitating problematic alternative conceptions.

5.7.5 Grade Nine Average Speed Lesson (C1)

The last lesson I want to look at is Ms Cole's grade nine lesson which introduced the concept of average speed. Ms Cole worked through a half-page of information on a worksheet, by nominating girls to read aloud, and interrupting them to talk about the information. An animated conversation about speed traps ensued (described in section 4.2.2), with the learners leading the conversation, and Ms Cole gently framing their contributions in scientific language. This meant that the class contributed significantly to the content object. Thereafter the girls worked mostly in pairs on an exercise comprised of calculations using the relationship $v = s/t$. The content object is given in Table 19.

Is the content correct? Ms Cole called the speedometer an odometer, and the class failed to challenge this, even though the word speedometer was used in the handout. This slip may have been a consequence of Ms Cole's nervousness at having an outside observer present, since she reported that she was nervous and not as relaxed as she would normally be (section 4.1.2), and this would have been true of this lesson, since it was the first lesson of hers which I observed. It is a minor slip which made no difference to the development of the concept of average speed.

Ms Cole also gave a completely incorrect explanation for the 'radar gun' which in reality uses the Doppler Effect. But such an explanation would have been way beyond the reach of the learners, and would have detracted from the purpose of the lesson. As Ms Cole reflected afterwards:

> What I always struggle with the juniors, I guess it's my inexperience, I never really know how far to explain things, like what's more beneficial for them. Because I think sometimes if we over-explain, it actually gets too much for them.

So this inaccuracy did not detract from the quality of the lesson but rather reflects the PCK and good judgement of Ms Cole. A third glitch in the content object was that the girls related the word 'displacement' to the displacement of water which is used to measure the volume of an irregular object – this was logical, since they had just finished a module on density where they had used this method. However Ms Cole did not pick up on this misinterpretation. Overall I judged the accuracy at level 3.

Table 19: Average speed lesson content object and curriculum

Content Object: C1 – Average Speed		**Curriculum**
Subject matter content **Propositional knowledge**	**Transformation**	
1. Average speed = total distance / total time	• We experience speed in cars, as indicated on odometer (which is one of 2 dials) • similar to power eqn • Traffic cops get the speed of a car by measuring the time between two tapes, and the distance between the tapes. (Or by using a 'radar gun', which measures time it takes for signal to return to gun.) • Average speed is the not the same speed the whole time, but the same effect as if you travelled at average speed the whole time	N/A
2. Units: km/h or m/s	which can be written m/s, or m over s, or m.s^{-1}	
3. Total distance = displacement		
Procedural knowledge		
4. scientific notation: 1 x 10^{-3}	means ...	
5. how to do problems in science: highlight 'given', do triangle, identify quantities from units	Learners worked through problems	

With regard to appropriateness, this is an interesting case. The *Revised National Curriculum Statement* (Department of Education, 2002) did not include speed at all. But this curriculum was problematic insofar as it specified content for the whole senior phase (grades 7-9) and did not give any indication of how to divide this amongst the three grades. This was particularly problematic given that grade seven is taught in primary schools, whereas grade eight and nine are taught in secondary schools. The response of many schools to this situation was to continue to teach what was taught in the previous curriculum, and this is the case here. Despite its irrelevance to the curriculum, the lesson develops an important concept which learners will need for the grade 10-12 curriculum. Thus I judged it to be at level 4 in terms of appropriateness.

The transformation of the content was excellent (level 4). Ms Cole related the notion of speed to the experiences the girls have in cars. She used their contributions to the discussion to advance the lesson. She also used the particular equation the girls were working with as an exemplar of how to work with equations more generally. Overall this was a very good lesson, with age-appropriate content well transformed.

5.8 Discussion

I started this chapter by complaining that although the subject matter content of a lesson is central to the quality of the lesson, education research tends to have a blind spot for the subject matter content of lessons. My analysis of existing frameworks found that none gave an adequate treatment of lesson subject matter content. In response I developed an analytical framework for assessing the quality of the content of lessons. This involved first identifying the content object for each lesson, and then assessing that content object in terms of a three dimensional rubric which I developed. I compared my approach to other approaches, both other ways of classifying knowledge and other ways of approaching lesson content, in particular classroom observation schedules. Finally to illustrate my approach, I discussed the content objects of five lessons in some detail.

My analysis covered the 21 lessons which introduced new physical science content. The lessons span grades 8 to 12, and include both physics and chemistry lessons. The analytical framework worked robustly over this span. In contrast the two other studies which critiqued lesson content (mentioned in section 2.2.6) only did so for one or two lessons. The content object container provided an easily accessible representation of what each lesson was about. In addition, this approach allowed me to initially capture the content without judging, thus separating observation and analysis appropriately. The approach also allowed me to provide evidence for the judgements which I subsequently made. The rubric distinguished between different aspects of content, and so gave a more nuanced evaluation of the content than simply an indication of whether it was right or not.

Overall what has this analysis revealed about the quality of lesson content? First, what matters is not only how teachers teach, but also what they teach. These results support those who see the subject matter content of lessons as important (Lijnse, 2000; Palmer, 1997; Rusznyak, 2011a; Wallace, 2005). The hydrosphere lesson illustrates the form of a lesson can be excellent – a highly interactive, enthusiastic lesson – but the lesson undermined by problematic content. This concurs with Rusznyak's conclusion regarding student teachers' lessons:

> The findings of this study show that lessons marred by inaccurate, disjointed or incoherent content knowledge can undermine the construction of potential learning opportunities, however well managed and replete with interesting learner-centred activities they may be. (Rusznyak, 2011a, p. S107).

However, she did not look directly at lesson content as I have done, but rather analysed the assessments written by their supervising lecturers.

Second, both accurate and appropriate content *and* transformation of that content are necessary for meaningful lessons. The hydrosphere lesson shows how good transformation of poor content has limited value. The torque lesson shows how a lack of transformation of good content renders a lesson with limited meaning for the learners. However if the transformation is good, the quality of the lesson survives minor content glitches, for example the mistake with the odometer in the average speed lesson and the temperature of melting ice in the phase change lesson. Of course what counts ultimately is learners' take-up of content, which I have not assessed. Learner take-up is influenced by individual factors, but is facilitated by a good quality content object: without accessible content, meaningful take-up is impossible.

Third, learners contribute significantly to the quality of lesson content through their contributions and their silences. Other researchers have commented on the effect which this has, not only on lessons, but also on teacher SMK. Akerson (2005) observed how three grade two teachers had their own knowledge of astronomy extended by the contributions of their learners. In contrast Clark and Linder (2006) see learner silences as having a negative effect on the teacher's SMK over time, in two ways. The first is that teacher errors go unchecked, as a result of which "there is a great danger that content and conceptual errors may creep unnoticed into a teacher's delivery and, unchallenged from the students' side, make take root and grow" (p. 195). The second is that the lack of student questions about content means that the teacher's SMK is eroded over time. The township teacher Clark and Linder worked with observed in regard to the latter aspect "so you don't bother to think very hard about things. You just think at a low level and it's just enough to carry on" (p. 194). Erosion over time could be responsible for Mr Dube's incorrect definition of displacement (see section 5.5.2).

Overall in the past two chapters I have presented analyses of both the form and content of the teachers' lessons. These analyses give a view of the kinds of teachers who participated in this study. In the next two chapters I look at what kinds of teachers the teachers saw themselves as and the conceptions they had of teaching.

Chapter 6: Science Teacher Identities

In the last two chapters, I described what happens in the classrooms of my sample, as co-constituted by themselves and their learners. A look at classroom practice prompts the question: what shapes the practice of teachers? In Chapter 2 I argued that teachers' personal histories, their identities as teachers and their conceptions of teaching are key to their practice. In this chapter I explore the sample's identities and aspects of their personal histories, and in the next chapter I look at the samples' conceptions of teaching. The purpose of this chapter is to address my third research question which asks how the teachers in this study narrate their professional identities.

In section 1.2.1 I concluded that an identity identifies a person as a certain kind of person, and is authored with emotion through labelling, storytelling and actions within the constraints of a particular context. This chapter is concerned with the first two modes of authoring: the labels and the stories. Out of the multiple identities which a teacher has, the identity of interest in this chapter is her professional identity of science teacher. In Gee's (2000) terms, this encompasses both her institution-identity of 'science teacher' and her discourse-identity, i.e. the 'kind of science teacher' she sees herself as. In Sfard and Prusak's (2005) terms, the identity of science teacher is a person's designated identity before it becomes her actual identity.

In this chapter I use narrative inquiry to explore teachers' identities. In section 1.2.1 I gave this definition of narrative: a story constructed or authored by a narrator about her past which makes sense of her present and identifies her in a particular way for a particular audience, at a particular point in time and space. Narrative thought is different from 'logical scientific' thought which works with generalisations. A narrative is:

> an instance of the possible relationships between a narrator's active construction of self, on the one hand, and the social, cultural, and historical circumstances that enable and constrain that narrative, on the other. (Chase, 2005, p. 667).

Thus, like identity, narrative is authored in a particular context and constrained by contexts both present and past.

Narratives are a window on identity, with Sfard and Prusak (2005) seeing identities as stories about self, whereas for Gee (2000) stories are part of the construction of identity through 'Discourse', and for Wenger (1998) stories are part of the reification of identity which works together with participation in the construction of identity. This means that a person's narratives and identities are intertwined, but I note here that they are distinct constructs. Identity is about the present, though it has a trajectory through time and hence draws on the past and looks towards the future. Narrative is about the past, though it is constructed to make sense of the present, and hence is a window on a teacher's current identity. However it is not the only window possible: Thomas and Pedersen (2003) use the Draw-A-Science-Teacher Test to explore the images which teachers have of themselves, thus capturing identity in an image rather than words.

This chapter is framed in terms of two questions: how did you come to be a science teacher? And how did you come to be the science teacher that you are? The first question is about career choice whereas the second is about the unique way in which that career has played out in an individual's life. In Gee's (2000) terms, the first question is about institution-identity whereas the second question is about discourse-identity – the attributes of the science teacher. After addressing these two questions for each of the teachers in turn, I will talk across the narratives, and allow the narratives to talk back to theory from Chapter 2. First, I describe how I invited and worked with the teachers' narratives.

6.1 Narrative Data Collection and Analysis

Polkinghorne (1995) distinguishes between two types of narrative inquiry: analysis of narrative and narrative analysis. In analysis of narrative, the researcher analyses the narratives which are provided as data using Bruner's 'logical scientific' thought and finds themes or types across the narratives. In narrative analysis the researcher uses narrative thought to construct a narrative from data which is usually non-narrative. However Riessman (2005) uses Polkinghorne's latter term for his former category, and distinguishes between four types within this category, which she terms thematic analysis, structural analysis, interactional analysis and performative analysis. The four types differ in how much emphasis is put on the content versus the form of the narrative. Riessman posits that there is value in analysing the form – the way the story is told – instead of treating language as a neutral medium for content. Unlike Polkinghorne, Chase (2005) sees the narratives in narrative inquiry as always co-constructed by the researcher to some extent, because the researcher first asks the questions which guide the narrative, and then selects and organises the data into a coherent whole. Clandinin and Connelly (2000) disagree with Polkinghorne's assertion that analysis of narratives does not use narrative thought: they see narrative thinking as informing the whole research process, with relationships and experience key. In summary, the narrative research experts disagree about narrative research, and so I need to position myself clearly in this playing field.

While Polkinghorne's distinction between analysis of narratives and narrative analysis has intuitive appeal, I found it did not work for me in practice. I had naively thought that the teachers would provide complete narratives for me to analyse, but many of the stories I present in this chapter were constructed by me from data which was both narrative and non-narrative, i.e. Polkinghorne's narrative analysis. I now agree with Chase that the researcher is always involved, to a greater or lesser extent, in the construction of the narratives. But my analysis has gone beyond the construction of stories to Polkinghorne's analysis of narratives. In other words, my experience of narrative research is that it includes both of Polkinghorne's types.

In section 3.8.2 I described how I invited teachers' narratives by asking something along the lines of what I called the 'story' question: "Please will you tell me the story of what has made you the unique science teacher you are today." As described in Chapter 3, the conversations prompted by the 'story' question happened in the context of my spending two days observing a teacher's lessons, and having other conversations about the teacher's practice, fitted around the teaching and other demands of the school day. I gave the teachers the question when I made the arrangement to visit them, to allow them time to think about it. I allowed the teachers to answer the 'story' question in whatever way they chose, and allowed the conversation to unfold from there, consistent with a narrative inquiry approach. But over the course of my time with them, I made sure that all of the following were addressed, by specifically asking if the teacher had not volunteered the information: her reasons for choosing teaching and science; major influences from school, university, teaching practicums, in-service training and colleagues; her choice of her current school; and her personal preferences in terms of mathematics versus science, and physics versus chemistry.

There are two kinds of narrative in this chapter. The first kind is a vignette told by a teacher which is presented in its entirety, and which often describes a defining moment for the teacher. The second kind is a larger narrative assembled by me from the data: a coherent story constructed from interview data which was less coherent. The larger narratives employ both the teachers' words and mine, with extracts taken from different conversations. These extracts employ both logical-scientific discourse and narrative, including vignettes – so the first kind of narrative is often nested in the second type.

While my contribution to the narratives I assembled is obvious, I am also a co-contributor to the vignettes in three ways. First, I authored and asked the questions which prompted them. Second, I was a particular audience – the teacher's past physics lecturer; a white middle-aged female researcher – though as described in section 3.7.2, I took steps to ameliorate the historical power relations between us. Third, for both types of narrative, I selected what I saw as significant out of many pages of transcripts. For example I had conversations with one teacher – about corporal punishment and about teacher strikes – which I found fascinating, but which are excluded because I do not see them as contributing to the two questions I have chosen to use to frame this chapter.

In presenting the results in this chapter, I follow what narrative inquiry experts consider to be good narrative inquiry (Chase, 2005; Josselson & Lieblich, 1993; Riessman & Speedy, 2007). I allow the teachers' voices to speak: I use lots of the teachers' own words. I look at each individual as a whole first, before making any comments across teachers. I go beyond retelling stories to analysis. I am interested in both the content and the form of the narratives, considering both the events which the teachers saw as significant, and the agency with which they positioned themselves in their stories. I note here that there are other aspects of form which I could have considered, and which it would be interesting to explore, but they are beyond the scope of this research project. Josselson and Lieblich (1993) also want to know "What was the meaning of this story or issue in the writer's life?" (p. xii). I answered this question in Chapter 1 (in the introduction and in section 1.4.3) where I narrated my own story and showed its intersection with the stories of my sample. Clandinin and Connelly (2000) argue that the most important criterion for narrative research is 'wakefulness' (p. 184) – on-going reflection and thoughtfulness about the research process. They identify the 'narrative critic' as one of the identities necessary for a narrative researcher. I have given evidence of my wakefulness in Chapter 3.

6.2 How Did You Come To Be A Science Teacher?

The question of how someone came to be a science teacher is about a trajectory into science teaching. The answer has bearing on the kind of teacher a person is, and so I will start with this question. There are two elements to this question: how she chose teaching as a career and how she chose science as a subject. Most of the teachers were enabled to study teaching by a Department of Education bursary which was available for people studying to be mathematics or science teachers – the only exception is Ms Gray whose father paid for her studies. This means that the choice of teaching subject was narrowed to a choice between mathematics and science, although to be eligible for the bursary, the teachers needed to have demonstrated ability in these subjects.

In this section I will relate the narrative for each teacher followed by comments on the narrative. While each narrative is unique, I have grouped similar stories together. The first three tell the stories of teachers who 'always wanted to be a teacher', while the next four tell of serendipitous entries to teaching. For the last teacher, teaching is a logical stepping stone to what he wants to do ultimately. Some of the stories are shorter, some are longer: for some teachers the decisions and trajectories were straightforward whereas for others they were more complicated. Each story gives part of the life history of a teacher, histories which have bearing on the kinds of teacher they are, and which I also refer to in section 6.3 where relevant. This chapter is considerably longer than any other data analysis chapter in this thesis and yet I feel I do not do justice to the teachers' narratives. In part this is because most narrative researchers report on one or two teachers at a time, whereas I have dealt with eight.

6.2.1 Ms Emeni

Ms Emeni told the story of her decision to be a teacher:

> I remember when I was in Standard 3 [grade 5], this other teacher […] used to say that none of us inside that classroom will ever pass grade twelve. So it was like "what is she talking about?" So from that moment I said to myself "This woman doesn't know what she's talking about because I'm going to be like her, I'm going to be a teacher." I actually wanted to be a primary teacher because she was also teaching primary kids, we were in primary school. I wanted to be a primary teacher so that I don't say those horrible things to those kids. Because it really really really got into me, why can't we pass grade twelve?
>
> But now I understand why she was saying that there was no hope [laughs]. There was no hope, there was no hope, because I mean from the generation that we were growing in, looking at those who were older than us, there was no progress at all.

Ms Emeni explained that out of two classes of eighty learners each who started grade one with her, she thought that fewer than ten passed grade twelve.

Ms Emeni's journey into science was an interesting one. The secondary school she attended did not have a physical science teacher, so Physical Science was not offered as a subject. Her mother could not afford transport money for her to attend the school in town which offered physical science. So at the end of grade nine, Ms Emeni and a dozen of her peers approached the headmaster and asked him whether they could study science on their own. He agreed, and the kind man took on the job of setting and marking their science examinations, despite his lack of science knowledge. They studied the worked examples in the textbook under a tree, knowing that all the questions in their examination would be drawn from these examples, as the headmaster did not have any other resources to draw on.

Ms Emeni was one of only four students at her school who achieved university entrance in the grade twelve examinations. I asked her why the four of them were inspired to work so hard:

> We just wanted to be different, that was the first thing. Because from the older people that we saw, those who were here, this one used to get maybe position one or position two [in their class], and now they are driving cars when they come back from Jo'burg. They come back driving cars, and that was cool life. And we knew that the only way to break through from where we were was through education. So that motivated us a lot.

Ms Emeni was able to work hard because her mother was supportive of her studies, though she herself had had no schooling:

> She loved school. So she loved us to go to school. […] She will buy us uniforms so that we have uniforms to go to school with. She will buy us shoes. But whether you're doing your homework or not doing your homework, she will just make sure that you wake up in the morning, you go to school.

But her mother would also have supported her if she had dropped out of school and had children: "if I have had ten kids now sitting at home, I'm telling you she will support me a hundred percent."

Ms Emeni was the youngest of five girls. The next youngest sister "broke through" from rural poverty ahead of Ms Emeni, and hence also 'broke through' for Ms Emeni – she opened up the path. She was the first person to go to university out of Ms Emeni's extended family. Her sister achieved a university entrance in grade twelve, partly because she had the advantage of attending the better school in town. She got a bursary from a bank and did a degree in commerce.

However, after Ms Emeni finished school, she did not immediately go into teaching, but worked for a year as a messenger. Although her initial intention had been to be a primary school teacher, after finishing school she decided was there a bigger need for secondary teachers. Initially she planned to be a mathematics teacher since, not surprisingly, she did better in mathematics than science in grade twelve. But she changed to science as her major when she realised that few of her peers were choosing science as a major and "the need out there again for science is a lot." However she finds mathematics easier to teach, so initially wanted to teach mathematics when she qualified, but circumstances dictated otherwise – thus affirming her assertion that the need for science teachers is greater.

In both her decision to become a teacher and her choice of science, we see Ms Emeni positioning herself with agency, in hostile contexts – contexts which predicted that she would neither finish school nor be able to study science at school. And this agency means that out of a context of rural poverty with an illiterate single parent (her father died when she was two), she became a qualified teacher. In this she was helped by her mother's support for her studies. We also see her agency in strategically choosing to major in science rather than mathematics.

In summary, Ms Emeni selected her designated identity as a teacher for herself. In this her strongest role model was a negative one: a teacher who predicted non-success. Ms Emeni rejected the identity of failure imposed on her by this teacher, yet she gave some credence to this teacher's comment, saying that she was right that "there was no hope." Another significant role model was her older sister who not only 'broke through' from rural poverty ahead of her, but also provided accommodation: Ms Emeni lived at her sister's house while she studied.

6.2.2 Mr Baloyi

Mr Baloyi's desire to be a teacher was also the result of a particular teacher, his grade one teacher, but for him the teacher was a positive role model:

> I saw this person who knows every single thing in the world. You will ask her anything, she has an answer for it, and the answers just make sense. And that is what I aspired to be, I wanted to be like her, now and then. And she was very strict, but she was like a mother. And what makes me much more like her, she used to wear the same perfume as my mother. She used to smell like my mother. So I think that is where I got this love of being a teacher.

However his parents did not want him to be a teacher, so he started a different qualification, a three year National Diploma in Industrial Engineering. In his second year he started a teaching qualification, and continued the engineering qualification part-time, so that he finished the two diplomas at the same time. He comments "During [teacher] strikes sometimes I feel like going and looking for a job [in engineering] because the pay is much better."

Like Ms Emeni, his entry into science was unconventional:

> I was in the history class, grade ten. The whole class there was just one gangster. So I didn't fit very nice with the gangsters, although they were not really bullying me or anything, it's just they were gangsters and I was just there, part of the class. But I didn't feel part of the class. And I've noticed that the science class there everyone was – no gangsters in the science class. Everyone just does work. And I went to ask the school if they can move me, now that is in grade eleven, to do science.

So Mr Baloyi's move to science was an escape from an uncomfortable social situation. His decision to teach science was because he "really enjoyed science more than maths."

This vignette identifies Mr Baloyi as 'not a gangster'. The identity of gangster was available to him in his context but he rejected this resource. Hence he had affinity with a class where everyone "just does work." This aligns with his designated identity in the first vignette to be someone who is knowledgeable like his grade one teacher, and also his identification of himself as someone who respects his parents. These identities together with his rejection of a gangster identity facilitated his agency in asking to move class, a move which took courage.

Mr Baloyi's parents were 'significant narrators' (Sfard & Prusak, 2005) who provided him with the designated identity of engineer. This conflicted with his own long-held designated identity of teacher. He initially deferred to his parents' designated identity, thus showing them respect. However he then negotiated a way of both fulfilling their and his designated identities – a way to respect his parents and achieve his own goals, though one which required extraordinary hard work on his part. His own designated identity of teacher facilitated his agency in this negotiation. In both vignettes Mr Baloyi positioned himself with agency.

6.2.3 Ms Fikela

The third teacher who 'always wanted to be a teacher' is Ms Fikela:

> Well, I've always wanted to be a teacher. I started teaching at – how old was I? When I was in sub B [grade 2]. I would learn the maths time[s] table[s], and I will come back home and I will gather all the kids around, and then all my cousins, I was starting them, two times one is two. So it's something that I gradually grew up doing. When I'm bored on holidays, I'll start teaching people, and it's something I always wanted to do.
>
> But it wasn't easy because I finished matric in '97, and then I went to an engineering school. I went to TWR, Technikon Witwatersrand. Remember that one? And I didn't want to do engineering, I wanted to do teaching, but I didn't know where to go, because there was no information to where to go.
>
> But funny enough, I used to work at Killarney Mall, I used to [work] part-time at Killarney Mall, and I used to pass JCE[20] every time and I had no idea what JCE was all about. Up until in 2000. I was working with this old lady, and she said to me, "what are you doing?" At that time I had dropped off at TWR, so I was now working full-time. She says to me "you look very young, you've passed your matric, what are you doing with yourself?"
>
> I'm like, "I'm working."
>
> So like "But do you want to work?"
>
> I'm like, "no."
>
> She said "What do you want to do?"
>
> "I want to teach."
>
> And she's like, "Why don't you go teach?"
>
> "I don't know where to go."
>
> And she's like, "My daughter is a teacher, she just graduated from Wits[21]."
>
> And then we phoned Wits, and then a whole story came, and then Wits referred me to JCE, and then the rest is history.

Ms Fikela was part of an unusually large cohort of science student teachers, and so after qualifying she did not find a job easily. The first job she was offered was a science post,

[20] The Education campus of the University of the Witwatersrand (previously the Johannesburg College of Education)

[21] The University of the Witwatersrand

and that is the reason she has ended up a science teacher rather than a mathematics teacher.

In her narrative, Ms Fikela first positioned herself as a leader – a child who rounded up other children and taught them. But later she lacked the agency to find out about teaching, despite this being her designated identity and despite the fact that she could have asked her own school teachers how to become a teacher. Instead she started an engineering diploma, presumably because that was something she had heard about. But she dropped out after a year because her heart was not in it. She was swept on the current of life until a 'fairy godmother' figure or mentor asked her five questions which served to remind her of her designated identity and then gave her the answer she needed to fulfil her lifelong ambition. The story about her mentor was one of many stories where the teachers used direct speech, putting on different voices for the different characters in the story, reflected by quotation marks in transcription.

6.2.4 Mr Hlope

Unlike the teachers above, the remaining five teachers did not plan to be teachers when they finished school. Mr Hlope would have liked to study law, despite being put into a special science programme when he was at school, which meant he went weekly to a special science centre from grade nine onwards. He was one of two learners from his area who were selected for this extraordinary opportunity in his context of rural poverty. However that did "not help me to develop some interest in science though, but I did realise that science is my strong subject, that it's well catered for." When he finished school, he found he couldn't get a bursary for law and didn't look further. He got work building a road, and ended up working as a car guard[22] at a shopping centre. The car owners:

> used to encourage me, saying, "Mr Hlope, judging by the way you communicate, you seem to be one person that has undergone through some sort of education."
>
> I said, "Yes."
>
> "But what stopped you? Why would you choose to come here and just stand up on a parking lot?"
>
> Then I told them my situation.
>
> I had made lots of friends, it was very, very nice. I do remember Mr [Cabier?] from Italy he used to come there visit, come with a bible [*interruption*]. And then

[22] Someone who watches over cars in parking lots in return for tips.

> he used to encourage me, come read the bible for me. He used to come with bags of clothes, give me the clothes, and all this. So lots of people liked me a lot.
>
> Then I realised that there is something that is missing in me, that maybe I need to fulfil. It does not matter which type now because I had no choice now. Age was catching up with me and then I had to make something out of what the people are encouraging me to do.

In the above vignette, Mr Hlope is identified as one who is educated because of "the way you communicate." The language of communication was English, so here 'educated' equates to fluency in English. Mr Hlope's English was good because he had worked hard at improving his English by getting old newspapers from a security guard at the mines:

> There was a man who used to work in Rustenburg, he was a security [guard] at one of the mines, they used to give them these newspapers, *ja*, big newspapers. They would be outdated. I'd always go and ask for two.
>
> Then how I used to learn, ma'am, I would underline sentences, the word they've written, take a dictionary then pick up those words which I don't understand, then work them out. Then myself, re-read the very same sentence, then take the sentence, stays in my mind and go and apply it to someone, the way it is.
>
> And in spelling I was very, very good because when – I remember if you want to write beautiful, for example, I would go be-au-tiful. […]
>
> So they thought that I was good. I wasn't. I was not clever, it was just that I found way of improving my language.

Mr Hlope became a teacher because he saw an advertisement for a Department of Education bursary in the *Sowetan* newspaper. By then he was in his early thirties. The first time he applied, he was too late, so he came back the following year. The bursary was for mathematics and science teachers only. Mr Hlope chose to major in science because he did better in science than in mathematics in his final school results, a decision which was affirmed when he achieved 73 % for first year physics.

In the story about the newspapers, Mr Hlope identified himself as 'not clever', despite the fact that he'd been identified at school as clever and selected for a special programme. Instead he recognised that being able to speak English served as a proxy for being clever, similar to his first vignette above where being able to speak English served as a proxy for being educated. Despite his 'not clever' identity, Mr Hlope recognised that he had a strength in science: he said that at school "I did realise that science is my strong subject" which was confirmed by his first year university results more than a decade later.

Mr Hlope's story resonates with Ms Fikela's: he recounts considerable initiative and agency while at school, teaching himself English by creative use of resources in his context: out-of-date newspapers, but then, despite having had a clear designated identity, he was swept along by the current of life until a mentor intervened. Mr Hlope's designated identity was not teaching, and appears to have been unreachable. Mr Hlope's mentors were many, though one stood out. His mentors renewed his confidence in himself, and he had the experience that "lots of people liked me a lot." His agency was in response to those mentors: "I had to make something out of what the people are encouraging me to do."

6.2.5 Mr Dube

Mr Dube declared: "Teaching was like the last thing that I actually wanted to do." However he did not have a clear idea of what he did want to do. Mr Dube was the top student in his grade, which he explained came from his experience of being "abused verbally" at home (his grandmother's house), explaining:

> at home they'd swear at me, because there was no good relationship between my mother and my grandmother. And now and then I'd be reminded that my grandmother's house is not my home.

He said of his grandmother: "I love her dearly, it's just that my other uncle used to actually influence her to actually swear at us. And that kind of changed my attitude towards her." His response to this situation was that he:

> decided better I try to do well at school so that maybe I can get a bursary if there is any, and in that way I can then to actually change my life, so that I can move away from this place that I'm not comfortable. And so basically I kind of used my performance at school as a healing for me, because I just told myself that whatever happens, I will answer to those people with pen and paper. […] So I managed to find parents at school, and when I'm at school I made sure that I enjoy as much as I can, so that even if I go back home and such things start again, at least I would have enjoyed some of most of the time for that particular day.

Mr Dube's "parents at school" were teachers who in their relationship with him took the place of his own parents. One of his strategies for success at school was to work ahead:

> When we were actually in Chapter 2 with our teacher – I used to do it a lot with mathematics because one can be able to do mathematics even if there is too much noise in class. So this is what I would do, if perhaps we are doing multiplications of expressions, I would go further to do division and so on and so on, so that by the time the teacher gets to that section, I would have already gotten an idea about that particular thing. So it would be like a revision for me.

However, despite his desire to use his school results as an escape from home, Mr Dube spent the year after matric at home, doing some teaching at a Saturday School which ran in his old school and from which he had benefitted substantially when he was at school. He was persuaded by a friend to study a teaching diploma the next year because the friend said "I don't want you to stay at home." Initially he registered as a science major, but changed to mathematics because of an incident with a fellow student over a physics test:

> I went to him for help, he just said he did not actually know anything based on that. […] So we went to write, I remember I got thirty something [percent] and that question [I had asked him about] consisted of twenty marks. So I lost most of my marks in that question. You know, I was heartbroken.
>
> And when I looked at his script he had actually got a total [full marks] on that question, the very same question that consist on things that he said he did not know. And then I went to him and I said, "But you said that you did not know this." And he said, "I was joking" […] , that kind of broke my heart and I said, you know what, let me rather do maths, I won't continue physical science.

This story is framed by the larger context of Mr Dube's experience of university: try as he might, he could not achieve the distinctions he wanted to. He described how hard he worked the night before a test:

> at probably half past seven, I'd eat, take a bath, then sleep a little bit, then probably at ten I'd study up until twelve, and then at two o'clock or half past two - or at twelve o'clock I'd sleep again, then at half past two or at two sometimes depending on what we are going to write, I'd wake up and study again.

What Mr Dube identified as particularly helpful from university was the compulsory sociology module he did "because it's practical, it's something that you come across every day and it enables you to cope in life" and a personal development course (run by *The Pacific Institute*) he did while at university. He also expressed gratitude to me for teaching him good discipline in filing. He may have been referring to my requirement for his class to keep on-going 'resource' files, which were submitted once a year for a mark, or it may have been that early in his first year I asked his class to submit their physics files. Either way I had clear stipulations regarding the organisation of files, in particular the use of file dividers. But this was certainly not a big input on my part. This is an example of a small input levering up a big effect – the butterfly effect of complexity science (see footnote 7, p. 29).

Despite dropping science at the end of third year, Mr Dube started his career teaching both mathematics and science. In his second year of teaching, the principal suggested he teach the grade twelve mathematics for Paper II of the examination, while another past student from the University of the Witwatersrand taught the Paper I mathematics. At the end of the first year of this arrangement, the school achieved a mathematics distinction for the first time in a long time, and there was a braai[23] to celebrate. At the end of the next year there were seven mathematics distinctions, though the principal who had suggested the teaching arrangement passed away in the course of the year and so could not celebrate with them. However the next year:

> our mathematics HoD came and then he suggested that I take grade eleven so as to give another teacher the chance to actually teach grade twelve. So I was like, "okay, no that's fine." Though I thought that I was doing a jolly good job then. But then I just said we all have to share, we all have to give one another a chance. Okay, right. And then I taught grade eleven, everything went okay for that year.

At the end of that year, Mr Dube saw that he had been allocated to teach grade twelve the following year. But he asked to be given grade eleven instead, to avoid conflict. Hence he started the new year teaching grade eleven mathematics. However three weeks into the term a new mathematics teacher arrived:

> this is what happened, my HoD decided to take all of my four classes for maths and give them to him [the new teacher], without consulting me. I got to know that when the principal called me and said that "Mr [Dube] what other subjects can we add to your timetable since you are now running short of certain periods?"
>
> And I was like, "What! I mean, last time I checked, my timetable was full."
>
> And then the principal said, "But your mathematical HoD said that he has actually spoken to you about the situation and he said that you agreed to that."

Mr Dube explained that was not the case and there was an apology. He decided to speak up about his unhappiness with the situation in a staff meeting:

> I explained the scenario. Then I told them that I felt like, okay, the mathematic department did not need someone like me. And according to me as well, I mean I also went to school just like them. I have got the four year diploma, just like them. I did not buy my qualification from anyone, from Hillbrow or something. They said, "language, Mr [Dube]." But I was angry at that time and so, I said to them "if you want to make changes about me, you have to consult with me."

His speaking up did not however change the allocation, and Mr Dube had not taught mathematics since – he opted instead to teach technology. Mr Dube commented later:

> From that incident, you know, I realised that teachers who arrived in the system a long time ago, when they see young teachers, they become threatened. Because young teachers they come with new information that are relative to the system that is being practised at that moment in time. So if he or she finds that you are actually doing well on that particular section than him or her, then they start to actually get

[23] Barbeque

> threatened, you become a threat to them. So it's difficult to cope in such an environment. Because my personal belief is that we are all here for one thing, to make sure that our learners are having the best that they can have, the best education they can have. So we should not actually put our personal feelings before the personal needs of learners. But we really need to cope in such situations.

However not all the teachers at Mr Dube's school were like this. Mr Dube's own grade eight class teacher still teaches Natural Sciences at the school, and Mr Dube said of him "I learnt lot of things from him; he's my father figure" which fits with his earlier comment that "I managed to find parents at school." Mr Dube described how "I actually go to him for any assistance be it spiritually or sometimes for certain advice." This situation is reciprocal:

> If perhaps he finds that he needs an assistant pertaining certain sections, in grade nine. […] He is not too proud to come and ask you to take over his class for that section. So we help each other there and then, okay. *Ja*, we actually depend on one another in this school.

Mr Dube told two stories which follow the same pattern: an incident with a fellow student, and an incident with the mathematics head of department. In both stories Mr Dube is treated unfairly, and feels hurt. In these situations Mr Dube felt empowered to talk, whereas when he was growing up he was silenced at home. He spoke up and got a response but then made a change to avoid further conflict, in both cases changing subject – the first time towards mathematics and the second time away from mathematics.

Mr Dube's story of his schooling resonates with Ms Emeni's: showing agency and working hard at school to get away from a home situation. But unlike Ms Emeni, he did not have a supportive environment at home. Instead his encouragement came from his teachers – by doing well at school, Mr Dube found the affirmation he did not get at home. His strategy of working ahead in the textbook has a resonance with Mr Hlope's use of newspapers to learn English. Both of them used resources available to them to 'get ahead'. At university Mr Dube's identity as a top student was undermined by his results, and so he no longer got affirmation from his studies. Perhaps the courses which facilitated his personal growth helped him cope with this situation.

Mr Dube implicitly identified himself as a good teacher. He understood that older teachers feel threatened by young good teachers, particularly as young teachers have been trained in the current curriculum. Although he made the point in the staff meeting that they all had the same qualification, the truth is that he obtained his qualification at a good university, whereas his older colleagues would have mostly obtained their qualifications at inferior black colleges of education under apartheid. When the grade twelve mathematics was taken away from him, he was disappointed, but told himself “we all have to share” though he was aware of the dynamics operating. This is evident insofar as when he was offered the grade twelves the following year, he turned them down to avoid conflict with older colleagues. There is a sense of him walking a tightrope – trying to give learners the benefit of his teaching without upsetting colleagues.

6.2.6 Ms Cole

Ms Cole planned to be an architect but in her first year of study:

> realised it was quite an officey job, like I didn’t actually want to sit behind a computer all day, so I became quite unhappy in that degree, so then I left that. And then, when I went to JCE, I just was trying it out.

Her reason for ‘trying it out’ was:

> I think just it being in the family, because my Mom’s a teacher as well. And also like that bursary because I was having to support myself at that time so I wouldn’t have been able to study if I didn’t have that money.

She concurrently completed an arts degree by correspondence through a distance education university (UNISA).

Ms Cole did not study physical science at school. She took it up in her teaching diploma because she got credit for the mathematics she did in architecture, so had space in her timetable, and a lecturer suggested at registration that she try science. She found she “loved it way more than maths.”

Ms Cole’s initial designated identity was based on her preferred subjects: art and mathematics. Thus she chose a career which seemed to combine them. However she was sufficiently aware of her own preferences to realise early on that it was not a suitable identity for her. Her entry into education was opportunistic, and her entry into science happened because of the intervention of a mentor. I noted at the start of section 6.2 that some of the stories are shorter, some are longer: for some teachers the decisions and trajectories were straightforward whereas for others they were more complicated – Ms

Cole's and the next story are both in the former category. However their stories will be picked up again in more detail when I consider their discourse-identities.

6.2.7 Ms Gray

Ms Gray loved chemistry at school, and so wanted to study chemistry at university. For her pharmacy seemed the best option, and she put down teaching as a second option:

> That came from my Dad telling me to put down a course in case I didn't get into what I wanted. I got accepted for pharmacy at Rhodes [University], and he didn't want me going into that, so I went into teaching. I don't regret it though. I enjoy it now.

Her father vetoed her career choice, because the pharmaceutical industry was in some disarray at the time, with new legislation which affected pricing. So she is a science teacher because teaching was a way to continue with chemistry which met her father's approval.

Ms Gray identified strongly with a particular subject, and hence chose a designated identity of pharmacist. But similar to Mr Baloyi, Ms Gray accepted her parent's designated identity. From other stories she told me, it is clear she saw her father as having her very best interest at heart.

6.2.8 Mr Abrams

Mr Abrams wants to work for the Department of Education and run workshops for teachers. He thinks "that would be the ideal, dream job to do" because "it would be more beneficial if you could help upgrade some teachers." He wants to do this "for the benefit of the children." His mother is a primary school teacher who:

> often complained on people from district sending people in to come and help them with curriculum development, and the complaint was that they could not understand them because they could not reach to their level, first of all. And second of all, sometimes they didn't know what they were doing in the first place. So that's the reason why I'm in teaching now.

In contrast to such ineffective training, he would like to address the needs of teachers:

> And it also depends on the need of the teachers over there, so you'd also have to do a bit of research to see where are they lacking skills and what can you help them with. And often if you do ask them where you actually need the support, then they can verbally tell you as well.

In order to do this, he needs seven years of teaching experience.

He chose to teach science because it was his favourite subject by the end of secondary school, although “the light bulb only came on” in grade twelve. He explained “when I started understanding the sciences at matric level [grade twelve], then I started enjoying it, so I thought why not do something that I would enjoy doing.” This understanding was precipitated by a new teacher.

After completing an honours degree in science education, he wanted to teach at a township school, so:

> I applied at various schools as well within the area, and I did not get in. And one of the principals actually called me in to say that, well they’ve got connections between the different principals and I won’t get in because some teachers in the Head of Departments feel threatened by me coming in, based purely on qualification. And that’s the reply that I got, so I couldn’t get in.

I asked him how that made him feel: “Very sad, very sad, because I mean, when I went to go teach at [the one school during a teaching practicum], the response I got from the kids was overwhelming.” However he was happy at the multicultural school where he taught at the time I visited him.

Unlike the other teachers, Mr Abrams had not yet achieved his designated identity. Teaching was to him what studying was to the other teachers: a qualification for the job he wants to do. He had a clear trajectory and was accepting of the time that his designated identity would take to accomplish. Mr Abrams’ experience of not being able to get a job in a township school resonates with Mr Dube’s experience within a township school: both were perceived as threats because they were well qualified. For both their graduate identity conflicted with their teacher identity.

6.2.9 Discussion

The teachers’ narratives made sense of their institution-identity of ‘science teacher’. These teachers have ability in science but are not in more lucrative scientific fields, even though three of them started to enter engineering or architecture. Hence their stories justify this reality and make sense in terms of this reality. In constructing their narratives, the teachers made selections from their histories in the physical context of the teacher’s classroom or office and the social context of my two days of research with the teacher. The teachers had their reasons for becoming science teachers readily to hand – the reasons did not appear to be conjured on the fly for me as audience. However the reasons they gave may well not be the only reasons, but they are the reasons which the teachers remembered and selected as significant from the resources available to them in their personal histories. Polkinghorne (1995) makes a useful distinction between "accuracy of the data and the plausibility of the plot" (p. 20).

In section 2.4.1 I noted that nearly ten years ago, Hindle (2003) proposed a research agenda for teacher education in South Africa, the first item of which was research into why South Africans choose teaching as a career. The results of this study give a partial response to Hindle's call. In section 2.4.1 I noted three clusters of reasons which people give for choosing teaching: altruistic, intrinsic, and extrinsic (Kyriacou & Coulthard, 2000). None of teachers in my study gave extrinsic reasons – a fact which reflects the reality of the challenges of teaching in South Africa. Most of the teachers expressed deep altruistic concerns for their learners in their conversations with me, but only Mr Abrams expressed these concerns in explaining his entry into teaching. The rest of the teachers gave intrinsic reasons – always seeing themselves as teachers (Ms Emeni, Mr Baloyi and Ms Fikela), wanting to continue with a favourite subject (Ms Gray), or wanting to study further, consistent with their potential (Mr Hlope, Mr Dube and Ms Cole). Teachers who say they always wanted to teach have been identified in a number of studies (Andrews & Hatch, 2002; Azman, 2012; Bastick, 2000; Jarvis & Woodrow, 2005; Krečič & Grmek, 2005; Manuel & Hughes, 2006; Smart, 2008), as have teachers who become teachers because they have an affinity with a particular school subject (Andrews & Hatch, 2002; Chuene et al., 1999; Jarvis & Woodrow, 2005; King, 1993; Manuel & Hughes, 2006) and teachers who want to fulfil their potential (Azman, 2012; King, 1993; Krečič & Grmek, 2005).

A number of the teachers in this study mentioned people who had been significant in their career decisions: parents, teachers, a friend, a work colleague and members of the public Influences by parents, friends and teachers have been identified in other studies (Azman, 2012; King, 1993). Ms Fikela, Mr Hlope, Mr Dube and Ms Cole's stories of mentor figures who intervened in their lives resonate with research by Andrews and Hatch (2002) who found some people became teachers because of a 'serendipitous life-event'. Ms Emeni's story has resonance with that told by Samuel and Stephens (2000) of a rural South African student who decided to become an English language teacher because of the negative attitude of her English language teacher to poetry.

The conditions of the Department of Education bursary constrained most of the teachers to becoming mathematics or physical science teachers (section 6.2). Most of the teachers now have a strong affiliation with the physical sciences. However, with the exception of Ms Gray and Mr Abrams, the teachers had a circuitous trajectory to their affiliation with science. Moreover, despite the availability of bursaries, the teachers in this study did not move smoothly from school to studying teacher education. Three teachers started by doing another qualification, two teachers completed another qualification while they were busy with their teaching qualification, and four teachers spent at least a year not studying before starting their teaching qualification.

6.3 How Did You Come To Be The Science Teacher You Are?

In this section I will address the question: How did you come to be <u>the</u> science teacher you are? Here I will focus on the initial response which teachers gave to the 'story' question where I invited them to "tell me the story of what has made you the unique science teacher you are today." Despite being invited to give a story, most of the teachers did not , though they all showed themselves more than capable of storytelling in answering other questions. Instead the teachers responded by identifying themselves as certain 'kinds of teacher', and so their responses are a window on their teacher identities. In retrospect I realised the interview question prompted such a response, by asking them to identify what was distinctive about themselves. In fact I did not start out planning to research teachers' identities, but found their identities central in the data, and so adjusted my research question accordingly.

I will present the teachers in the same order as the last section, recognising that eight actors are too many main characters for one story, and so a challenge for any reader. I look first at each teacher's immediate response to the 'story' question, and then draw on other data to unpack her response further. In particular I am interested in the origins of these identities. I. These origins come out of their particular life histories, which I have related in part in section 6.2, and to which I will refer where relevant. I have added italics to words in the quotes which are key to a teacher's identity, as this draws attention to how they used these particular words.

6.3.1 Ms Emeni

Ms Emeni identified herself as a teacher who uses apparatus to elucidate content for her learners. When asked the story question, Ms Emeni's immediate response was:

> Earlier on when I was teaching Physical Science it was all *content* and *content* and *content*. As I was growing into the science, I thought maybe let me put some *experiments* in, and once I started doing that, it became a whole lot easier.

From there she told two stories of how demonstrations using science apparatus made the content more accessible to learners.

Ms Emeni's emphasis on content is in part because she finds the content challenging "Physical Science for me, it is still difficult – I'm teaching grade twelve, yes, but the *content* itself is heavy." This reflects her major dilemma: when she was at university, her goal as a student was simply to pass (a habit she acquired at school), not to acquire the knowledge which she needed as a teacher. So while she admits that at university "the only thing that we will do to pass is to do the minimum of what will make you pass, because that was all that was needed for us to pass, fifty percent" she says in retrospect:

> if they say you go back to the college, I think I would concentrate more now than then, because most of that stuff is coming up, and it's like, hello, I've done this but I know nothing about it. And if we go back to the tests we wrote, I did pass them, but [laughs].

She also draws on this deficient university experience as her primary source of teaching methodology, since she did not have a physical science teacher at her school. In different conversations she repeatedly described how she used me as a role model for her practice, for example:

> If Dale was sitting there, what is that she was going to be hearing me telling the kids? That's what comes back on my mind all the time. Even when, before you even came here.

Concerned that the claim of me as role model could be influenced by my position as researcher, I challenged her on this claim by saying "I know you're talking to me now, but when you teach chemistry, do you ask what Mrs Harris was going to do?" Her response was:

> No, no, no, no, no, no I don't ask what Mrs Harris is going to do. So taking in that you were a teacher before and you were not only teaching physics, everything goes back to you. I don't know why, but [laughs].

When I asked her for specific strategies drawn from me, she gave two, the first of which was my use of an A4 book for planning lectures:

> as you were seeing, when I was teaching photoelectric effect, I had notes for myself there. So that I don't get out of what I am teaching and that is from the book that you always had when you came to the classroom. With your notes there, then you will have your notes and make sure that you are teaching what is there, and then you will be writing stuff for us. Because you won't come and say, okay, these are the notes and then you copy these and, no, you will teach, not your textbook, you had that that book. So I prepare like that also, I sit and write stuff for myself to understand. For me it's to understand and then I go sit and then I teach it.

Embedded in Ms Emeni's use of notes is her desire to understand the content she teaches.

The second strategy Ms Emeni identified as having come from me is her use of apparatus:

> every time when I'm sitting and doing my planning, then I get, like you said, "the science department will have the budget to buy this stuff", then we do have the budget to buy that stuff, but then am I buying? My first year, no I wasn't. I was still sitting and it was fine, you can just do the *content* from the textbook, but now as time is going, I do sit down and say, what is that I will need?

In a fourth year methodology lesson on the topic of laboratory management, I had told her class that wherever they teach, they should stake a claim for science apparatus. My handout included "If you lack equipment, put pressure on your district official and your principal." I told them that there is always some money available somewhere. However this wasn't a message which I repeated. I see this as another example of the butterfly effect. My small, once-off input of urging student teachers to ask for science apparatus was key to Ms Emeni's identity as a teacher who uses apparatus to elucidate content, which was in turn key to her agency in asking for apparatus.

In summary, Ms Emeni identified herself as a teacher who elucidates difficult content by means of science apparatus. She saw both her engagement with content and her use of apparatus as learnt at university, specifically from my practice.

6.3.2 Mr Baloyi

Mr Baloyi identified himself as a teacher whose classroom is a safe space. He noted that learners chose to be in or around his classroom at break because of the sanctuary it offered:

> If you notice the relationship I have with my learners, all of them. I argue with them, or you are firmly strict with them, but somehow they just enjoy coming to my classroom. That just makes me very happy. During break time, you see it's always full around here. This area is infested with gangsters, and I've noticed that

> if they come around here they feel *safe*. Just around my class, on the stairs, or in the class itself. I grew up in an area that is also similar to that, where there's lots of gangsters. And sometimes you can't find a sanctuary, where am I going to go during break time. Although all teachers do break duty, they are there outside but it's not always *safe*. So this environment should be *safe* for everyone. They feel *safe* to be here, they feel *safe* to come and do their homework, and there is a library, fully resourced with the internet and so on, but they hardly go there. They prefer coming here. So it means somehow they feel it's a *safe* environment.

In my first conversation with him he said "class must be some form of escape from their home life reality" and gave one learner's situation as an example:

> she comes from an extremely violent background, her brothers are half gangsters. But when she comes to school, create escape for her, so that she feels *safe*, can feel this is some other place where I could be just me [unclear], where everyone is going to listen to me and respect my opinion.

This suggests that an aspect of safety is being heard and respected. Respect was central to his description of his most influential high school teacher, his Zulu teacher. He said of her both that "she was extremely respected as a teacher" and that "she also respects everyone." Mr Baloyi's description of the area around the school as "infested with gangsters" harks back to his description of his own grade ten history class. So it seems that the idea of school as a safe haven where people are respected comes from his own experience of moving to a safe science class.

Inherent in this notion of school as a safe haven is the idea that his job goes beyond that of teaching science, an idea also drawn from his own experience:

> I believe mostly I'm here because I was helped by my teachers the whole way from primary school, high school, varsity, all those who were involved in my learning were also involved in my personal life, they helped me a lot. And that is also a big influence on how I teach also. When I stand in front, I have to know and accept that all these people are different from different backgrounds. And most of them look at me for help, they come to me for help. I should be there for them. And that's because it's only fair because I also got the same treatment from my teachers and that's what influenced [me] mostly.

He went on to tell a story of an activity he used with grade eights which illustrates HIV transmission[24], and the emotional space which this opened up.

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[24] In this activity one learner is given a test-tube containing a solution of sodium hydroxide or some other base, while all the other learners are given test-tube containing water. No-one knows which test-tube contains the base. The contents of the test-tube represent their body fluids, which they then exchange randomly with other learners by pouring some of their liquid into other's test-tubes. After a while, the

Mr Baloyi also has a strong identity as a teacher who encourages learners to take ownership of their learning. For him ownership is achieved by having learners find information themselves and talk about their ideas. He has lots of textbooks and other reference books in his classroom and has inculcated a culture of using books to find information. His idea of learning was disrupted by university. At his secondary school:

> teachers did the best they could do, but when I went to varsity I noticed that I was really not taught [at school] the way I should have been taught. I believe that I should have been taught to get information, inquire information, enjoy what I'm doing. I should not be told this is that and that. I should get my information; I should have *ownership* of what I'm doing.

Likewise his understanding of the importance of talk in this process of getting information draws from his university experience which was different from his secondary experience:

> At school I wouldn't answer, wouldn't talk to somebody, but as soon as I came to varsity that is where I had opportunity to explain some of the things.

He explained how he uses talk in his own teaching, with reference to a lesson I had observed:

> Although it's a portfolio task, I encourage them to *talk* about their answers. And if you've still noticed that I keep on walking around, they keep on arguing, that this person is saying this is the answer, and I think that's the answer. And then I must come and "but why do you think this is the answer, why do you think that's the answer?" The whole idea of science, it comes in: science should be *talked* about, it's just someone's ideas that you just simply accept and you talk about these ideas. We shouldn't just accept everything as it is. We must *talk* about it and see if it makes sense to us.

In summary, Mr Baloyi's identity as a teacher with a safe classroom was a response to his own experience of school, but his idea about how science should be taught came from his university experience, which was distinctly different from his experience of school.

6.3.3 Ms Fikela

Ms Fikela identified herself as a passionate teacher who does a thorough job. Her response to the story question was to talk about various role models she had, at university, on teaching practicums and at the first school where she taught. The common quality she identified in all of them was their passion for science:

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teacher adds a drop of phenolphthalein to every test-tube, and all the test-tubes with basic solutions turn pink.

> So those are the people that I actually looked up to, to say that, these people do teach and they're very *passionate* about the science, and they do it *thoroughly*, they don't do a cheat job, for example, they do a *thorough* job. So I also want to be like that, I want to do a *thorough* job. I don't want to stand in front of the kids and cheat them of the knowledge

A bit later she described her grade twelve science teacher:

> I look at my matric science teacher, he was also a young guy, very *passionate* about it, and then I thought – this is what I want to be. This is a guy who's *passionate* about science,

Interestingly, he dealt with a large class of forty learners by dividing the class into the two streams of science available at the time (Higher Grade and Standard Grade), and then focusing his attention on the Higher Grade half. Since Ms Fikela was in the Higher Grade stream, she appreciated the attention. Perhaps being identified as someone with ability also helped to boost her confidence.

So Ms Fikela's identity had its origin in her role models. Whereas Mr Baloyi and Ms Fikela's role models inspired them to become teachers, Ms Fikela already wanted to be a teacher, but her role models inspired her as to the type of teacher she aspired to be. She expressed their common quality as passion for science, but implicit in this is a passion for teaching science, so as to not cheat learners out of the opportunity to learn.

6.3.4 Mr Hlope

Mr Hlope identified himself as a well-trained township teacher. He answered the story question in terms of two factors: his teacher training and the environment he teaches in:

> it's the type of *training* that I got actually. I think I got the best *training* that any teacher would actually want.
>
> And then, the other thing that made me is, looking at the *environment*, the *environment* that you are operating within. If you look in here, we are operating in an area where it's full of poor families, so we need every time to take these learners out of the trouble that they are actually in. Because if one learner get light here, that light is going to shine for the whole family. Then the younger brothers, the mother, the parents, will get assistance from them. So that actually influenced me.

Although he experienced the constraints of teaching in a township school – a point I will return to in the final chapter – he experienced his agency in having chosen the context:

> with the *training* that I've got, if you check, I could easily have landed a good job somewhere there in those [good] schools. But I said that is actually not the aim, because the bursary that you got to go and study was meant to come and fill the gaps in these poor schools. So that actually helped me a lot, in moulding the type of teacher that I am.

He saw the bursary he got as mandating him to teach in "poor schools". His teacher identity was bound up in making a difference to these learners – thus taking them "out of the trouble that they are actually in." The trouble is poverty, since a learner who gets "light" will be able to assist the rest of the family. This resonates with Ms Emeni and Mr Dube's stories of using education to escape poverty, and with Mr Baloyi's notion of school as 'escape from home life reality'. Mr Hlope's own journey out of poverty was more complicated, but education was ultimately also an escape from poverty for him, and he has been a light for his family:

> You couldn't believe the amount of change that happened through me having been a teacher, the contribution that I made to my family and all. […] Like I could provide every month, maybe give them two thousand rand. Oh, that will make my Mom jump up and down. They thought that I was rich. I mean, the difference was that we were not used to that before, we actually were not used to that before. So now she's very happy, I'm a professional, I'm a teacher, she knows that whenever – things like poverty, it will be there as such, I'm not a rich man per se, but at least a few basic things that I can provide at home, they mean a lot, you see.

What did Mr Hlope see as good about the training he received? He was effusive about my role, saying things like "you made such a great impact on my life." As with Ms Emeni, I was concerned that his emphasis on my input could have been because I was the researcher, and so I asked him about the input of his mathematics and chemistry lecturers. He said that his mathematics lecturer would "tell you to stand up and explain to the whole class. And I like that in a particular sort of – it did impact. It actually did work wonders." But he only had the mathematics lecturer for two years, and so he said he fused the mathematics lecturer's approach with mine. Of the chemistry lecturer he said only that she "was good also. Though she was very soft on us. She used to treat us like babies."

He said of me "I was encouraged by the way in which you structured your questioning, because you're looking for conceptual understanding, mostly [more] than calculations." This has impacted on his practice:

> Although I try to implement it with the learners as well. Try to find their conceptual misunderstanding, try to spot the misconceptions that they might have through a particular sort of a concept. It is nice. And I suppose science should be taught that way.

He described my 'approach' to physics of seeing an equation as reflecting relationships which can be expressed in words and graphs, and referred to a lesson I had observed in which he had taken that approach. He also described the way I asked questions in lectures:

Mr Hlope	You used to treat us as a family.
Researcher	What do you mean by that?
Mr Hlope	Because, did you realise instead of you teaching us, we were the centre of this. Because you used to [clicks fingers] seek answers from us as learners. You were not coming in and then "this is done this way, this is." No, you always were seeking our input, and that made us great learners. Irrespective of how many wrongs that we got, but at the end of the day, it [ironed / earned?] us to become very, very quality, quality material. Because you used to want to train us to think. And that's exactly how a science learner should be. That's exactly how a science educator should be. You can't believe, if you treat our learners the same way, some of them cry. [*Pause*]. They feel embarrassed.
Researcher	But you ask a lot of questions also.
Mr Hlope	Yes, we ask lot of questions. Isn't that your style of teaching has actually impacted a lot – the way in which you used to approach, like the teaching, in that particular form. And I believe that that's exactly what forms the backbone of your *National Curriculum Statement.* Because I said, the learners should be the centre of that, then an educator should be there to facilitate this.

This suggests that Mr Hlope saw my style as consistent with the demands of the curriculum he was required to teach (the *National Curriculum Statement*) which had an emphasis on learner-centred teaching. But his experience of my teaching went beyond pedagogy to the experience of being part of a family. However he found this pedagogy difficult to implement with learners in his context – his learners found it embarrassing if they were pushed to answer questions.

Unlike Ms Emeni, Mr Hlope did have good role-models from school: the person who ran the science centre he attended and his grade ten science teacher. He described his grade ten science teacher as someone who:

> loves his science, he's very good. He had a Master's degree in chemistry from University of Cape Town. And in those times it was very, very rare to find somebody who's that qualified. But I liked his way of approaching or giving solution whenever learners come with their problems. [interruption] He will give you three approaches to one problem, still coming to the same solution. He was exceptional. […] He impacted that area tremendously positive, because he managed to produce lots of doctors, lots of professionals. He actually knew his stuff. Everybody will aspire to be like him, the way he knows his stuff, the way he approach the problem. You'll never go to him with a problem, be it science or mathematics, and then [have him] tell you that maybe come tomorrow, he'll take it on straight away from the ground. […] We used to call him a genius, he was very good, he was gifted.

Mr Hlope identified this teacher as a faultless problem solver, someone who knew science and mathematics well. This teacher served as a role model for Mr Hlope, whom he identified in the same way as he identified himself: a well-trained township teacher.

6.3.5 Mr Dube

Mr Dube identified himself as an empathetic teacher who inspires his learners to work hard. His response to the story question was "I've learnt to actually put myself in another person's footsteps, like I've learnt to have *empathy*." I asked him "how do you think you came to learn that?" He responded "when I grew up, things were not easy for me, so they were challenging." He then proceeded to tell me about his experience of growing up in his grandmother's house which I related earlier. He continued:

> I got to understand that normally you would see kids, sometimes fight with them for not writing their homework, and so on. And on the other hand you wouldn't actually know the real reason that actually led to that. And there are lots of kids in this school that undergo such challenges, even challenges that are more than the ones that I went through. So by doing that, most of them they learn to open up to me; if they do have problems they do not become afraid to come and tell me, and then I do assist them if I can. If I don't, then I refer them to an LO[25] teacher, and then the Life Orientation teacher will therefore refer them to the social workers and so on. *Ja*, so basically I'd say the father figure comes from there.
>
> And I always *motivate* them to do well and to do science. Because without science subjects it becomes difficult for them or for anyone to get bursaries out there. And you don't have to do science for the sake of doing it, you have to do it for the love of it, and you have to make sure that you perform *well* in it, because there's no company that can take anyone there, who's not capable of actually hmm. So such things we fight a lot about them when they do not perform *well*. I always say they must make sure that they get at least 60%[26] or more than 60% when they actually write any task. Right? They laugh at me initially, but towards the end of the year, they then come back to me and say, "But Sir, you once said this."

In this excerpt Mr Dube first identifies himself as an empathetic teacher, one to whom learners can bring their problems, and then explains how he motivates them to do well. Like Mr Baloyi, he encouraged them to take ownership of their learning, though in different ways:

> I always say to them, "If there's no teacher in the class, don't sit outside or talk to your friends. […] And one other thing that I always say to them is that to actually look at what they came in knowing at the gate, each and every day. And if you came in knowing four things in each subject, you must make sure that when half

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[25] Life Orientation, a compulsory school subject which is intended to help learners with personal development, emotional and physical health, and career guidance.

[26] The pass mark is only 30 %.

past two or three o'clock comes, at least you would have actually added other two or three points or three levels on top of what you came up knowing.

Mr Dube's empathy, derived from his own experience, extends beyond recognising learners' home problems to the problems they may encounter in the classroom. He usually had a question time at the end of a period, based on his own experience of *not* having had the opportunity to ask questions at school:

> if you perhaps have questions based on that particular topic for that particular day, you'd find that you don't have time to actually ask that particular question. And even tomorrow, if you actually try to ask the question again, you won't be given the opportunity to do that. So that gave me a certain picture somewhere somehow that maybe there are learners in class who do have questions and would love to ask them, but yet educators – some educators, not all of them – they do not actually give them the opportunity to do that. So in that way you'd find that learners have to struggle to actually answer some of the questions so and so on. So as I said before, I like to *empathise*, put myself on their footsteps.

So Mr Dube identified himself as empathetic to learners in a multidimensional way: as empathetic to their home situations as well as to their learning needs.

6.3.6 Ms Cole

Ms Cole identified herself as a teacher who makes concepts visual. Her immediate response to the 'story' question was "Well I think one of the main reasons why I teach the way I teach is from my artistic background." Her secondary schooling was at an art school, and she described how:

> When we had to do a portfolio, we were given a topic, and then we'd have to go and brainstorm it and stretch it to its outer limits. And each time you stretch it, you have to think more laterally. So you actually train your brain to keep removing it in a lateral way until you've got a very removed idea. That's how it works in art. But that process has helped me in science because I'm able to remove the concept.

However I came up against the limitations of language (though we share English as a mother tongue) and my own inexperience of the artistic process in trying to understand this 'storied description' (Polkinghorne, 2007). So though I never fully understood the process, Ms Cole explained that this process helps her to "make each concept *visual* for them" because "especially with things that the kids can't see, like atoms and molecules and that sort of thing, I think I have a good way of making them imagine it." Along with wanting learners to see things visually, she wants her learners to metaphorically 'see' the big picture – both making connections between sections and "giving the girls a bigger picture of what science actually is as a study."

If this was the impact of her school art training, what was the impact of university? She commented that she found the arts degree (BA) which she did by correspondence at the same time as her teaching qualification more useful in terms of understanding pedagogy generally:

> I did Sociology and Philosophy. And I did Philosophy of Science. So I think I drew more from that in terms of the social aspect of teaching than from the JCE offering [teaching diploma]. So I think that stuff is worthwhile and stuff, but I think I benefitted more from my BA than from Wits [teaching diploma].

However she said she found the science content and methodology courses useful: “I do find all of that training very valuable, I know I use it all the time.” Having not done Physical Sciences for matric, she liked her first year physics lecturer (not me) who “was very concrete” and “always broke down the components with colours.” She felt her mathematics lecturer had a big impact on her “in terms of creativity, and lateral thinking.” And she liked the way her chemistry lecturer “when she taught about one particular thing in chemistry, she actually tied in – she made connections for us to all the other parts.” She also appreciated the exercises done in methodology courses which involved lateral thinking and “being in a group and working through those things ourselves.” She commented that in the physical science practical work “I remember having to think a lot, all the time.” It seems that the lecturers who appealed most to her were those whose approach fitted with her existing preferences for ‘right brain’ thinking – lateral, visual and big picture thinking. This was confirmed by the teacher herself: at the end of the above conversation I asked “And then in terms of how you teach today, how does that influence you?”, and she responded “Well I think it is a lot of my personality”. By inference her identity as a teacher who makes concepts visual is consistent with the kind of person she is by nature – her nature-identity – with her art and teacher training having served to enrich her teacher identity.

6.3.7 Ms Gray

Ms Gray’s immediate response to the ‘story’ question was:

> I think that these kids, specifically in [this school], don’t *think for themselves*. I think that they are spoon-fed and they want a method and they follow it. And I’ve noticed that with teaching maths as well, that’s how they do it, so I try to keep the classroom as *open* as I can to allow them to figure out a method *for themselves* or to – so I throw them into the deep end a lot. But I want them to be able to *think for themselves* and to come up with a way of doing it that makes sense to them rather than following a method I put on the board.

Ms Gray identified herself as an ‘open’ teacher who wants learners to think for themselves. These two ideas are related: being open means allowing different methods, which means learners have to “figure out a method for themselves”, and hence think for themselves. Ms Gray used the term ‘open’ as a description both of her classroom and of herself. Being ‘open’ and wanting learners to ‘think for themselves’ were notions which came up repeatedly in Ms Gray’s conversations with me, for example:

> *Researcher:* You say the boys want to be in your class, how do you think they describe you as a teacher?
>
> *Ms Gray:* Very *open*. I had a grade 11 boy from last year come to me and say to me that I should actually just have the top boys because the way that I teach isn’t conducive to the lower level boys.

This identity was born of her own experience at a private girls' school. In this extract she moves from past to present, using her narrative of the past to make sense of the present:

> [*Past*] Because specifically when I was in school, specifically with chemistry and physics, I had my own way of doing things that was right. And they [teachers] made me follow what they were doing.
>
> [*Present*] And I want them to have that opinion in this classroom that it counts, and that we can work together and figure out a way that will make it work for them. So my classes are quite *open* and you’ll see they’re constantly walking around, because they constantly help each other. And I don’t mind that, as long as they’re not being boisterous. So you saw Dean constantly walked over and was asking for help.

At school most of her teachers wanted her to answer questions with particular algorithms, whereas she could see that there were other valid ways to get to the answer, but her methods were not legitimated. This served as a negative role model for Ms Gray. In contrast her one chemistry teacher served as a positive role model insofar as she:

> was very *open* and bubbly and we did a lot of experiments and we – also very *open*-ended. We created the methods ourselves as we were going along, and I think that’s where a lot of the way I do it stems from.

Here Ms Gray identified this teacher in the same way as she identified herself, as ‘open’, and noted how she did open-ended investigations in this teacher’s class – another aspect of an ‘open’ teacher.

Ms Gray’s agency in her identity was strong – she saw herself as taking a stand which was different from the other science teachers at the school:

> And that’s very different to the way that all the other science teachers do it. So it does take me a bit longer, and I am always a little bit behind in the syllabus, but I’m not going to stop.

Being ‘a bit behind’ the other teachers meant:

> they put me under pressure because I’m not finishing the syllabus and then I got into trouble for them having a work book where the other classes didn’t. So there’s a few things. They’ve left me alone now, they understand that the boys want to be in my classroom, because they have a problem at the moment because the parents wanting their kids to get taken out of theirs and put into mine.

The work book she referred to was a notebook which her learners used for exercises and notes to supplement the prescribed ‘fill-in-the-gaps’ textbook. Ms Gray defended her stance by drawing on the evidence of learners wanting to be in her class. Her strong identity provided her with the agency to engage in practice which was distinctly different from her colleagues, despite pressure to confirm.

Ms Gray's identity as an open teacher came from her own experiences at school. What then was the effect of university? It seems university served to give her some good ideas which fitted her existing identity and which she found worked for her, for example mind maps, and solving chemistry problems using a table.

6.3.8 Mr Abrams

I indicated in section 6.2.8 that Mr Abrams has a strong designated identity insofar as he plans to become someone who runs workshops for teachers. Hence his identity is still under construction. His response to the ‘story’ question was:

> Well, first of all as I said, it’s just the – with the course that I’m doing now, the [further degree], it’s kind of like opened different ways of thinking, because last year, thrown in the deep end, you were told for instance you’ve got an x amount of grade nines, this is a weak, this is a strong class. And then you have to vary your teaching accordingly. And what I found difficult is with the weaker learners especially, I couldn’t understand especially with the grade nines, where they were given certain tutorials to do which just emphasised a whole lot of repetition and plugging things into a formula without understanding, which I had a big problem in, as opposed to understanding the content first and applying it.

This response weakly identifies Mr Abrams as a teacher who wants learners to understand content before applying it. It also expresses a conflict between the ideas of his further study and the way in which his school has told him to teach the ‘weaker learners’. He then told me the story of another conflict: this time with parents who complained about a test he set, where he included two application type questions. For example he put an electroscope diagram in the test which was different from the diagram in the learners' notes. Thereafter Mr Abrams returned to talking about a course in his further study which:

> teaches you that first of all you've got learners with different abilities. So it's almost impossible to cater for everybody, especially in subjects where you bring things that are quite controversial. But, how you structure your teaching in terms of using your different analogies to show your understanding of the content, transforming that content to be at the learners' level. So that was a big change in terms of how I thought about that.

Here he identified the use of analogies as a useful strategy, and referenced jargon from the postgraduate course he was doing, that of the 'transformation' of content to make it accessible to learners. Thereafter he spoke about conflict between the school's timeframes for teaching and a pedagogy of working with learners' ideas: "spending time engaging with the learners and trying to find out what they know and trying to actually restructure the lesson, so that you go according to what they're thinking." Finally he referred to the lesson I was about to observe, where learners were given kidneys to draw:

> I mean, like with this, what we're going to be doing now, with dissection, they've learnt it, so it's kind of saying that you've learnt the content now let's see the application, this is what you're going to do, this is what one has seen in terms of labelling. And that's that.

The above monologue was all in response to the 'story' question, with no further interjection from myself as interviewer. In it I see a conglomerate of different teaching ideas from his further study mixed in with the challenge of teaching learners of different abilities and covering content within the school's timeframes. I followed up this monologue by asking what his further study brought to his situation, and he mentioned language and the abstract of nature of chemistry where "you're continually moving between your macroscopic and your microscopic, and trying to make it visible to the learners." Later I asked him "what else do you think has been a significant influence in the kind of teacher that you are now?" He responded "Just doing things out of the blue." And told the story of where a learner had created a water rocket which he then used with his grade eights when studying pressure. Then he told of a learner who said "I never knew what a triple beam balance actually looked like."

At the time I thought Mr Abrams missed the point of my questions, but now I think he was trying to identify himself as a good teacher who has taken the learning in his further study to heart and hence caters for learners with different abilities; teaches for understanding so that his learners can apply their knowledge; explores his learners' thinking before teaching so that he can adapt his teaching accordingly; responds spontaneously to input from learners; and uses science apparatus. However his preferred mode of teaching, identified in Chapter 4, was exposition. The above conglomerate of teaching ideas had not yet been distilled into his identity or his practice. This was in part because the demands of his further study limited his time for preparation, and in part because he was only in his second year of teaching. In section 2.4.1 I mentioned that Anderson et al. (2000) gives two indicators of growth in a teacher: changes in thinking and the trying out of new approaches, even if unsuccessfully. Mr Abrams' changes in thinking suggest the possibility for future development. In the meantime the kind of teacher he identified himself as was: a future teacher trainer.

6.4 Discussion

Table 20 summarises the discourse identities of the teachers. Ms Emeni and Ms Cole both identified themselves as teachers who use visual means to help learners apprehend content – Ms Emeni by using apparatus and Ms Cole by making concepts visual in some way. Mr Baloyi, Mr Dube and Ms Gray all identified themselves as teachers who want learners to take responsibility for their learning in some way: Mr Baloyi by learners having ownership of their learning; Mr Dube by encouraging his learners to work hard; and Ms Gray by having learners think for themselves. All three identified themselves as teachers with supportive classrooms conducive to the risk taking which this involves: Mr Baloyi by having a safe classroom; Mr Dube by being empathetic; and Ms Gray by having an open classroom. These three teachers sought to give their learners voice in some way: Mr Baloyi wanted learners to talk; Mr Dube gave learners a time for questions and Ms Gray wanted learners to think for themselves, which involved them talking to each other. Ms Fikela and Mr Hlope identified themselves as good teachers in their contexts: Ms Fikela identified herself as a passionate teacher, and Mr Hlope as a well-trained township teacher. Mr Abrams identified himself in terms of his designated identity of being a future teacher trainer.

The similarities between some of the identities prompts the question as to whether teacher with similar identities studied in the same university class or came from similar backgrounds. Ms Emeni and Ms Cole did not study together, but in successive years. Their own school backgrounds were radically different: Ms Emeni came from a rural school and Ms Cole from a good Art school. But neither of them was taught science in grades 10-12 – Ms Cole because she did not study science and Ms Emeni because there was no science teacher at her school. This may be a reason for their concern with conceptual understanding of subject matter knowledge. Mr Baloyi and Mr Dube were in the same university class, but Ms Gray started her qualification three years later. Mr Baloyi and Mr Dube both attended township schools, similar to the schools they teach in, whereas Ms Gray attended a private school and now teaches in a multicultural school. This difference is reflected in the fact that Mr Baloyi and Mr Dube's concerns with safety and empathy respectively extend beyond science whereas Ms Gray's concern for openness is in regard to science.

Table 20: Discourse-identities

Teacher	Discourse-identity
Ms Emeni	A teacher who uses science apparatus to elucidate content.
Mr Baloyi	A teacher whose classroom is safe and whose learners have ownership of their learning.
Ms Fikela	A passionate teacher who does a thorough job.
Mr Hlope	A well-trained township teacher.
Mr Dube	An empathetic teacher who inspires his learners to work hard.
Ms Cole	A teacher who makes concepts visual.
Ms Gray	An open teacher who wants learners to think for themselves.
Mr Abrams	A future teacher trainer.

In the introduction to this chapter, I noted that identity involves identifying someone as a certain kind of person, by assigning labels – in Gee's (2000) terms identifying a person as a certain 'kind of person' – and telling stories. The phrases in Table 20 are identifying labels, mostly using the teachers' their own words which occurred repeatedly in their conversations. They are backed up by the stories which the teachers told, as well as general comments they made. These labels are hooks for hanging rich meaning, and mostly hold a greater depth of meaning for the teachers than I have presented here. I could not fully apprehend the meaning because of my own limitations and subjectivity, and because of the limitations of the research situation, despite my seeking meaning in my conversations with the teachers. For example in section 6.3.6 I described my limited understanding of Ms Cole's description of 'removing' an idea to make it visual, despite asking her to explain it. I have looked at each teacher separately, though pointing out resonances between some of their narratives. In the rest of this chapter, I look across the teachers, bringing the narratives and identities into contact with theory and other research.

6.4.1 Learning to Teach

In Chapter 2 I explored the challenges of learning to teach, citing the opinions of experts in the field. In this section I consider how my results talk back to this body of literature. In section 2.4.4, I described the trajectory of a teacher through three contexts: their own schooling, then university and then the school(s) they teach in. Each individual has a unique trajectory through these three contexts. The first of the three contexts, which serves as an ‘apprenticeship of observation’ (Lortie, 1975), means that teachers typically come into teacher education programmes with resilient teacher identities based on their own experiences as learners (as explained in section 2.4.2). These identities draw on the role models they have encountered, both positive and negative. The apprenticeship of observation is evident in half of the sample’s identities: they located the origins of the ways in which they identified themselves in their secondary school experiences. Ms Fikela, Mr Dube and Ms Gray identified particular positive role-models: Ms Fikela described her grade twelve science teacher as passionate; Mr Dube found an empathetic father figure in his grade eight class teacher; and Ms Gray’s one chemistry teacher was an ‘open’ teacher. Ms Cole did not identify a particular role-model but rather drew on another aspect of her schooling: her art training. Mr Dube also drew more broadly from his school experience: he attributed his empathy not only to his grade eight teacher but also to his own hardship while at school, and he inspired his learners to work hard in the way that he did at school.

One of the four challenges for teacher education which emerged in Chapter 2 is that individual histories fundamentally affect the way student teachers make sense of and appropriate their initial training. Student teachers tend to take on board that which fits with their existing identities and conceptions of teaching, and ignore that which doesn’t. Thus the four teachers discussed above mostly took up elements of their university training which fitted with their existing identities. Ms Fikela found other passionate teachers. Ms Cole took up ideas which appealed to her ‘right brain’ thinking preferences. Ms Gray adopted strategies she found worked for her. But Mr Dube’s experience of university damaged his identity as a top student, so he found the personal development aspects of university most helpful.

In contrast, university has been the major influence on Ms Emeni, Mr Baloyi, and Mr Hlope's identities as teachers. Ms Emeni and Mr Hlope claim to model themselves on their physics lecturer. Mr Baloyi came to see ownership and talk as centrally important to science learning, though the importance of safety comes from his own experience of a science classroom as a safe space. Thus the results of this research show that a teacher education programme can in fact have a major influence on prospective teachers, particularly teachers who know their own school experiences of science teaching to be deficient. The variation in influence accords with the idea that inputs in teacher education programmes act as forces on teachers' trajectories which affect the directions they take, but affect different students in the same programme in different ways (Anderson et al., 2000; Samuel, 2003). This variation is consistent with a complexivist view of education.

In addition, small inputs in teacher education may have a large 'butterfly' effect. My suggestion to teachers that they ask for money to buy equipment (see section 6.3.1) and my getting students to organise particular files (see section 6.3.5) were both small inputs which levered up significant advantage for Ms Emeni and Mr Dube. Both turned out to be very useful perturbations in the complex system of teacher education. I am not suggesting that these two inputs are useful in every context, but rather suggesting that teacher educators should be encouraged by the butterfly effect that small but thoughtful inputs can have.

The experts agree that secondary teachers need a good foundation of subject matter knowledge. However Ms Emeni's story of learning only enough subject matter knowledge to obtain 50 % at university (recounted in section 6.3.1) reveals that it is not enough just to teach subject matter to teachers, the teachers also need to see how the content is relevant to their designated identities. Although the subject matter content of a teaching degree is not the same as that of secondary curricula, Ms Emeni's experience suggests that some student teachers need to see the links between secondary and tertiary curricula in order to take full advantage of their subject matter courses at university.

Teacher self-identities are explicitly about self, so one would expect the focus to be on the teacher. However Mr Baloyi, Mr Dube and George's identities include a gaze on learners, and the kinds of learners they want to encourage. I mentioned in section 2.4.3 that the ‘stage’ theories of teacher development see teachers moving from stages focused on the teacher to stages focused on learners. In terms of these stage theories then, these teachers were at a more advanced stage in their thinking, although, as mentioned, the stage theories have limitations.

Teacher education not only starts before a teacher education programme, it also carries on after the end of the programme. In section 2.5 I noted that the experts recommend mentoring beginning teachers. The teachers in this study were not part of any formal mentoring programmes. However Ms Fikela, Mr Dube and Ms Cole spoke with gratitude of the mentoring they had received from more experienced teachers in their schools in their first year of teaching. I have not included details of this in their narratives because in my interpretation they did not position mentoring as significant in their identities. However the experiences of these three teachers suggest that all beginning teachers would benefit from mentoring. In particular young township teachers would benefit from being supported in the challenge of being perceived as a threat because of their education, as Mr Abrams and Mr Dube were: Mr Abrams was unable to get a job in a township school (see section 6.2.8), and Mr Dube was side-lined out of mathematics teaching (see section

Chapter 2 not only dealt with the challenges of learning to teach, but also explored what should happen in an initial teacher education programme (in section 2.5). I concluded that the experts agree that teacher education programmes are likely to be most effective where they help students develop their identities as teachers. The results from this study are in agreement with the premise that teachers’ identities are important: I did not start out planning to research teachers’ identities, but found their identities central in the data. Moreover the teachers had identities not just as science teachers, but as particular kinds of science teachers. Thus the results of this study concur with the suggestion in section 2.5 that teacher educators should recognise the identities with which teachers enter teaching programmes, and then help student teachers develop their identities. Since the identities in this study were often drawn from particular role models, it may well be helpful to facilitate student teachers’ reflection on their role models, both positive and negative, consistent with the Darling-Hammond et al. (2005) suggestion of using autobiography as a starting point for making student teachers aware of their initial professional identities and the origins of these identities.

Although the teachers in this study were influenced to different extents by their initial teacher education, the majority of them drew far more on *how* they were taught science (and mathematics) rather than *what* they were taught about teaching methodology or educational theory. Ms Emeni's and Mr Hlope's use of a physics lecturer as role model; Mr Baloyi's emphasis on talk and ownership; Ms Cole's emphasis on the visual; and Ms Gray's use of mind maps and problem-solving tables derive from their subject matter courses rather than their methodology courses. The exception is Mr Abrams, who has been influenced by what he has been told about subject specific methodology in further study, although this has not yet impacted his practice. Overall these results point to the central importance of modelling good teaching of the subjects which teachers are going to teach. This suggests that how teacher educators teach is of critical importance. Adams and Krockover (1997a) also found that "the subject matter courses serve as a model for instruction" (p. 647) for four American science teachers with less than three years of experience even though these courses were mainstream science degree courses and not courses specifically designed for teachers, in contrast to the subject matter courses which the teachers in my study took.

What kinds of teaching count as 'good' for modelling to prospective teachers? In section 2.2.5 I argued that what counts as 'good teaching' is contested in science education and beyond. In section 2.5 I noted Rodgers and Scott's (2008) point that a teacher education programme which takes identity development as central needs to be flexible in regard to what counts as good teaching. Identity is a vehicle for mediating agency, so identity development increases teachers' agency, including their agency in choosing the kinds of teacher they want to be. So instead of decreeing particular approaches as good practice, teacher education programmes should provide teachers with a diversity of good practice which can be recruited by student teachers in constructing their discourse-identities. This is supported by Ms Emeni and Mr Hlope's choice of their physics lecturer as their role model, despite having also had chemistry and mathematics lecturers who were good in different ways. In addition teacher education programmes should encourage teachers in their agency, so that they are empowered to do what they see as best in their contexts.

6.2.5). Mentoring could help teachers like Mr Dube walk the tightrope of trying to give learners the benefit of his teaching without upsetting colleagues.

In summary, the results of this study concur with the learning-to-teach literature in regard to the importance of student teachers' professional identities, the effect of individual histories on the way student teachers appropriate initial teacher education, and the usefulness of mentoring beginning teachers. However the results of this study show that teacher education programme *can* have a major influence on teachers, particularly teachers who know their own school experiences of science teaching to be deficient. In fact small inputs in teacher education may have a butterfly effect. The results of this study also show the value of modelling good teaching – even teachers who derive their identities from their own schooling benefit from modelling which is consistent with their identities. Finally this study suggests that students need to see the relationship between secondary and tertiary subject matter in their disciplines in order to take full advantage of the subject matter courses in their teacher education.

6.4.2 Agency in the Context of Structure

In section 2.1.3 I noted that a complexivist view of education takes into account both the agency of the individual, and her past and present contexts which impose constraints on the agency of the individual. In the introduction to this chapter I noted that both narrative and identity involve the interplay of agency and structure: people author their own narratives and identities, but in authoring they are constrained by their current and historical contexts. In this section I regard the teachers' narratives and identities through an agency/structure lens. First, I consider their agency in authoring. Then I look at how that agency has been constrained by their current and historical contexts. Finally I consider how their identities have helped the teachers mediate agency in their contexts.

The teachers authored their own identities: they chose to be science teachers and they chose the kinds of teachers they see themselves as. They also authored their narratives: they selected particular events from their personal histories and they positioned both these events and themselves in particular ways in their narration. For example, Ms Emeni selected the event of her grade five teacher telling her class there was no hope (recounted in section 6.2.1). She positioned the event positively as the cause of her becoming a teacher, rather than as a negative factor. She also positioned herself with agency in this story – as someone who made a conscious decision to prove her teacher wrong.

Like Ms Emeni, most of the teachers reported some sort of hardship in their narratives: Mr Hlope's position as a car guard; Mr Baloyi's experience of gangsterism in school; Mr Dube's difficulties at home as a learner, subsequently with another university student and later with a colleague; Mr Abrams' failure to get a job at the kind of school he wanted; and Mr Baloyi and Ms Gray's parental sanction against their careers of choice. But instead of the teachers positioning themselves as victims of circumstance, they positioned themselves with agency in their narratives. They either showed significant agency in changing their situations, or, in Mr Abrams and Ms Gray's cases, accepted their situations without rancour. Overall, the teachers' tended to position themselves with agency as they authored their narratives.

In addition most of the teachers who came from disadvantaged schools told stories of their own agency as learners: Mr Baloyi asked to be moved to the science class of his township school; Ms Emeni asked to study science despite the lack of a science teacher at her rural school; Mr Dube in a township context worked ahead in the textbook and Mr Hlope in a rural context improved his English using old newspapers. The outcome of this agency was that they were identified as clever learners in their schools.

However the resources narratives and identities are constrained by past and present contexts. An individual may not be aware of the extent to which her context structures her identities and narratives – the structure of the context may be unconsciously internalised in her habitus (section 2.1.3). While the teachers mostly positioned themselves with agency in choosing to teach, in fact their institution-identity was a choice from limited professional options – the constraints of finance meant that most of them could only study that for which they could get bursaries. Furthermore their choice of subject was limited by the bursary to a choice between mathematics and science. Their discourse-identities were selected from limited resources available to them in their own histories: positive and negative experiences at school and university, and role models from school and university.

I note here that a significant contextual constraint is the curriculum a teacher is mandated to teach. Mostly the teachers in this study neither identified strongly with the curriculum, nor complained about it as a constraint apart from the sheer quantity of content to be covered in the senior grades. Their identities were not drawn from the dominant discourse of the curriculum – they did not refer to themselves as learner-centred teachers or emphasise group work or outcomes. In part this was due to my contribution as audience: I wanted to steer away from the jargon of the curriculum, so talked to them about their teaching on a particular day rather than their teaching ideals, thus inviting specifics rather than the generalisations of jargon. However the context of curriculum change seems to have opened up possibilities in their practice. Some of the teachers experienced the differences between themselves and their colleagues who were trained under the previous curriculum in a positive way: the differences facilitated their agency in teaching differently from their colleagues.

An individual does not simply accept the identities available in a particular context, but rather negotiates possibilities. Identities are negotiated in the interplay of individual agency and the structure of a context. Identity is not only in the head of an individual but needs to gain traction in her context: self-identification happens in the context of and in relation to identities made available by others. For example, Mr Baloyi has successfully negotiated his identity as a teacher with a safe classroom – learners choose to spend their breaks in and around his classroom. Likewise his identity as a teacher whose learners have ownership of their learning is possible because his learners buy into his approach and participate meaningfully in his lessons.

Identities are not only negotiated in current contexts, they also facilitate negotiation. Whereas habitus limits agency, identities are "possibilities for mediating agency" (Holland et al., 1998, p. 4). Priestley et al. (2012) see agency as "repertoires for manoeuvre." Identities serve as a source of agency for getting into teaching – a designated institution-identity of teacher helps someone become a teacher. For example Mr Baloyi's designated identity of teacher helped him negotiate his entry into a teacher education programme with his parents. Ms Emeni's designated teacher identity helped her negotiate with her principal to study science and succeed in her context of rural poverty. Identities also facilitate agency in the job of teaching. A strong discourse-identity helps a teacher do what they see as right, even if the institutional environment is not really supportive of that practice. Ms Cole's identity as a visual teacher meant she felt confident trying out new approaches in a school where teaching is heavily scripted from above. Ms Gray's identity as an open teacher meant she was confident that her approaches were better than those of her colleagues, and she was comfortable in being behind her fellow teachers in her coverage of content. Despite finding limited equipment in their choice of schools, Ms Emeni and Mr

Hlope used their discourse-identities of being the kinds of teachers who use apparatus to obtain and use apparatus, skilfully negotiating the logistic constraints.

Some of the teachers showed considerable agency in innovations with impact beyond the boundaries of their classrooms, which I have not yet mentioned. Mr Abrams, Ms Emeni and Ms Fikela initiated and organised investigative science projects and participation in science fairs[27], across multiple grades, in their first years of teaching. In addition Ms Fikela initiated a project at her first school which involved learners at her school helping learners from disadvantaged schools do science experiments – a project which continued even after she left the school. Mr Baloyi suggested a classroom management strategy in his school which was implemented throughout the school. Mr Hlope participated in a television series about beginning teachers, and regularly taught teachers in an in-service programme. Samuel and Stephens (2000) also report the agency of their teachers, noting that they saw "themselves as agents of reconstruction in the school environment, rather than as victims of their own apartheid schooling" (p. 13).

In summary, the teachers in this study authored their own identities and narratives. However they had to construct their narratives and negotiate their identities within the constraints of their past and present contexts. At the same time, their identities served as resources for negotiating entry into teaching, and agency in the job of teaching. The examples I have given of each of these aspects illustrate how I have found identity useful in understanding the interplay of agency and structure in the context of education.

6.4.3 Kind of School and Identity

A dimension of the identities of half the sample is the type of school they choose to teach in. In other words, a dimension of the 'kinds of teachers' they are is the 'kind of school' they teach in. Identities are constructed in contexts, and these teachers chose their contexts. Mr Baloyi, Mr Hlope and Mr Dube all made a deliberate choice to teach in township schools despite the greater challenges in doing so, because they saw a greater need there. Mr Hlope justified this choice by referring to the intention of the bursary, although this was never articulated in the bursary conditions. Ms Emeni's initial intention was to teach back in the rural context she came from, but she got too used to the city “lifestyle”, which she described as “the lights, electricity, you see the luxury of having everything that you want at your convenience.” However she felt that teaching in an intervention school (where donor funding provides quality education to disadvantaged learners) was consistent with her original mission. Her concern was to provide quality access to science knowledge for such learners. Similarly Samuel and Stephens (2000) found that the type of school they chose to teach in was central to the identities of two South African student teachers. Smart (2008) also found type of school was central to some British student teachers’ identities.

These four teachers came out of the tough end of the South African education system themselves. Mr Dube and Mr Baloyi both attended township schools, and Mr Hlope and Ms Emeni both attended rural schools. The notion of school as escape featured in some way in all of their narratives, both in terms of their own experiences and in terms of what they hoped for their learners. Mr Baloyi found that moving to the science class was an escape from gangsterism, and wanted his classroom to be an escape and a place of safety for his learners offer his learners “escape from their home life reality” (section 6.3.2). School provided an escape for Mr Dube from a difficult home life situation (section 6.2.5) and he had empathy with learners who face similar challenges at home. Ms Emeni and Mr Hlope used education to ‘break through’ (Ms Emeni’s words) from rural poverty. Mr Hlope wanted learners to get ‘light’ and be able to provide for their families. The idea of school as escape has resonance with a South African teacher who said of his own rural secondary education that “education was an escape from the every day world into another world” (Samuel & Stephens, 2000, p. 481). This concurs with Oakeshott’s (1971) view of school as “detachment from the immediate local world of the learner” and hence “an emancipation achieved by a continuous re-direction of attention” (p. 44). Mr Baloyi’s concern that school should be a place of safety has an echo in a study which found that novice American teachers consistently expressed a need for safety for themselves (Chubbuck et al., 2001).

Despite the limitations of the schools which they attended, these four teachers all identified particular teachers who had made a significant difference for them. Ms Emeni had a principal who was sympathetic to her desire to study science despite the fact that it meant considerably more work for him. Mr Baloyi found safety in his grade one teacher’s class and Mr Hlope had an excellent grade ten science teacher. Mr Dube reported that he found parent figures in his teachers, in particular his grade eight class teacher. These teachers were key to the ways in which school functioned as an escape for these four teachers. In turn these teachers have a strong sense of responsibility towards their learners, similar to what Henning (2000) found with unqualified teachers working in an informal settlement in South Africa, and what Moore (2008) found with three African American teachers. Similarly Samuel and Stephens' (2000) one teacher saw himself as a 'replacement parent' to his learners.

The identities of the other four teachers were not strongly related to the kinds of schools they taught in. Mr Abrams wanted to teach in a township school but was denied the opportunity because of his postgraduate qualification. Hence he taught in a multicultural school. Ms Fikela had taught in three very different schools, and had only been in the intervention school where I saw her for a few months. When I visited Ms Gray she was thinking of moving because she was unhappy with interpersonal relations on the staff, under a new principal. Ms Cole battled to make ends meet on a government teacher's salary, and only stayed in teaching because she found a post at a private school which paid her more.

In summary, Ms Emeni, Mr Dube, Mr Baloyi and Mr Hlope attended township or rural schools themselves, where particular teachers meant that school functioned as escape in some way. They deliberately chose to teach in township schools in order to offer learners the same sorts of opportunity as they had and this is central to their identities. In contrast the identities of the other four teachers were not strongly related to their schools.

6.4.4 Conclusion

I have recounted narratives from eight teachers in an education system of hundreds of thousands of teachers. These teachers are not representative of the whole education system nor can they be assumed to be average teachers. Narratives are not expected to be generalisable (Chase, 2005) but provide instances of what is possible. However I note that there are many resonances in the narratives of the eight teachers with two teachers in another South African study which I have referred to a number of times in the course of this chapter. Similar to my study Samuel and Stephens (2000) used narrative inquiry to explore the identities of two teachers from rural backgrounds. Different from my study, their teachers were pre-service English language teachers at a different university in a different province. I have noted resonances with their study in Ms Emeni's story of becoming a teacher because of a negative role model (section 6.2.1); the agency of their teachers (section 6.4.2); the role which the type of school plays in teachers' identities, and the notion of school as escape and of teachers as 'replacement parents' (section 6.4.3). Overall I found that Samuel and Stephens' study had far more resonance with my study than narrative studies of identity from contexts beyond Africa. These resonances suggest the narratives in this chapter have something worthwhile to say in the South African situation.

Narrative inquiry into teachers' identities has proved fruitful. The narratives of the eight teachers resonate with other research and also bring new insights. They speak with hope to the literature on learning to teach and beyond into the realities of the South African education system. In the very particularity of these teachers' stories are messages which resonate beyond the specific contexts of their particular initial teacher education programme and teaching contexts. These stories and the identities they reflect are important because they are key to teachers' practice.

Chapter 7: Conceptions of Science Teaching

In Chapters 4 and 5 I analysed what teachers do in their classrooms. A look at what they do prompts the question: what do they *think* they are doing? Put another way, what are their conceptions of science teaching? This is my last research question and the purpose of this chapter is to address this question. Conceptions are important because teachers act in ways which are consistent with their conceptions (section 2.2.2). In Chapter 1 I explained that I would use phenomenography to explore my sample's conceptions of teaching, since phenomenography attempts to uncover the full range of conceptions experienced across a sample. In this chapter I first describe how I went about the analysis, then present the results, and then discuss the results in the light of other research.

7.1 Analysis

A phenomenographic analysis is essentially a grounded analysis of data (J. T. E. Richardson, 1999; Strauss & Corbin, 1990). I used QSR nVivo 8 to manage my analysis of the interview data. My first step in analysis was to identify all instances in the interview transcripts where teachers talked about their teaching, either in talking about lessons which I had observed, or in their responses to the story question, i.e. "Please will you tell me the story of what has made you the unique science teacher you are today."

My problem in analysis was that looking over my shoulder was the body of 'conceptions of teaching' research which I already knew about, described in section 2.2.1 and elaborated in Table 23 later in this chapter. This knowledge posed a threat to the validity of my analysis. In order to do a grounded analysis, I needed to bracket my knowledge of this body of research, which I initially battled to do. My solution to this problem was to go through the data and ask: what was the teacher's agenda in each case? By this I meant, what was the teacher trying to do? What was her underlying purpose? The agendas were either implicit in what teachers focused on, or explicit, for example Mr Baloyi said "That's my mission, that's why I'm in a township school, I want them to see that well, whatever it's there [is] still available here." I found this focus on agendas allowed me to bracket my knowledge of research into conceptions of teaching. I felt agendas were an authentic avenue for investigating conceptions, insofar the conceptions of teaching uncovered by previous phenomenographic research are about teaching purposes (see sections 2.2.1 and 7.3.1). This approach also worked for me because I found it easier to accept the notion of teachers holding many agendas at once, rather than the notion of teachers working with multiple conceptions at the same time. I found that I was able to code most but not all of the instances of teachers talking about their teaching in terms of these agendas.

This analysis gave me a list of 56 agendas, over a total of 636 coded extracts. The most common agendas were ‘keep learners interested or entertained’ (38 occurrences), and ‘get learners to understand’ (30 occurrences). Two major themes emerged: the teachers’ agendas in selecting content knowledge and their agendas in terms of what they wanted learners to do – such as ‘get learners to talk science’ or ‘get learners to know definitions’ – which reflected their ideas about productive ‘ways of being’ a learner in a science classroom. This suggested that the teachers experienced science teaching as mediation between science knowledge and knowers. In addition, two qualitatively different ways of viewing science knowledge emerged: as problematic or not. This distinction did not depend on grade or topic – grade eight density was taken as problematic by Ms Cole, whereas nuclear power for grade nines was not seen as problematic by Mr Baloyi. Out of the interplay of the above, the conceptions of teaching emerged.

Initially I worked with the data from only six teachers. Mr Hlope was not included because his interview data was not yet available. Mr Abrams used constructivist jargon fluently but I don’t know what he actually meant by it, since I saw no evidence of what he said he did in terms of getting learner conceptions in the classroom, and although I tried, I battled to access his meanings in the conversations I had with him. Thus I suspected it would be difficult to work with his interview data, as it would be difficult to get past the jargon to his actual conception of teaching. However my final step in analysis was to test the four conceptions on the data which I had not yet coded, that of Mr Abrams and Mr Hlope. I found that the data of these last two teachers could be coded in terms of the four conceptions.

7.2 Outcome Space

Four conceptions of science teaching emerged from the data in this study: transferring knowledge from mind to mind; transferring troublesome knowledge from mind to mind; creating space for learning knowledge; and creating space for learning troublesome knowledge. In phenomenography, the conceptions together form an 'outcome space'. Rather than just consisting of a list of conceptions, the outcome space has a structure which shows how the conceptions sit in relation to each other. Table 21 gives the structure of the outcome space of this research. It is a two-by-two matrix with the nature of the knowledge on one dimension and the nature of the mediation of that knowledge on the other dimension.

Table 21: Outcome space: conceptions of science teaching

		Nature of knowledge	
		Unproblematic	**Problematic**
Nature of mediation of knowledge	**Transfer**	Transferring knowledge from hand to hand	Transferring problematic knowledge from mind to mind
	Create space	Creating space for learning knowledge	Creating space for learning problematic knowledge

In phenomenography the structural aspect of a conception is constituted by the 'internal horizon' and the 'external horizon' (Marton & Booth, 1997). The horizon is the boundary of the conception. The internal horizon is not just the boundary, but everything which is internal to the boundary, i.e. the conception and the parts which constitute it and the relationships between the parts. That which is external to the boundary is termed the external horizon – this is not part of the conception but is the context in which the conception occurs and hence is the backdrop against which the conception is perceived. The structural aspect of the outcome space of this study is given in Table 22. The internal horizon has three constituents: science knowledge, the role of science learners, and the role of the science teacher. The interaction between the three is the referential aspect of the conception, which gives meaning to the way in which the teacher facilitates learners apprehending science knowledge. In this way the structural and referential aspects are co-constituted. For all the conceptions, print and other media, as well as practical work, form part of the external horizon, but they have different roles according to the different conceptions.

I next explore each of the four conceptions. In doing so I will use quotes from the transcripts, but no single quote captures a whole conception: the conceptions emerged from analysis of the pooled data, rather than from individual statements. In phenomenography, individuals are not tied to particular conceptions and a particular person may demonstrate different conceptions of a phenomenon at different times (section 1.2.3). However I will identify which teachers said what, since I have introduced the teachers elsewhere in this thesis. I will start by discussing the second conception, since it is a helpful reference point for the first one.

Table 22: Structural aspect of outcome space

Conception	Internal horizon			External horizon	
	Science Knowledge	Learner role	Teacher role	Role of Media	Role of practical work
1. Transfer knowledge hand to hand	Given object for teacher to present	Listen	Find and present knowledge	Teacher uses textbooks or internet to find knowledge	Make science fun; give knowledge
2. Transfer problematic knowledge mind to mind	Problematic object for teacher to present	Understand	Grapple with knowledge then present it	Teacher uses textbooks and internet to understand knowledge; Teacher mediates textbook to learners	Elucidate content
3. Create space for learning knowledge	Given object for learners to access	Find knowledge	Facilitate exploration	Learners find knowledge in texts	Exploration
4. Create space for learning problematic knowledge	Problematic object for learners to make sense of	Construct their own knowledge	Grapple with knowledge and then facilitate	Teacher uses texts to prepare; Learners use texts to help them construct knowledge	Elucidate content; teach investigation skills

7.2.1 Transferring Problematic Knowledge from Mind to Mind

The second conception, ‘transferring problematic knowledge from mind to mind’, is about a movement of knowledge from the teacher’s mind to the learners’ minds. Preceding this is a movement of the knowledge from textbooks and other reference material into the teacher’s mind. Because the knowledge is problematic, there is considerable effort involved in both these processes. Ms Emeni commented on teaching the topic ‘light’, “The content I find it very heavy. It’s difficult for me to cross it to the learners.” Her use of the word ‘cross’ suggests the phrase ‘getting the message across’, and the implication is a crossing of content from her mind to the learners’ minds. She also made an interesting comparison with mathematics, which she also teaches:

> maths is much easier to teach than physical science. The content itself – for mathematics you just show them ways to do it, but with physical science you have to put the content into their head, which is quite difficult, yoh.

The difficulty of the knowledge means that the teacher's engagement with it is key to the successful mediation of the knowledge to learners. Ms Emeni makes a considerable effort to come to grips with the content herself before she presents it in lessons. The learners' role is to understand the content which the teacher presents.

With regard to the external horizon, the textbook plays a significant role when a teacher conceptualises knowledge as problematic. Textbooks feature both as a resource in her preparation and as needing to be mediated in the classroom – learners are not expected to simply 'get it' from the textbook. The textbooks used in preparation include the teacher's own university textbooks and school textbooks other than the ones the learners have. Books are central to the teacher's initial grappling with the knowledge to be taught, thus getting it 'into her head' that she may facilitate learners' access to it. The role of practical work is to help elucidate difficult content.

7.2.2 Transferring Knowledge from Hand to Hand

The first conception, 'transferring knowledge from hand to hand', is also about a movement of knowledge from teacher to learner, but in this case the knowledge not seen as problematic, for example Ms Gray said "So I say to them, I'm not re-teaching anything you should have been listening to in the first place." Her need to only say things once implies a transferral of knowledge from teacher to learner as long as the learner is listening. Similarly Mr Dube said of his learners "they prefer you to actually teach them and whilst you are teaching them, just give them notes at the same time." The 'just' giving of notes implies that the knowledge is not problematic, and can be adequately captured in notes. This knowledge is often seen as given in definitions – when asked what his learners got out of a particular lesson, Mr Dube said:

> I think they came away with the definition – lots of definitions actually [laughs]. And they were able to actually say the integration between water cycle as well as nitrogen cycle plus the hydrosphere as well.

The fact that this given knowledge is viewed as straightforward means that there is no need for effortful engagement with the content on the teacher's part. Mr Dube typically gets information from the internet, prints it out and highlights what he thinks is important, but I have seen him fail to engage conceptually with content, to the extent of writing statements which do not make sense on the board (see section 5.5.2). Whereas in the first conception, knowledge passes through the teacher's mind, in the second conception it appears to merely pass through the teacher's hands. Books and the internet are part of the external horizon of this conception, but instead of using multiple sources, one source suffices for teachers to find the information. Practical work makes science fun and gives knowledge to learners.

7.2.3 Creating Space for Learning Knowledge

The remaining two conceptions create space for learning the way a science museum does, as Ms Fikela described:

> we went to the SciBono Centre, and it was lovely, they were exploring, they were experimenting, doing all these fun things. And then I said, "Just by doing this, that makes you scientists."

Here Ms Fikela positions her learners as scientists: the space created allows them to explore like scientists. They bought into this identity, as the following extract from a lesson narrative illustrates:

> Ms Fikela introduced the section on elements with the poem 'what are little girls made of?' The text underneath the poem said 'modern scientists know that this poem is not true.' Ms Fikela interrupted the learner who was reading the text aloud to the class and said "Most of you know that, *angish'?* [isn't it so]. Most of you said 'nooo'. So are you modern scientists?"
>
> The class chorused "yes" in reply.

Mr Baloyi creates a museum situation in his classroom:

> All your stuff, your science equipment: don't put them in a storeroom and hide them. Put them visible where they'll see them every day. So they may ask "What is this?" and you'll tell them "I'll tell you when we get to that point" or "Come break time, I'll show you what it does." Don't explain what it does, just show them what it does and then that's it. They will ask a question "Why does it does this?" and then there is a lesson that you've just done.

But creating space is not only about learning from engagement with apparatus. Mr Baloyi gets his learners to use the considerable collection of textbooks and other reference books in his classroom to find useful information:

> they can read, but it's important that they must select the information that they need. And that is what I'm really trying to get across. What information do you need. Then if you notice the books are always closed, they must close them, once you're done with it you close it, so the next person must come in and they must search and find whatever [unclear].

His last sentence indicates that he wants his learners to be able to access information from a closed book – not merely a book which someone else has left open at the right page. He has also taught them that encyclopaedias typically give easier information first and more complex information later, so a reader should ascertain the level of the information which is appropriate. Mr Dube gives learners copies of pages from textbooks in preparation for his lessons, so that learners can use the information in the handouts to answer his questions. These last examples imply that learners will be able to get the knowledge from the books – the knowledge is taken as unproblematic in the third conception, 'creating space for learning knowledge'. Teachers who work with a conception of teaching as creating space are likely to want to get their learners to use books to find information in some way, either in the classroom or out of it. Practical work allows learners to explore, as captured in the first two quotes above.

7.2.4 Creating Space for Learning Problematic Knowledge

In contrast, it is also possible to create space for learning problematic knowledge, which is the last conception. Learners are likely to be busy where teachers work with this conception. I commented to Ms Cole about a unit she had taught on density which involved lots of hands-on work with apparatus. I thought her response was profound in the way it expressed the non-linearity of learning:

> *Researcher*: Those density notes were really interesting to me, because they were so well structured, the logic of them was fantastic, and yet I sensed, as you did, that the kids were going through the motions doing all the experiments, without getting the big picture.
>
> *Ms Cole:* […] And I think, even if they don't quite understand what they're doing, I think it gives them enough first-hand experience. You know, it's just sowing seeds so that – it's a complicated concept, very abstract, so I think even just sowing those thought processes, a seed, I think it will eventually help. Some of them do get it but, *ja*.

Although the density notes were linear, Ms Cole understood that the learners' take-up of the concepts was not. Her role was to sow seeds to facilitate their engagement with the knowledge. She then commented that in the end, the grade eights seem to have got it, insofar as they did quite well in the test. The density notes had been given to her by another teacher, as were some notes on magnetism. Here is the way she worked to create space for learning this problematic knowledge:

> instead of just going through the notes, because the notes were quite dry, I first got a bunch of videos from YouTube especially on solar flares and how the earth's magnetic field disperses them. And I used that as an introduction. And the kids

> found that totally fascinating. And then they started asking questions themselves about how it works, and that sort of thing. And then once they were asking those questions, we could get into the real concepts, as opposed to me saying "these are the concepts, they're important, learn them."

This quote reflects that the created space is not just any space – it is a carefully thought out and well-constructed space which is conducive to productive engagement with particular content. Texts, in this case YouTube videos, are provided to help learners construct knowledge. Similar to the second conception, 'transferring problematic knowledge from mind to mind', the teacher needs to engage meaningfully with the content – the content needs to pass through her mind and not just her hands if she is to be able to answer learners' questions. Thus the teacher also uses texts in preparation. The role of practical work is twofold: to elucidate content and to teach investigation skills.

7.2.5 Hierarchy of Outcome Space

As mentioned in section 2.2.1, other researchers have found that the outcome spaces of conceptions of teaching are hierarchical, with learner-centred conceptions encompassing lower teacher-centred conceptions. This prompts the question whether any of the conceptions in the outcome space of this study encompass any others. Not all science knowledge is problematic so it makes sense that this view of knowledge should encompass unproblematic knowledge – i.e. the conceptions on the right side of Table 21 encompass the corresponding conceptions on the left side.

Both conceptions involving problematic knowledge were significantly evident in Ms Emeni and Ms Gray's interview data. Using teachers as a proxy for data which fits together, this suggests that either 'create space' or 'transfer' is inclusive of the other. But in Mr Dube's data, only the 'transfer of knowledge' conception was evident, which suggests this conception is not inclusive of any other. From these two statements it follows that 'create space' includes 'transfer' rather than the other way around - i.e. the conceptions on the bottom row of Table 21 encompass the corresponding conceptions above.

7.3 Discussion

One possible criticism is that the conceptions which emerged in this study are conceptions of teaching generally and not specifically conceptions of *science* teaching. My first response to this criticism is that the nature of the school curriculum and school organisation forces these teachers to be generalists rather than specialists. Whereas I have a strong identity as a physicist who gave up chemistry after my first year of university, these teachers are neither physicists nor chemists nor biologists nor mathematicians – they are forced by the system to study three and teach at least two of these disciplines. Only three of the sample had the luxury of teaching only science, though this included life science in the lower grades. Another two taught both mathematics and science at the time of the study, and the remaining three had done so previously.

However these teachers do see the disciplines of physics and chemistry very differently and most of them have a strong opinion about which one they prefer, with a half-half split between the two disciplines. Oddly, two of the teachers prefer physics because they find it more challenging to teach. For example, when asked whether he prefers physics or chemistry, Mr Hlope responded:

> I always believe that the best science is physics. Physics is nice. Yoh, physics it's super. Because that's where it will expose you, it actually select the best from the worst. It will tell you if you've got lots of misconceptions. You're sure that you know stuff only to find out that you know nothing. I like physics because it's so challenging, meaning that it always keep you working as such. With chemistry I don't need much. If I look at chemistry FET [grade 10-12], the one that I'm dealing with, ah, I always can prepare that within no time at all, but with physical science [physics] I need to read, practice.

My second response to the criticism is that the understanding of knowledge as problematic reflects the subject matter. Physics is notoriously difficult because of the way a lot of physics principles contradict commonsense derived from life experience. Similarly chemistry is difficult because it explains observations by means of abstract models reflected in a particular language of symbols and representations which has to be learnt. Of course there is difficult content in any discipline, but it is no coincidence that the research into alternative conceptions has been more extensive in the physical sciences than in any other field of education research (Meyer & Land, 2006). Certainly Ms Emeni experienced her teaching of science as considerably more demanding than her teaching of mathematics, because of the content (see section 7.2). The understanding of the content as problematic has not appeared in other conceptions research. Perhaps this is because most other research into conceptions of teachers has cut across disciplines.

7.3.1 Comparison with other Phenomenographic Research

How do the conceptions in this study compare with other research into conceptions of teaching? Table 23 gives a comparison between this study and the others which I referred to in section 2.2.1. I have put what I see as comparable conceptions in the same horizontal position, but this fit is better with some conceptions than with others. The conceptions at the top of the table are characterised as learner-centred, while those at the bottom are characterised as teacher-centred.

Table 23: Comparison of conceptions of teaching research results

This study- secondary science teachers	**Lecturers** (Prosser & Trigwell, 1999)	**Australian secondary teachers** (Boulton-Lewis et al., 2001)	**Chinese secondary science teachers** (Gao & Watkins, 2002)	
		Transformation of students	Conduct guidance	Learner-centred
			Attitude promotion	
Creating space for learning problematic knowledge	Helping students change conceptions	Facilitation of understanding in students as learners		
Creating space for learning knowledge	Helping students develop conceptions	Development of skills / understanding	Ability development	
Transferring problematic knowledge from mind to mind	Helping students acquire teacher knowledge			
Transferring knowledge from hand to hand	Helping students acquire conceptions of the syllabus			
			Examination preparation	Teacher-centred
	Transmitting the teacher's knowledge	Transmission of content/skills,	Knowledge delivery	
	Transmitting the concepts of the syllabus			

The teacher-centred conceptions in Table 23 did not surface in my study – all the conceptions in my study involve learners in some way. 'Transferring knowledge from hand to hand' has a weak resonance with 'helping students acquire the conceptions of the syllabus', since in both conceptions the knowledge passes from the source to the students – moving through the teacher's hands rather than her mind. 'Transferring problematic knowledge from mind to mind' is similar to 'helping students acquire teacher knowledge'. 'Creating space for learning problematic knowledge' has resonance with 'helping students change conceptions' since conceptual change often involves problematic knowledge: to change one's conceptions, one needs to change pre-existing ideas. This suggests that 'creating of space for learning knowledge' might fit with 'helping students develop conceptions'. But one could also argue that the idea of creating space for learning is qualitatively different from that of helping students develop or change conceptions. Surprisingly the conceptions of this study fit best with the 'top' end of the conceptions of lecturers, rather than with the other studies conducted with secondary teachers.

However the structure of the outcome space of my study is substantially different from the others. The other outcome spaces are simple hierarchies where higher order learner-centred conceptions include lower order teacher-centred conceptions. In other words, any conception in Table 23 includes all the conceptions below it. In contrast, the outcome space of this study is a two dimensional matrix, given in Table 21, which pays attention to the nature of the knowledge to be communicated.

In section 2.2.2 I noted that conceptions of teaching are sometimes broken down into beliefs and intentions. The distinction arises as a result of the conflict between ideals and contextual constraints. I did not see evidence in the data of this particular breakdown, although the teachers were well aware of the constraints of their contexts.

The conceptions of teaching as 'creating space for learning' resonates with the 'space of learning' which phenomenographers Marton and Tsui (2004) see as the variation of the subject matter's critical features which is afforded to learners (see section 2.2.5). These conceptions also echo a phenomenographic study which explored university students' expectations of teaching in physics, and found that students viewed lectures differently, with some seeing it as "potential space for learning to occur" (Marshall & Linder, 2005, p. 1265).

7.3.2 Problematic Knowledge

Two of the conceptions in this study are about 'problematic knowledge'. This is similar to the idea of 'troublesome knowledge' which was coined by Perkins (1999). Troublesome knowledge has proved to be a useful way of thinking about some of the knowledge in science, and so in this section I want to relate problematic knowledge to troublesome knowledge. Perkins originally defined five types of troublesome knowledge: 'ritual knowledge', 'inert knowledge', 'conceptually difficult knowledge', 'alien knowledge' and ‘tacit knowledge’. But researchers who have picked up on this idea have tended to narrow troublesome knowledge down to only two of these types: ‘conceptually difficult knowledge’ and ‘alien knowledge’, for example “What Perkins (1999) refers to as *troublesome knowledge* – knowledge that is ‘alien’, or counterintuitive or even intellectually absurd at face value” (Meyer & Land, 2006, p. 4). This reduction seems sensible, since Perkins’ ‘ritual knowledge’ and ‘inert knowledge’ refer respectively to ways in which people deal with ‘conceptually difficult knowledge’ or ‘alien knowledge’ by reducing it to ritual procedural knowledge without understanding, and inert knowledge which is memorised but not applied.

A related term is ‘threshold concept’ which is a concept needed to get over the threshold of a particular discipline and enter that discipline (Meyer & Land, 2006). Without the acquisition of the necessary threshold concepts, a student cannot access the powerful ways of thinking of the discipline. Threshold concepts usually involve troublesome knowledge, and so present a significant hurdle to students. It is thus productive for teachers to identify the threshold concepts of their discipline (Meyer & Land, 2006). Threshold concepts are similar to ‘big ideas’ which I mentioned in section 5.4. Loughran and his colleagues see identifying the big ideas of a topic as fundamental to teaching that topic. They see big ideas and an understanding of the difficulties of these ideas as central to the domain of PCK (Loughran et al., 2004). Insofar as they are central to teaching, they are similar to threshold concepts. But the different metaphors used – a threshold and a large object – have different implications: ‘big ideas’ are large objects within the discipline, whereas threshold concepts are the gatekeepers to the discipline.

Problematic knowledge is similar to troublesome knowledge insofar as it is difficult to apprehend because it is conceptually difficult. This can be because it is abstract or counter-intuitive, i.e. knowledge which conflicts with commonsense ideas about the world. However I have chosen not to use the term troublesome knowledge because I do not want to imply that the teachers in this study were referencing the idea of a gate-keeping threshold concept.

7.4 Conclusion

In this chapter I have presented four conceptions of teaching, explored their relationship to each other in the outcome space, looked at their internal and external horizons, described how I bracketed my knowledge and related the conceptions to other research. Each conception includes a view on science knowledge as either problematic or not, and a way in which a teacher acts on that knowledge, either by transferring it to learners or by opening up space for learners to appropriate it. Internally these conceptions are constituted of three parts: the science knowledge to be learnt, the role of the science learners and the role of the science teacher. Externally these conceptions see the roles of media and practical work differently. The four conceptions of teaching which surfaced in this study have resonances with other research, however the outcome space is a matrix rather than a simple hierarchy. This is because the conceptions have a view on science knowledge as problematic or not, which may be because this study looked specifically at science teachers' conceptions, and science knowledge is recognised as having troublesome knowledge. I have now addressed all four of my research questions, and so move to the final turn of this research project which involves drawing together the results, reflecting on the journey and considering the ways in which this research speaks to the field. This is the content of the final two chapters.

Chapter 8: Reflection, Summary and Discussion

Over the past four chapters I have unpacked each of my four research questions in turn. Each chapter has used a different viewpoint – a different way of regarding the teachers. In this chapter I put these different slices together to give a more holistic picture. In so doing I bring the results of the different chapters into contact with each other, and ask to what extent the results are consistent across the different viewpoints. I then give a more detailed picture of one teacher, as an example of good practice in a challenging context. However I first reflect on the research process.

8.1 Reflection on the Research Design

My first attempt at a research proposal was developed during the second half of 2006, when I did a Masters research methods course with the express purpose of developing a doctoral proposal. After another four drafts, my final proposal was submitted in May 2010. By then I had already collected two days of data (having obtained ethics clearance), the experience of which fed back into the research design reflexively. The result of such a tortuous process of design was a research design which, apart from the addition of another research question, essentially worked, and did not need any major revisions in the way the data was collected and analysed. Both my research instruments (classroom observation and interviews) produced rich and useful data. Although narrative inquiry did not turn out quite the way I had anticipated (see section 6.1) and I found the phenomenographic analysis initially challenging (see section 7.1), the research approaches of phenomenography and narrative inquiry worked well for me.

Nonetheless, I initially felt my novice status as a researcher acutely. I lacked confidence in my lesson narratives, and wondered whether I was seeing anything useful. I was aware of the contrast between my confidence as a teacher with twenty years' experience and my lack of confidence as a researcher. I found myself exhausted after a day of collection – the exhaustion of being in a new setting, doing something where I did not feel very competent. At the same time I had to deal with the technology challenges which come with doing new work – getting and using a video camera, voice recorders, more memory and new software. Because of this, I continued to read about interviewing and observing as I was doing it, thus engaging with other researchers' experience and wisdom. Janesick (1998) helped me realise that other experiences in my life helped equip me for this research, for example I realised that I could draw on my experience of noting and describing details in the non-fiction creative writing I had done. I could tick most of the qualities of a good qualitative researcher which Janesick gave. She also challenged me to work with the 'intuitive sense' whereas my data collection was centred on my senses of hearing and seeing.

From the beginning, I was concerned about the trustworthiness of my research and paid attention to considerations of validity throughout my research. As explained in Chapter 3, I was concerned about two major threats to validity: site reactivity and researcher subjectivity. My concern about the reactivity of classrooms due to the presence of the observer turned out to be justified. Despite my efforts to reduce the effect of the observer by paying attention to issues of power, by asking teachers and learners to behave as normal, and by other means (section 3.7.2), my presence had an effect. However this effect varied across teachers and across learners (section 4.1). For the teachers it varied dramatically from no effect to Mr Hlope's experience of difficulty talking because his mouth dried out. For some learners my presence had no effect observable by their teachers, whereas with other learners there were significant silencing effects, positive and negative – inhibiting bad behaviour but also inhibiting learners' contributions to the lesson, in particular in bilingual classrooms. I took the teachers' nervousness into account when I looked at their first couple of lessons, which is when they were most affected (for example, see section 5.1). In the end I am satisfied that I took classroom reactivity into account well in my research design and adequately in my analysis.

I addressed researcher subjectivity by being both aware of it and explicit about it (section 1.4.4). This transparency did not reduce my subjectivity but shows the ways in which my subjectivity influenced the research, and hence allows the research to be read appropriately. Transparency also gives evidence of integrity and reflexivity in my methodology and analysis. The biasing effect of my subjectivity was reduced by rich data in the form of lesson narratives and good transcriptions, peer and teacher feedback, and the use of established methods of analysis: phenomenography, narrative analysis and grounded analysis. While my subjectivity could be viewed as a necessary evil, I note that who I am benefitted the validity of the research insofar as I had a substantial background in science education and teacher education, and an established relationship with the teachers on which to build the research.

In section 3.5 I started my argument for the validity of my research, and I have now completed that argument. I have argued that my research design and analysis has sufficient validity for the results to be trustworthy. I claim sufficient construct validity (see section 3.5.1) for the measured constructs of normal classroom practice, conceptions of science teaching and teacher identity. Thus I present my results as credible and justified, being not the only possible interpretation, but a valid interpretation. Apart from validity, I argued in Chapter 3 that my research was ethical, based on the principles of ‘no harm’ and privacy, although I encountered ethical tensions in classroom observation (section 3.4.2).

8.2 Summary of Results

Table 24 gives a summary of the results of this research project by teacher. In this section I will unpack this table, thus summarising the results for each of my research questions. As I described in second 3.1, the sample comprised eight secondary teachers who taught grade 8-9 Natural Sciences and / or grade 10-12 Physical Sciences typically to two or three grades, with some of them also teaching Mathematics or Technology, in a variety of different schools: poorly resourced township schools, better resourced intervention schools working with township learners, well-resourced multicultural schools and an elite private school.

Chapter 4 addressed my first question research question: what is the variation in activities which early career secondary school physical science teachers use in their lessons? Choosing activities rather than lessons as a unit of analysis worked well. As described in Chapter 4, the activities in the lessons I watched could be classified both according to the teachers’ underlying purpose and the mode of engagement used. The teacher’s purpose could be the introduction of new content in the form of general principles, the application of that content to specific situations, feedback on learners’ work or revision of work done previously. The mode of engagement in which this purpose was achieved could be exposition by the teacher, questions asked by the teacher and answered by learners (Q&A), or a conversation in which questions were asked by both teacher and learners with the direction of the lesson affected by the input of learners.

Table 24: Summary of results

Teacher		A	B	C	D	E	F	G	H
Grades taught		8-10	8,10-12	8-10	8-11	11-12	9	10-11	9-10
School type		Multicultural	Township	Private	Township	Intervention	Intervention	Multicultural	Township
1. Preferred mode of engagement		Exposition	Conversation	Q&A	Q&A	Q&A	Q&A	Q&A	Q&A
2. Content objects	Accuracy	2,4,2,3	3,4,3,2	3,4	1,4,1	3	3,2	3,3	3,3,3
	Appropriateness	2,2,3,3	4,3,3,3	4,3	1,3,2	3	3,3	3,4	3,3,3
	Transformation	2,1,3,3	4,3,3,3	4,3	3,1,2	2	2,3	2,3	3,3,3
3. Teacher identity	Reason for entry into teaching	To train teachers	Always wanted to	Didn't enjoy architecture	Friend suggested	Always wanted to	Always wanted to	2nd choice	Encouraged to study further
	Discourse-identity	Future teacher trainer	Safe classroom; learner ownership	Makes concepts visual	Empathetic, inspires learners to work hard	Uses apparatus to elucidate content	Passionate teacher who does a thorough job	Open; wants learners to think for themselves	Well-trained township teacher
4. Conceptions of teaching science	Transfer knowledge from hand to hand	x			X				x
	Transfer problematic knowledge mind to mind	x				X		X	x
	Create space for learning knowledge		X						
	Create space for learning problematic knowledge			X			X	x	

Key:

2. Content objects: levels 1 and 2 are problematic, level 3 is good, and level 4 is exceptional.

4. Conceptions of teaching science: **X** is strongly evident in data; **x** is less strongly evident.

The classification of individual lessons in terms of these two dimensions is given in Table 6 (section 4.2.3, p. 146). The teachers' preferred modes of engagement are given in Table 24 above. I found that some teachers had strong preferences for particular modes of engagement while others worked with a wider repertoire. All of the teachers who preferred a Q&A mode of engagement also had times where the mode shifted to conversation.

Chapter 5 addressed my second research question: what is the quality of the science content of their lessons? As described in section 5.3, I could not find a suitable framework for analysing the content of lessons, and so developed my own framework, based on issues which emerged in the data. I identified the 'content object' – the propositional and procedural science knowledge and the transformation thereof – for each lesson where the main purpose of the lesson was the introduction of new physics or chemistry content. I developed a rubric to assess the quality of the content objects (see Table 13 on page 172). The rubric had three dimensions: the accuracy of the content, the appropriateness of the content and the transformation of that content to make it accessible to learners. Table 24 indicates the rubric scores for these three dimensions of each lesson, with the scores given in the order the lessons were presented. Level three of the rubric represents a good level, with level 4 being exceptional. Levels 1 and 2 are problematic.

My third research question asked: how do these teachers narrate their professional identities? My analysis in Chapter 6 addressed two questions: how did the sample account for how they became science teachers, i.e. what did they see as having led them to teaching as a career and to science as a subject? Second, what kinds of science teachers do they identify themselves as? Table 24 summarises the reasons they gave for becoming teachers: four said they wanted to be teachers – three wanted to since primary school, though none of the three went directly into a teacher education programme after grade twelve, and the fourth wants ultimately to run workshops for teachers. In contrast four teachers recounted that they 'fell' into teaching, three because of the bursaries available, and the last as a second choice. That they happen to teach science is mostly serendipitous, though for most the choice was limited to mathematics or science by their bursary. Whatever their original choices, all but one were enabled to study teaching by a bursary. The teachers identified themselves as particular kinds of teachers, summarised in Table 24. These identities reflect diverse influences, many of which are outside their initial teacher education.

My final research question was: what conceptions do these teachers have of science teaching? This was addressed by a phenomenographic analysis in Chapter 7. Four conceptions emerged, with two dimensions. One dimension is whether the science knowledge to be taught is seen as problematic or not. The other dimension is the nature of the mediation of that knowledge, either by transferring the knowledge from the teacher to the learners, or by creating space for learners to acquire the knowledge. Although the data were pooled for the phenomenographic analysis, in Table 24 I show the conceptions most evident in the interview data of each teacher, with 'X' indicating conceptions strongly evident in the data of each teacher, and 'x' indicating conceptions less strongly evident.

Clandinin and Connelly (2000) talk of narrative intersections: this research has been the intersection of my own narrative, the narratives of my past students, and my narratives of their lessons. There are other narratives which intersect the research which I have not considered, for example the learners' narratives, their narratives of the lessons I shared with them, and their take on my presence in the classroom. I do not know what these stories are – my focus has been on teachers. In looking at the teachers I brought four lenses to bear on the data, two addressed the practices of teachers, and two addressed teachers' thinking. I note that these are not the only lenses which I could have used, but they have addressed aspects which I have argued are critical: the form and content of lessons, and teachers' identities and conceptions of teaching science. While I have argued that these aspects are critical, I do recognise that they are not the only the aspects which affect learning. For example the quality of a lesson is not only due to the quality of the subject matter content and the mode of engagement, but also due to affective factors, such as the ways in which teachers affirm learners.

8.3 Synthesis of Results

In the previous section I summarised the answers to my research questions individually. In this section and the next, I bring the different kinds of analysis into relation with each other. In this section I ask whether the results are consistent with each other and in the next section I bring the results into relation for one teacher. However there is no easy synthesis of the results – the sample is too small to generalise any correlations.

My first two research questions explored the classroom practice of the teachers, in form and content. Thus it is worth asking whether there is any correlation between form and content, i.e. is there any correlation between the mode of engagement and the quality of the content object? I can see no correlation in Table 24. Ultimately a good quality content object is central to the quality of a lesson, whatever the mode of engagement. So some learner-centred lessons where learners engaged enthusiastically were compromised by problematic content objects (see. sections 5.7.1and 5.7.2). In contrast the only lesson I saw with a good quality content object compromised by other factors was a lesson just before a holiday, where Ms Cole's learners behaved well in body, with minds elsewhere. However interactive modes, in particular conversations, have value in facilitating learner contributions which impact positively on the quality of lesson content.

However what is not reflected in Table 24 is my realisation from some of Mr Baloyi's lessons that an extended dialogic conversation may lead to a weak content object if the teacher does not give closure by bringing in the authoritative voice of science. This concurs with Brodie's conclusion after analysing mathematics lessons: "My analysis confirms that "not telling" is not always the best option for teachers" (Brodie & Coetzee, 2010, p. 120). Similarly Mortimer and Scott's (2003) model has the teacher starting with a dialogic approach but then shifting to an authoritative approach, thus bringing in 'the scientific story' and guiding learners in applying the scientific view.

The last two research questions were about teachers thinking – their conceptions and identities. Are the teachers' identities consistent with the conceptions of teaching evident in their interview data? Obviously identities and conceptions have different subjects – identities are about teachers and conceptions of teaching are about teaching, but some identities have resonances with particular conceptions of teaching. For example Ms Emeni sees herself as a teacher who uses apparatus to elucidate content, which has a good fit with the conception of teaching as transferring problematic content – she uses apparatus to help learners understand difficult content. Mr Baloyi's concern that learners should have ownership of their learning, and Ms Gray's identity as a teacher who is open to different approaches by learners are both consonant with a conception of creating space for learning. The identities of Ms Cole and Ms Fikela, using visual means and being passionate respectively, do not conflict with the idea of creating space. Likewise Mr Dube's identity as someone who inspires learners to work hard does not conflict the conception of transferring knowledge mind to mind – learners who work hard should be able to learn this knowledge unproblematically. Similarly Mr Hlope's view of himself as a good township teacher and Mr Abrams' aspiration to be a teacher trainer do not conflict with the conceptions of teaching evident in their data. This suggests that the teachers have achieved the integrity which Palmer (1997) sees as essential to good teaching.

I now bring classroom practice (explored by the first two research questions) into relation with teacher thinking (explored by the fourth research question), by asking whether the teachers did what they said they did. Were their classroom practices consistent with the conceptions evident in their data? I pointed out in section 2.4.3 that novice teachers often have a gap between what they say they do and what they do, in part because their teaching contexts offer real and imagined constraints (see section 2.2.2). In this study, the only teacher for whom there was a significant gap was Mr Abrams (see sections 5.1, 6.3.8 and 7.3.1). The rest of the teachers' descriptions of themselves were consistent with their practice – what I observed had a good fit to what they said about what their practice. In regard to modes of engagement, where conceptions involving 'creating space' were evident in a teacher's data, the teacher used conversations which allow learners to affect the direction of a lesson, which are consistent with the idea of teaching as creating space. In contrast the conceptions about transferring knowledge are consistent with exposition, but the teachers in whose data the knowledge transfer conceptions were evident mostly preferred Q&A. I think this is the influence of the 'learner-centred' doctrine of the South African school curriculum: the teachers used Q&A to engage learners in knowledge transfer. In regard to the quality of the content objects, conceptions which regard science knowledge as problematic tend to correlate with better quality content objects. Hence it appears that a view of subject matter which problematises some of the knowledge is more powerful. A view of science as problematic knowledge might be expected to correlate with well transformed objects – a teacher who understands the difficulties which learners have in apprehending science knowledge might be expected to pay more attention to the transformation of that knowledge, although this is not borne out by the results in Table 24. However Ms Emeni and Ms Cole's focus on science content in their identities squares up with quality content objects.

Finally I look for correlations between classroom practice and teachers' histories by asking two questions. First, does a teacher's route into teaching make any difference to the quality of their teaching? The results of this study suggest not: those who report that they always wanted to be teachers (Ms Emeni, Mr Baloyi and Ms Fikela) were no better or worse on average than those whose entry was idiosyncratic. Second, what is the importance of a teacher's own secondary school science learning? Two of the teachers in the sample were not taught science beyond grade nine. Ms Cole did not take science (section 6.2.6), and Ms Emeni took it but she and her peers studied it entirely on their own because there was no science teacher at the school (section 6.2.1). Yet my analysis shows good content objects in their lessons. This suggests that poor or absent school SMK can be addressed through university subject matter courses.

8.4 Portrait of a Township Teacher

Effectively there is a portrait of each teacher contained in fragmented form across the previous chapters, and summarised in Table 24. Thus a different way of bringing the results of the different kinds of analyses together is to paint a portrait of each teacher. I will not do this for every teacher, but rather for one particular teacher, Mr Hlope. Whereas in the previous section I brought the different analyses together as a whole, I now bring those results together in one person. I chose Mr Hlope because my professional judgement is that most of his lessons which I observed were effective, despite his environment which in many ways conspired against good teaching. His story has value because "Any narrative is significant because it embodies – and gives us insight into – what is possible and intelligible within a specific social context" (Chase, 2005, p. 667). In other words, Mr Hlope's narrative gives us an 'imagination of the possible' (Slonimsky, 2007) within contexts such as his.

I have argued that what counts as good science teaching is contested, and there is a move in science education and in education research more broadly towards an understanding that what works as effective teaching depends on the individual teacher and her particular context (section 2.2.6). A complexivist view of education takes into account both the agency of the individual, and her past and present contexts which impose constraints on the agency of the individual (section 2.1.3).

However the discussion of the last section ignores the contexts within which the teachers worked, as these varied widely between the teachers. By focusing on a particular teacher, Mr Hlope, I am able to bring his context into focus. I will tell more of his story than I have already told in the preceding chapters, and reflect on his agency amidst contextual constraints and possibilities. I will first summarise what I have already presented about Mr Hlope, adding a few details, and then describe his context in more detail.

8.4.1 Mr Hlope's Story

Mr Hlope identified himself as 'not clever' at school, but recognised that he had talent in science: he was one of two learners from his area put into a special programme at a rural science centre. While at school, he showed agency by improving his English using resources available in his context (old newspapers) which meant that he was identified as a clever learner at his school. Mr Hlope studied to be a teacher because some of the people whose cars he guarded encouraged him to further his studies, and he realised he could study further with a teaching bursary (section 6.2.4).

When asked to identify "what it is that's made you the unique teacher that you are today", Mr Hlope identified his excellent training and his context as the key factors forming his practice, thus authoring his discourse-identity as a well-trained township teacher. In his teacher training he said he was particularly influenced by the way I, as his physics lecturer, emphasised conceptual understanding, saw equations as reflecting relationships and used questions. Mr Hlope deliberately made a choice to teach in a township context, in order to bring help learners bring 'light' to their families (section 6.3.4).

In the two days I spent with Mr Hlope, he consistently delivered good science lessons, even though on my first visit Mr Hlope initially experienced nervousness to the extent of his mouth drying out, making it difficult for him to speak (section 4.1.2). Mr Hlope's preferred mode of engagement was Q&A and I saw more lessons involving practical work with him than with any other teacher (section 4.2.3). He did demonstrations in which learners participated and he gave his learners hands-on activities working for example with electricity kits and stencils. The subject matter content of his lessons which I observed was consistently good, i.e. accurate, appropriate and well transformed to make it accessible to his learners (section 5.6). Learners made a positive contribution to the quality of Mr Hlope's lessons (section 5.5.2). Mr Hlope allowed learner input to change the direction of a lesson as happened in one lesson where he worked effectively with learners' incorrect responses that a resistor is an insulator, and a resistor 'disallows' charges to pass through. The didactic contract he had with his classes was such that learners could correct his mistakes without issue. Mr Hlope got learners to write things in their own words (described in section 5.5.2), a productive activity which almost never occurred in the many lessons I observed. He checked that learners' books were up to date, and signed in them.

8.4.2 Mr Hlope's Context

Having summarised Mr Hlope's path through this thesis, I now describe his context in more detail. Mr Hlope taught in a township school, similar to the school described in *A day with Mr Dube* (section 3.6). The timetable had been changed four times by the time I visited Mr Hlope in early March, and was still not completely functional, with Mr Hlope seeing his one grade nine class less often than the other grade nine classes. On the first day I visited Mr Hlope, the school was dismissed at first break because there was no water. Mr Hlope taught Natural Sciences to all the grade nines and Physical Sciences to all the grade tens – the same learners he taught the previous year, and would see all the way through to matric.

The classrooms at Mr Hlope's school 'belonged' to classes rather than to teachers, with teachers moving between classrooms. The grade nine classrooms had a teacher's desk at the front, but the grade ten classrooms did not, so Mr Hlope had to put any books or equipment he brought to a lesson on an empty learner's desk. The chalkboards were in good condition but dusters were non-existent and Mr Hlope used a rag from the floor and toilet paper provided by a learner to clean the chalkboards in lessons I observed. However Mr Hlope did have his own workspace in an office which he shared with a couple of other teachers.

The staffroom was not used by teachers, but housed bags of mealie meal and samp used in the school feeding scheme and a few computers which were at one time connected to the internet. Mr Hlope did not have internet access at school or home, and so went to a nearby internet café to find teaching resources, where he paid R 3.50 per page of printing. The school did have a working photocopier, but only one person was allowed to operate it, which meant Mr Hlope had to wait a day for printing, which he experienced as a significant constraint. Mr Hlope stayed in a house which belonged to his father and which was located in an informal settlement. His father wanted him to stay in the house so as to keep it in the family. However the house did not have electricity.

Learners were routinely late at the beginning of the day and after breaks, as reflected in this extract from the beginning of the lesson narrative for a lesson after break:

> The teacher writes the heading on the board, 'Gas volumes in balanced equations'. He says "I said if we react certain gases at certain temperature, we can be able to write volumes using the balanced chemical equation." He writes the unbalanced equation for hydrogen and oxygen reacting, talking through the reaction as he does so. *Two learners walk in while he is writing*. He says "at temperatures above the boiling point, you'll get water molecules as a vapour" He then balances the equation, saying "If you balance the equation, you will be able to work out the volumes which has actually reacted, using the number of molecules." He refers to something which happened yesterday, mostly in Zulu. *Another two learners walk in.* The teacher addresses one of the learners and asks him a question "You've [been out of / belong to] the classroom?" He asks who the class rep is, and there is some discussion – it seems there isn't one. *One of the learners who came in goes out, and another five walk in.* Learners walk past the classroom noisily. *Another one leaves.* The teacher says, "We said we can use the molecules to work out the amount of the gases that has actually reacted and the amount of the gases that has actually formed."

In this short extract there are five instances where learners enter or leave.

There are a number of constraints identifiable in Mr Hlope's context: constraints of school management, of school logistics, of resources, of collegiality, of technology and of time – less teaching time for one class and teaching time eroded by the lack of water on one day as well as by learner late-coming and interruptions. Mr Hlope was well aware of these constraints and remarked "things are actually not that well. Because if you look at the number of classes, you look at the resources that we work with as educators. They tend to limit you as an educator."

In this section I have focused on the constraints experienced by one teacher. To what extent are these constraints experienced more broadly? Mr Dube taught in a township school similar to Mr Hlope's school. With regard to the limitations of space and resources, Mr Dube had to wait for someone to unlock a security gate so that he could fetch a duster and chalk from his office, in order to start the day's lessons in a classroom which was not his own (section 3.6). With regard to the limitations of collegiality, he experienced professional jealousy such that mathematics classes were taken away from him (section 6.2.5). With regard to limitations of time or 'time leakage' (Clark & Linder, 2006), Mr Dube also dealt with late learners and multiple interruptions. I admired both Mr Hlope and Mr Dube's ability to maintain their train of thought through such interruptions, thus minimising the effect of the interruptions. Related to this, at the third township school in my study, Mr Baloyi's principal concluded from my lesson narratives that interruptions to Mr Baloyi's lessons were too frequent and so took steps to reduce the number of interruptions across the whole school (see section 3.4.1). Mr Hlope's constraints of school management, of school logistics, of resources, of collegiality, of technology and of time echo in Clark and Linder's (2006) account of a township teacher.

8.4.3 Negotiating Possibilities

How does Mr Hlope negotiate the constraints of this context? Clark and Linder (2006) in their rich description of a teacher working in a South African school refer to "sustaining possibilities" which help teachers cope with the "constraining tendencies inherent in teaching contexts" (Clark & Linder, 2006, p. 171). A 'sustaining possibility' (Clark & Linder, 2006) for Mr Hlope was the freedom he had to make professional choices about what he did in his lessons. Mr Hlope's narratives did not position the practices of his fellow teachers as a constraint: he never mentioned any pressure to conform to school norms, nor did he compare himself with his fellow teachers. Another sustaining possibility has been in-service training, in particular Radmaste[28] workshops and resources have given him practical ways of doing practical work within the constraint of not having his own classroom, and so added considerably to his PCK.

Teachers' identities facilitate their agency in negotiating the constraints of their contexts (section 6.4.2). Mr Hlope authored his identity as a well-trained township teacher. He deliberately chose to teach in a township school, noting that "with the training that I've got, if you check, I could easily have landed a good job somewhere there in those [multicultural] schools." Like other teachers in this study, he deliberately chose to teach where he saw the need as greater, so as to offer learners the same kind of opportunity which education afforded him (section 6.3.4). However his choice only made sense if he did a good job in that context, so the fact that he chose this aspect of his identity facilitated his agency in his context. Mr Hlope saw himself as well-equipped to do a good job in his context: he saw himself as well trained.

Thus his identity facilitated his agency in finding his way around the constraints of his context. For example the constraint of not having his own classroom should be a reason

[28] Radmaste Centre at the University of the Witwatersrand produces teaching resources and runs workshops for teachers. The electricity kits and stencils which Mr Hlope used came from Radmaste.

for not doing any practical work, and yet Mr Hlope skilfully negotiated the logistic constraints so as to make practical work happen in his context. His identity of being a ‘well trained teacher’ also meant he had confidence in his good conceptual understanding of science (section 6.3.4). Overall both the township and well-trained aspects of his identity facilitated his agency in his context. Although he experienced the constraints of his context, he also appreciated the critical difference he was choosing to make in that context.

Is Mr Hlope’s situation sustainable? He comments “I’m always very tired. You end the day here very, very tired, given the number of lessons. And it tends to weaken you as an individual. But you need to fight through.” In section 2.2.5 I mentioned Morrow’s (2007) concern with teacher burnout, and his experience as a beginning teacher of trying to apply the teaching model which he had learnt in his education diploma. Only in retrospect did he realise that such an ideal was unsuited to large class contexts. Likewise Mr Hlope holds to a lesson planning ideal from his training which is not reasonable in his context:

> Lesson planning needs to be sitting down, write lot of stuff about what they are going to do, and then filter all that information that you think it’s necessary that particular sort of a lesson, put them in order, within a time frame.

My concern for Mr Hlope is that he is at risk of burnout.

My description of Mr Hlope illustrates how personal history, context and practice come together in one person. Despite the considerable constraints of his context, Mr Hlope’s freedom to teach as he chooses, in-service training, identity, strong subject matter knowledge and PCK facilitate his agency in occasioning lessons with strong content objects where learners are engaged. Having summarised and synthesised my results, I am now in a position to consider how these results talk back to the field in which they are located.

Chapter 9: Conclusion

I invested ten years of my life in teacher education because I wanted to make a difference to science education in South Africa. I started this research project wanting to find out something about the effect (if any!) of my efforts. I wanted to know what happened in the classrooms of past students, how these teachers saw themselves and their practice, and what they saw as having formed their practice. However I recognised from the outset that education is a complex system, and so individual take-up of the 'inputs' in education depends on an individual's biological make-up and personal history. It follows that there cannot be some well-defined notion of 'best practice' for science teaching or for teacher education. Instead there is appropriate practice by particular people in particular contexts.

My research results presented in the preceding chapters are a window on how the Wits School of Education teacher education programmes in the past have played out. This has involved looking back at what has gone before this study. I now turn to face in the other direction and consider what the teachers' narratives have to say to the future of education in South Africa – the implications of the results for practice. The purpose of this final chapter is to consider how the results of my research speak back to initial teacher education and to education more broadly. I describe the contribution which I see my study making to knowledge in the field of education, and allow the results to speak back to the specific context out of which they come, i.e. the Wits School of Education.

9.1 Contribution to Knowledge

This study contributes to three bodies of knowledge: conceptions of teaching, teacher identity, and teacher practice in South African classrooms. The four conceptions of teaching which surfaced in this study have resonances with other phenomenographic studies into conceptions of teaching, but the conceptions in this study include a dimension of science knowledge as problematic or not (section 7.3.1). The particular discourse-identities identified in this study give insight into what teachers see as significant in the ways they do their work. This study shows the rich repertoire which some South African teachers work with, including a 'conversation' mode of engagement (section 4.2.2), where teachers relinquish their power and allow learners to ask questions and influence the direction of lessons. In addition I see this study as making a particular contribution to knowledge in four areas: the first is an understanding of the contributions which learners make to the content of a lesson, the second is in regard to initial teacher education, the third is in regard to teacher recruitment and mentoring in South Africa, and the last is to an understanding of what works as good teaching.

9.1.1 Learner Contributions

I think the most generative understanding to come out of this research project is a deeper view of the ways in which learners contribute to the quality of lessons (section 5.5.2). Traditionally the teacher is understood as being responsible for the quality of the subject matter content of a lesson but my analysis of the quality of lesson content reveals how learners contribute both positively and negatively with their answers, their questions and their silences. Over time their contributions influence the ways in which their teachers teach them. The results also show that the 'conversation' mode of engagement is useful for promoting learner contributions as this was the mode of engagement in which a lot of productive learner contributions were made. In addition, the results show a teacher needs to engage with learner contributions for the value of such contributions to be fully realised. Where learners' contributions reveal underlying alternative conceptions, the value of such contributions is only realised if the teacher addresses the alternative conceptions.

What are the implications of this finding for practice? Firstly, this does not mean that teachers can abdicate their responsibility for being the expert in the classroom: on the contrary a teacher with confidence in her own content knowledge can respond well to good questions from learners, and cope with having her errors pointed out. However if teachers saw learners as resources in this way, they might want to harness learner input by actively encouraging learners to contribute to the quality of lessons. Learners also need to understand their potential to contribute meaningfully to lesson content. This implies renegotiation of the didactic contract so that learners see their role differently. Such a didactic contract requires that learners know that their contributions are safe, encouraged and valued. Underlying such a didactic contract is a view that physics and chemistry are comprehendible, and so the didactic contract also needs to have the goal of conceptual understanding of physical science.

One could argue that certain cultural and school contexts militate against learners contributing, particularly in township and rural schools where learners are expected to show respect by their silence (sections 2.2.5 and 5.5.2). However the results of this study show that it is possible for teachers in township schools in South Africa to have didactic contracts with their learners whereby learners point out teachers' mistakes without issue, and where learners ask thoughtful questions. Mr Hlope's learners corrected his mistakes without this being an issue for either the learner or the teacher – even in the situation of being observed by his former lecturer. Mr Baloyi negotiated a contract where learners were comfortable arguing with each other. Mr Dube provided a space at the end of every lesson for learners to ask questions, and the quality of the questions asked was impressive.

Positioning learners as able to contribute to the quality of the content of lessons increases their agency. Mr Baloyi, Ms Emeni, Mr Dube and Mr Hlope's stories of their own agency as learners (section 6.4.3) prompt the question of what might be possible if learners in disadvantaged schools realised their own agency. Teachers in this study demonstrated ways of encouraging learner agency apart from valuing learner contributions: Mr Baloyi positions his township learners with agency by encouraging them to take ownership of their learning (section 6.3.2). Mr Dube encourages his learners to use their time at school productively regardless of what their teachers do (section 6.3.5). Ms Gray is open to her learners' agency in problem solving (section 6.3.7). In summary, a didactic contract which values learners' contributions is part of a bigger picture of encouraging learner agency.

9.1.2 Initial Teacher Education

The results of this study speak with hope to the despondency of some experts about the effect which an initial teacher education programme can have (section 2.4.1). The teachers' narratives indicate that an initial teacher education programme can have a major influence on teachers, particularly teachers who know their own school experiences of science teaching to be deficient. For three of the teachers in this study, their teacher education programme was a defining experience, core to their current identities as teachers. In addition this study has shown that small inputs in teacher education may lever up large but unpredictable 'butterfly' effects (sections 6.3.1 and 6.3.5). Overall the teachers' narratives revealed that the ways in which the university experience operated in the lives of the teachers are strikingly different (section 6.4).

This results of this study also suggest particular inputs in initial teacher education which are likely to lever up ‘sustaining possibilities’ (Clark & Linder, 2006) for future teachers. The first of these is the modelling of various kinds of good teaching, particularly in the South African context where many teachers lack appropriate secondary science teacher models to draw on, and so draw on their university science teachers. Such modelling extends student teachers’ ‘imagination of the possible’ (Slonimsky, 2007). The teachers in this study drew far more on *how* they were taught science (and mathematics) rather than *what* they were taught about teaching methodology or educational theory. Even the teachers in this study who derived their identities from their own secondary schooling benefitted from modelling which was consistent with their identities. This hints at the value of science content being taught in specialised courses for teachers – where good practice can be explicitly modelled – rather than in B Sc courses. However a teacher education programme which takes identity development as central needs to be flexible in regard to what counts as good teaching (sections 2.5), and so rather than prescribing a certain ‘kind of teacher’, teacher educators should model a diversity of effective practices from which student teachers can select to recruit into their own practice. At the same time teacher educators need to recognise that teacher training is not the only experience these teachers draw on, and there needs to be explicit recognition of other influences rather than an assumption that teachers will teach as they are taught in a teaching degree.

A second input to teacher education suggested by the results of this study is that student teachers should be made aware of the potential for learners to contribute to the quality of the content of lessons. However, student teachers may well not be in a position to recruit this into their practice initially: student teachers’ greatest initial concern is with classroom management (section 2.4.3). They want to keep learners quiet, not invite their critique. In addition, beginning teachers fear being asked a question they cannot answer. Thus a didactic contract which values learners’ contributions may not be feasible in the early stages of learning to teach, but I would argue that it is appropriate to Maynard and Furlong’s (1995) ‘reaching a plateau’ stage (section 2.4.3), which in my experience student teachers in the B Ed often reach in their third year. But even if they do not reach this stage, student teachers should be aware that in due course their practice will be considerably enriched if they are able to capitalise on learners’ contributions. Such practice can be modelled in teacher education: lecturers should make students aware of the importance of their contribution to the quality of the content of lectures, and cultivate the asking of good questions.

The results of this study concur with the view that investing in teacher SMK is an important input in initial teacher education (section 2.5) because of the contribution which the teacher makes to the content objects of the lessons she teaches. Mr Dube was the one teacher in the sample who only did three years of university science, and the quality of his lessons was regularly compromised by weaknesses in subject matter content (see Table 24) even though the form of the activities was good and he had an excellent rapport with his classes. Since conceptions of teaching which see subject matter content as problematic appear to be more powerful (section 8.3), it would probably be helpful for student teachers to understand that within the physical sciences there is troublesome knowledge with threshold concepts (section 7.3.2). However, in order to benefit from SMK input, this study suggests that student teachers need to see the relationship between secondary and tertiary subject matter in their disciplines, so that they do not make Ms Emeni's mistake of only aiming to pass (section 6.3.1). They need to realise that tertiary level content addresses the same discipline as they will teach, and hence should inform and deepen their understanding of the secondary level content. This means they need to see their courses in terms of knowledge value rather than in terms of certification value.

9.1.3 Teacher Recruitment and Mentoring

The results of this study also speak with hope to the recruitment of teachers. Ms Emeni, Mr Baloyi and Ms Fikela's stories imply that despite challenging working conditions and negative press about teachers in South African, there are still young people who want to become teachers, and who become teachers who are passionate about what they do. Amazingly, sometimes negative experiences of school provide motivation to become teachers.

However prospective teachers need help to get there. Bursaries are key – all but one of the teachers in this study were enabled to become teachers because of bursaries which paid for their studies. Even those in the sample who had not planned to become teachers ended up becoming committed teachers because of the bursary. However simply providing bursaries is not enough: they also need to be marketed. Mr Hlope, who had never planned to be a teacher, took up a teaching bursary because he saw a newspaper advertisement. Ms Fikela, who always wanted to be a teacher, did not immediately enter teaching because such marketing did not reach her. For all the teachers except Ms Gray, the subject they teach was less of a draw card than the desire to teach or the availability of bursaries.

The challenges of coping with teaching in township schools highlighted by this study suggest that a mentoring programme for beginning teachers in such schools would be worthwhile. In particular the results of this study suggest that young teachers would benefit from being supported in the challenge of being perceived as a threat because of their education (sections 6.2.5 and 6.2.8). This is pertinent given that the narratives of the teachers in this study reflect that a single good teacher can have an effect which far outweighs that of many mediocre or poor teachers, and allow school to function as an escape in one way or another from the harsh realities of poverty (section 6.4.3). Thus young teachers who have a vision of making a difference should be supported in this vision.

9.1.4 Good Teaching

Although I have argued that what counts as good science teaching is contested and context dependant (section 2.2.5), this study contributes to an understanding of what works as good teaching. The results show that the subject matter content of a lesson is key to the overall success of a lesson, and that conceptions of teaching which recognise that subject matter knowledge can be problematic may be more powerful (section 8.3). Both accurate and appropriate content *and* good transformation of that content are necessary for meaningful lessons, thus the best lessons were those where good transformation of mostly accurate content took place (section 5.8). Interactive modes of engagement do not on their own guarantee good quality lessons (section 5.8), and excessive use of a conversation mode may in fact detract from lesson quality (section 8.3). However interactive modes, in particular conversations, have value in facilitating learner contributions to the quality of lesson content (section 5.5.2). The implication of these findings is that both lesson content and interactive modes of engagement which facilitate learner contributions should be given attention in research and in initial teacher education.

9.2 Contribution to Methodology

I see this study as making two contributions to research methodology, specifically classroom observation. The first is in regard to the validity of classroom observation. Classroom observation is not an unproblematic measure of normal classroom activity because of site reactivity (section 3.7.1). The results of this study show that the effect of an observer on classroom action is not constant, either on a teacher or her learners (section 4.1), and can be exacerbated when the observer is perceived as very different, as in the case of a white visitor in a township school. This study also shows that an observer can have a negative effect on communication in multilingual classrooms (section 4.1.1). The measures I took to reduce reactivity paid off: my efforts to position myself with low power in the classroom and to put learners and the teacher at ease had some effect, as did my requests to teachers and learners to behave as they normally would (section 3.7.2). My method of asking the teacher about the reactivity afterwards worked well: teachers were able to articulate easily their increased nervousness and metacognition, and some changes in learner behaviour. In summary, the results of this study show the value of measures to both reduce classroom reactivity and account for it.

The second contribution of this project to research methodology is a tool for analysing the quality of the subject matter content of lessons. The tool involves first identifying the content object of a lesson, and then assessing its accuracy, appropriateness and transformation according to a rubric (section 5.6). This tool gives an overall judgement of the quality of the content of a lesson, and allows a researcher to make her assessment of the quality of the content of a lesson explicit with evidence. It is also a means of comparing the quality of lessons with different contents, though of course some content is more difficult. Although I developed this in the context of science, the tool may be generalisable to any content. This approach addresses education research's blind spot for lesson content (section 2.2.6) which tends to conflate lesson content with teacher SMK, or completely miss lesson content by taking it for granted at secondary level, or respond to curriculum innovations which tend to be about form rather than content (section 2.2.6). I see a focus on lesson content as crucial in the shift that I see happening from concern with the form of lessons to a realisation that what counts as 'good' depends on the individual teacher and her context (section 2.2.5).

9.3 Talking Back to the B Ed

I have spoken about what I see as the contribution of this study to knowledge. I now narrow my focus to allow the study to speak back into the context out of which it came, i.e. the Wits School of Education. This study has explored teachers' professional identities, i.e. the 'kinds of teachers' they see themselves as. As mentioned (section 1.4.2), since 2007 the Wits School of Education has had a clear idea of the kind of teacher they would like to produce, expressed in a document entitled *A Vision for a B.Ed Graduate: what kind of teachers for South Africa do we want to produce at Wits?* (Appendix A). Rather than identify weaknesses in the Wits School of Education, I want to let my research speak to its ideals, and so will use this *Vision* to frame this section. I note here that this *Vision* was not in place when most of the teachers in this study were at university, so it is not fair to ask whether this vision was achieved for the teachers in this study, although it has been achieved to some extent with all the teachers. Moreover the *Vision* explicitly acknowledges that it is a vision of an ideal teacher – one which teachers will probably not achieve in their first couple of years of teaching. Nonetheless it is the *Vision* of the present B Ed, and so I feel it is important to relate the results of my research to this *Vision*. I note however that the *Vision* is neither specific to science education or to secondary education.

The *Vision* lists nine characteristics of the ideal teacher, each of which is fleshed out in more detail (see Appendix A):

1. Teachers who engage in principled and reflective practice
2. Teachers with a high level of subject competence
3. Teachers who can interpret curriculum policy and official curricula and understand their relevance for her [sic] particular teaching context
4. Teachers who can transform their own subject competence and curriculum knowledge into conceptual learning experiences
5. Teachers who understand the history and contexts of the communities in which they work
6. Teachers who can work as a member of a department and school and provide leadership
7. Professional teachers
8. Teachers who act as agents for change in classrooms, schools and communities
9. Teachers who remain passionate and committed throughout their careers.

I will consider in particular how my research addresses characteristics 2, 4 and 8, and the way in which the Vision regards learners.

9.3.1 Is a Vision Appropriate?

Is it appropriate to have a vision? I have that teacher education programmes are likely to be most effective if they help students develop their identities as teachers, with flexibility as to what counts as good teaching (section 2.5). However, while the *Vision* recognises learners' identities, it does not mention teachers' identities. Instead it seeks to impose a discourse-identity, prescribing in its title the 'kind of teachers' that should be 'produced'.

Most of the teachers in this study identified themselves strongly in terms of the kinds of teachers they are, and the majority drew their identities from their secondary school experiences. This suggests that a single vision may be counterproductive: rather than trying to produce particular kinds of teachers as the B Ed *Vision* suggests, the B Ed programme should work with student teachers' emerging professional identities (see section 2.5 for ways to do this), and broaden their repertoires for being the kinds of teachers they want to be, so that they are able to work flexibly and effectively in widely ranging contexts.

However, despite what its title communicates, the *Vision* is in fact sufficiently broad to allow different identities to operate within its playing field, although it does not explicitly recognise this breadth. I will illustrate this by looking at how the identities of the teachers in this study align with the *Vision*. Ms Emeni and Ms Cole's teacher identities align with the fourth characteristic: Ms Emeni identified herself as a teacher who uses apparatus to elucidate content, and Ms Cole identified herself as a teacher who makes concepts visual. Ms Fikela's identity as a passionate teacher aligns with the last characteristic.

Aspects of the other teacher's identities align with some of the details of the *Vision*'s characteristics (given in Appendix A). Mr Dube's identity as an empathetic teacher and Mr Baloyi's desire to have a safe classroom resonate with the *Vision*'s desire to have teachers who "empathise with learners and parents, emotionally and intellectually" and "understand a range of social issues that may confront learners and their families" (characteristic 5) and manage "classrooms as disciplined, creative and safe spaces for learning" (characteristic 4). Three teachers identified themselves in terms of the kinds of learners they want: learners who have ownership of their learning (Mr Baloyi), learners who work hard (Mr Dube), and learners who think for themselves (Ms Gray). These ideas have some resonance with the *Vision*'s hope for "teachers who understand how different pedagogies produce different kinds of learners and citizens" (characteristic 3), though without the critical view implicit in the *Vision*. The *Vision* hopes for teachers who inspire "passion and commitment in learners" (characteristic 8) which resonates with Mr Dube's desire to have learners who work hard. The *Vision* wants teachers who instil "a sense of hope and possibility in learners" (characteristic 8) which resonates with Mr Hlope's desire to bring 'light' by being a well-trained township teacher, and with the 'escape' offered by

Mr Baloyi's safe classroom. However Ms Gray's identity as an open teacher who allows learners to use different approaches does not find a particular resonance with the *Vision*.

In summary, the identities of the teacher in this study, though diverse, are not at odds with the *Vision.* Thus while the Vision does not acknowledge teachers' identities, it is sufficiently broad to accommodate the teacher identities which emerged in this study. Furthermore, experts agree that one of the criteria for effective teacher education programmes is overall programme coherence (section 2.5) and the *Vision* document has certainly contributed to programme coherence in the Wits School of Education B Ed. Thus I conclude that it is appropriate to have a vision, though the *Vision* would be richer if it recognised teachers' diverse discourse-identities.

9.3.2 Subject Matter Knowledge and Transformation

The second characteristic of the *Vision* addresses teachers' subject matter knowledge. The results of this study demonstrate that the quality of the content object of a lesson is central to the overall quality of the lesson since the teacher's contribution to the content object draws on her subject matter knowledge (Chapter 5). Thus the results of this study support the emphasis which the *Vision* places on teachers' subject matter knowledge.

The fourth characteristic of the *Vision* talks about the transformation of subject competence into "learning experiences." This point rightly makes a distinction between a teacher's subject competence and the subject matter content of her lessons (section 5.1). In the current Wits School of Education B Ed, student teachers are taught to plan a lesson by first identifying the subject matter content of the lesson, and then considering how best to transform that content using suitable teaching strategies. They have a lesson planning pro forma which reflects these two aspects, similar to the content object form of Chapter 5, and they are expected to refer to their lesson plans while teaching on teaching practicums. However this may in fact undermine student teachers in the eyes of their learners, or at least in their own eyes, taking into account Mr Dube's perspective that his learners would see him as not having the necessary SMK if he referred to notes while teaching (section 5.7.1). In contrast Ms Emeni was proud that she referred to her notebook while teaching (section 6.3.1). Thus the results of this study suggest that it might help student teachers in the Wits School of Education if the relationship between SMK and lesson plans is unpacked.

9.3.3 Role of Learners

The results of this research show that learners can contribute significantly to the quality of the subject matter content of a lesson. But the *Vision* has a limited view of the role which learners do and can potentially play in the classroom. The *Vision*'s references to learners are mostly about how teachers should respect and empathise with learners, and understand "a range of social issues that may confront learners and their families." The *Vision*'s only acknowledgement of the contribution of learners is that teachers should "acknowledge the resources and knowledge that learners bring to the classroom." But this suggests a constructivist approach where teachers work with learners' preconceptions, rather than a view that learners actively contribute to the quality of the content of a lesson, even without bringing knowledge to the classroom. Overall the *Vision* lacks a view of learner agency in the classroom, whereas this study suggests that identifying learners as able to contribute to the quality of the content of lessons increases their agency, which is part of a bigger picture of encouraging learner agency (section 9.1.1).

However the *Vision* recognises the identities which learners bring into the classroom, requiring that teachers "respect learners and their identities" and "bring learner and community identities into contact with academic knowledge" (characteristic 5). The *Vision* also notes that "different pedagogies produce different kinds of learners", which implies learner identities are a result of pedagogy. Like teachers, learners draw on the resources available to them in authoring their identities (section 1.2.1). The view teachers have of learners impacts how they position learners in the classroom, and hence the identities which they make available to them in the classroom. For example Ms Fikela positioned her learners as scientists, thus making the identity of scientists available to them (section 7.2.3). Putting this logic together with the results from this study suggests that encouraging learner contributions avails learners with the identity of someone who contributes to the quality of lesson, an identity which facilitates both learner agency and lesson quality.

9.3.4 Agents of Change

The last characteristic of the *Vision* aims for teachers who are agents of change. In the South African context, Morrow (2007) cautions against such an aim:

> we need to avoid being overambitious about what can be accomplished through pre-service training. We need to avoid the illusion that we will be able to bring

> about a revolution in the practices of teaching by sending youthful missionaries into the schools. (p. 35).

Similarly Braund and Campbell (2010) conclude after researching first year British teachers' implementation of innovative practices from their PGCE that "relying on new entrants to teaching and their abilities to proselytise and therefore act as 'change agents' might be overly optimistic" (p. 219). Is it overambitious to aim to hope that young teachers will be agents of change? The results of this study suggest not: half the teachers in this study have been acting as agents of change in their schools, by initiating significant interventions in their schools which affected more than just the teachers' own classrooms (section 6.4.2).

Being an agent of change can also be about being a good teacher in one's own classroom. Despite the fact that the schools they attended were far from ideal, the four teachers who saw school as an escape identified particular teachers who made a critical difference to their own experience of school (section 6.4.3). Some of them now function as such a teacher for their learners. The results of this study suggest that a single good teacher can have an effect which far outweighs that of many mediocre or poor teachers, thus providing significant 'light' for learners in under-resourced schools.

The *Vision*'s 'agents of change' aim includes "working towards social justice." Certainly the teachers in this study who deliberately choose to work in township and intervention schools rather than middle class schools do so because they want to make a difference – their agenda is one of transformation and hence social justice. Most of them see school as offering an escape for learners in some way. Does the *Vision* take into account the challenges that come with such contexts? The *Vision*'s introduction notes:

> We also recognise that many of our students will teach in under-resourced schools and in schools with a myriad of social issues. While such constraints may inhibit some aspects of the ideal, part of our vision is for our graduates to be able to deal with these constraints.

Characteristic 4 of the *Vision* has teachers who create "conceptual learning experiences" by "working flexibly and improvising with available resources in both resourced and under-resourced contexts." So the *Vision* does recognise the challenges.

However, does the *Vision* translate well into practice – does the B Ed succeed in preparing teachers for such contexts? I think it is easy for the vision of teacher educators to become myopic: to see what students teachers lack when they do their teaching practicums and so prepare them accordingly, thus preparing them to teach in reasonably well-run schools where senior teachers make the big decisions. This may result in the belief held by Mr Hlope, after four years of teaching, that every lesson should have a lesson plan written out, a goal which is not reasonable in his situation (section 8.4.3). Overall the results of this study suggest that the Wits School of Education would do well to explore what it means for young teachers to be agents of change and make a difference, without being at risk of burning out.

9.4 Directions for Further Research

I brought four different lenses to my data, and these proved to be productive lenses. However there is always more analysis which can be done with any body of data. I would like to look more closely at the contributions which learners made to the subject matter content of lessons, and explore what conditions afforded learners the opportunity to make such contributions. I would also like to identify the content objects of 'repeat' lessons, i.e. the lessons which are intended to cover the same content, taught by the same teacher to different classes. It would be interesting to compare the content objects of the two (or in some cases three) lessons, and in particular look at the extent to which learner contributions shape the content objects differently across the two or three lessons.

These are questions not only for my research but also for other researchers in other subjects. I would like to know how well my approach to analysing the subject matter content of lessons by identifying and analysing the content object works in other subjects. Comparison of content objects across multiple lessons on the same topic would also be worthwhile, for example where a teacher teaches five grade nine classes, or where different teachers teach the same topic. Another worthwhile project would be to research the effect of explicitly making learners aware of their potential for contributing to the quality of the subject matter content of lessons, i.e. explicitly changing the didactic contract.

In section 9.1.2, I made two suggestions which are inferences from the results of my research: that student teachers should be made aware of the potential for learners to contribute to the quality of the content of lessons, and that mentoring of beginning teachers in township schools could be valuable. However both of these suggestions are unresearched. For example I do not know whether student teachers are able to embrace learner contributions. Thus both of these suggestions would need to be piloted in research settings to ascertain their practicalities and merits.

9.5 Final Word

In the introduction to this thesis, I noted South African calls to “track the careers of some of the newly trained teachers” (Hindle, 2003, p. 334) and for “deeper explorations of teachers and teaching, more closely linked to the contexts in which teachers work and why they do what they do” (Malcolm & Alant, 2004, p. 77), echoed in international calls for research which “captures the experiences and development of the new science teacher” (Luft, 2007, p. 536). This research project is one response to those calls. In addition I have satisfied my own curiosity about what happens in the classrooms my past students after graduation, and how they see themselves and their work. Though the journey of a thesis is arduous, it was a delight and a privilege to have walked this journey though teachers’ classrooms. Their stories speak with hope into the realities of the South African education system.

Appendix A: University of the Witwatersrand B Ed Vision

A VISION FOR A B.ED GRADUATE
WHAT KIND OF TEACHERS FOR SOUTH AFRICA DO WE WANT TO PRODUCE AT WITS?

Foreword

The following represents an image of ideal teachers, one which we hope many of our students will grow into during their initial years of teaching. We recognise that on graduation, many students will need to survive their first one or two years in the classroom and will focus on some dimensions below at the expense of others. However, we should lay the basis so that teachers who are able to, do develop the full range of teaching competence outlined below. We also recognise that many of our students will teach in under-resourced schools and in schools with a myriad of social issues. While such constraints may inhibit some aspects of the ideal, part of our vision is for our graduates to be able to deal with these constraints.

1. Teachers who engage in principled and reflective practice through
    - understanding the relationship between theory, research and classroom practices
    - being highly literate, able to decode, interpret, critique and transform different kinds of semiotic texts
    - having the requisite survival skills, skills, values and depth of knowledge required for teaching

2. Teachers with a high level of subject competence who
    - identify intellectually with a discipline(s) and/or learning area(s) in a particular phase(s) of schooling
    - understand and identify with the intellectual practices of their discipline and/or learning areas and can induct learners into these practices

3. Teachers who can interpret curriculum policy and official curricula and understand their relevance for her particular teaching context
    - teachers who understand principles of curriculum, learning, pedagogy and assessment as fundamental to their practice
    - teachers who understand how different pedagogies produce different kinds of learners and citizens

4. Teachers who can transform their own subject competence and curriculum knowledge into conceptual learning experiences through
    - purposeful, coherent planning
    - appropriate probing of learner thinking
    - developing and modifying teaching materials
    - working flexibly and improvising with available resources in both resourced and under-resourced contexts
    - managing classrooms as disciplined, creative and safe spaces for learning
    - managing their own time efficiently

5. Teachers who understand the history and contexts of the communities in which they work and

- respect learners and their identities
- acknowledge the resources and knowledge that learners bring to the classroom
- bring learner and community identities into contact with academic knowledge
- understand a range of social issues that may confront learners and their families, and can refer and/or deal with these appropriately
- empathise with learners and parents, emotionally and intellectually
- use a range of languages, language practices and modes of communication flexibly to do the above

6. Teachers who can work as a member of a department and school and provide leadership through

- participating and taking responsibility in aspects of the school e.g. curriculum planning, school organisation and extra-curricular activities
- sharing knowledge e.g. about new curriculum, practices etc. gained in pre-service study
- remaining respectful of the experience of senior colleagues
- working within the constraints of the department and school while striving to forge space to implement their own ideas where possible

7. Professional teachers who

- understand that professional practice is informed by a knowledge base and know what this knowledge base is
- are accountable to learners, parents and colleagues through reasoned, principled explanation of their practice
- maintain professional conduct at all times
- understand the need for continuous professional development and can plan for such development in ways that will enhance their own intellectual development and practices
- understand the role of research in improving teaching
- become active in professional bodies and/or subject associations, where these exist

8. Teachers who act as agents for change classrooms, schools and communities through

- understanding that educating is as much a moral as an intellectual practice
- consistently maintaining practices that are consistent with a democratic, human rights culture
- challenging unethical practice
- respecting diversity while maintaining and working towards social justice
- encouraging environmental awareness and sustainability
- inspiring passion and commitment in learners
- instilling a sense of hope and possibility in learners

9. Teachers who remain passionate and committed throughout their careers.

Appendix B: Ethics Clearance: University of the Witwatersrand

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel: +27 11 717-3007 • Fax: +27 11 717-3009 • E-mail: enquiries@educ.wits.ac.za • Website: www.wits.ac.za

Protocol:2009ECE60

25 August 2009

Ms. Dale Taylor
M243
WSoE

Dear Ms. Taylor

Application for Ethics Clearance: Doctor of Philosophy

I have a pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has agreed to approve your application for ethics clearance submitted for your proposal entitled:

Early Career Teachers' Conceptions and Enactment of Science Teaching

Recommendation:

Ethics clearance is granted

Yours sincerely

Matsie Mabeta
Wits School of Education

Cc Supervisor: Dr. T Lelliott & Prof. S Booth (via email)

Appendix C: Learner Information Letter and Consent Form

Dear Learner,

I am a researcher at the University of the Witwatersrand. I am interested in what happens in science classrooms. Your science teacher has agreed to help me with my research. This means that I will be sitting in his/her classroom for two or more school days and interviewing her/him.

The results of my research will be presented in my thesis, at conferences, and in academic journals. But I will not use the names of the school, teacher or learners.

I will video some lessons. Portions of the videotapes may be transcribed (written down). There is a small possibility that I may use a short video clip to help me present the results of this research to researchers, teachers or student teachers. The teacher, learners or school uniforms in a video clip could be recognized by people who know them. I will check carefully that such a video clip does not in any way compromise the dignity of your teacher or any learners. I will show the video clip to your teacher and use it only if I have his/her permission *and* your principal's permission.

You can help me with my research by giving your consent (permission) to have me present in one or two of your science lessons, videoing the lesson. You will not be excluded from lessons if you do not give your consent (Instead I will not observe lessons in which you are present). Participation in this research is entirely voluntary. If you are willing to help me with my research then please complete the attached form.

Dale Taylor

Marang Centre for Maths and Science Education
Wits School of Education
University of the Witwatersrand

University of the Witwatersrand
Wits School of Education

Informed Consent Form
Research Topic: Becoming a Teacher: Narratives and Conceptions

I, ______________________________ *(write your name)*, agree to the videotaping of one or more of my science lessons by Dale Taylor of the University of Witwatersrand for her research.

I understand that portions of the video may be transcribed (written down).

I understand that the researcher may wish to use a video clip as part of presentations on this research to researchers, teachers or student teachers. I understand that my teacher, school uniform and/or the learners in a video clip could be recognized. I give consent for the video clip to be used for research and teaching only.

I understand that I will not be excluded from lessons if I do not give my consent. I am not forced to participate and I understand that I may withdraw from the study at any time.

Signature: ______________________

Date: ______________________

Appendix D: Teacher Information Letter

Dear

Thank you for being willing to assist me with my doctoral study entitled ‘Becoming a science teacher: conceptions and narratives’. I hope that my research will help to improve the preparation of future science teachers.

Participation will involve allowing me into your classroom for two school days, which would include conversations with you about the lessons and this question: Please will you tell me the story of what has made you the unique science teacher you are today. You can give this question some thought beforehand. The other questions will relate to the lessons I observe. I will audio record these conversations, and transcribe them.

Classroom observation

In observing your lessons, I will not ‘crit’ you – this is different from Teaching Experience! Different people have different ideas about science teaching. I would like to see ordinary days, with all their messiness – I am not expecting a special show. I do not want to intrude on any lesson where the content of the lesson may be sensitive or in any other way unsuitable for the presence of an observer, e.g. human reproduction.

Having an observer has an effect on the learners. But it will help if they do not think I am too important. So please don’t say to them ‘my lecturer is coming’, rather you can say there will be a ‘researcher’ joining them, or better still say nothing at all – I will explain when I get there.

I will take field notes during the lessons and will also videotape the lessons to allow me to revisit the lessons afterwards. However, for the most part, the videos will not be transcribed.

Permission

I have obtained the permission of the Gauteng Department of Education and the Human Research Ethics Committee of the Wits School of Education to do this research. If you are willing to participate I will also obtain your principal’s permission. At the beginning of each lesson, I will explain to each class what I am doing and ask them if they are willing to participate in this study (by allowing me to sit in their lesson) and I will withdraw from the lesson if any learners are not willing.

Participation in this study is entirely voluntary, and no harm is envisaged. If you choose to participate, you may choose to accept or decline to answer any questions, and you may withdraw from the study at any time. You may also freely choose after the study to decline video segments being used as described above.

Research results
My research results will be presented in my doctoral thesis. Part or all the results of this study may be presented at conferences and/or published in academic journals. I will provide you with a summary of my research results on completion if you would like me to.

In order to maintain anonymity and confidentiality, all names I use will be pseudonyms. Transcripts of the interviews and lessons will not contain the participants' names and participants will be allocated pseudonyms for the analysis, thereby ensuring anonymity of you and your learners. The audiotapes will be destroyed after they have been transcribed.

There is a small possibility that I may want to use a segment of the video in presenting the results of this research in a seminar, conference, or lesson to student teachers. Such a segment will be carefully vetted to ensure that it does not in any way compromise the dignity of you or your learners. Also, I will show you the segment and I will ask for your written consent to use it. Consequently, I will use the segment only if I have you and your principal's written consent to do so. The teacher and learners in such a video segment could be recognizable to people who know them. The same applies to the learners' uniforms which means that the school could be identifiable. This means that, although the school and video subjects will not be explicitly identified to the audience, confidentiality cannot be guaranteed if such a video segment is used. Thus you may freely refuse to allow all or any segments to be used. Your choice in this regard will not affect your participation in the research or the results of the research, but only the way in which the results are presented orally.

Next steps
If you are willing to participate, please could you:

- Tell me what would be suitable dates (preferably a day when you see a variety of different grades, but also have at least one free period), or else send me your timetable (email / fax).
- Talk to your principal and see whether s/he is willing to allow me to come into your school. I am attaching a letter of information for your principal.
- Think about what has made you the unique science teacher you are today. (What are some of the stepping stones or events which have led to the creation of you as a unique science teacher?)

Regards,

Dale Taylor
Marang Centre for Maths and Science Education, Wits School of Education
Dale.taylor@wits.ac.za 011 717 3249 w 011 646 1721 h 082 515 1062
Fax: 086 529 6736

Appendix E: Teacher Consent Forms

University of the Witwatersrand
Wits School of Education

Informed Consent Form: Interview Consent: Teacher

Research Topic: Becoming a science teacher: narratives and conceptions

I, ____ agree to participate in this study to be conducted by Dale Taylor of the University of Witwatersrand for her doctoral study entitled 'Becoming a science teacher: narratives and conceptions'. I further agree to being interviewed as part of the study.

I realise that no harm will result from my participation in this study, and that the study is being conducted for purposes of improving the preparation of science teachers. I give consent for the material to be used for research or teaching only. I am not forced to participate and understand that I may withdraw from the study at any time.

Signature: ____

Date: ____

University of the Witwatersrand
Wits School of Education

Informed Consent Form: Audio-recording Consent: Teacher

Research Topic: Becoming a science teacher: narratives and conceptions

I, ____ agree to the audiotaping of interviews between Dale Taylor and myself for her doctoral study entitled 'Becoming a science teacher: narratives and conceptions'. I understand that the interviews will be transcribed and the audiotapes will be destroyed after they have been transcribed. I understand that the transcripts will not contain the participants' names, and that participants will be allocated pseudonyms for the analysis, ensuring anonymity of the participants.

I realise that no harm will result from my participation in this study, and that the study is being conducted for purposes of improving the preparation of science teachers. I give consent for the material to be used for research or teaching only. I am not forced to participate and understand that I may withdraw from the study at any time.

Signature: ____

Date: ____

University of the Witwatersrand
Wits School of Education

Informed Consent Form: Videotaping Consent: Teacher

Research Topic: Becoming a science teacher: narratives and conceptions

I, ____, agree to the videotaping of my science lessons by Dale Taylor of the University of Witwatersrand for her doctoral study entitled 'Becoming a science teacher: narratives and conceptions'.

I understand that portions of the videotapes may be transcribed. I understand that the transcripts will not contain the participants' names, and that participants will be allocated pseudonyms for the analysis, thereby ensuring anonymity of the participants.

I understand that the researcher may wish to use segments of video as part of presentations on this research to fellow researchers or to student teachers. I understand that the teacher, learners, school uniforms and/or school in such a video segment could be recognizable to people who know them which means that confidentiality cannot be guaranteed if such a video segment is used. I understand that this will only happen if I and give my express written consent after seeing that segment replayed and my principal gives her/his express written consent. I understand that such segments will be carefully vetted to ensure that they do not in any way compromise the dignity of the subjects. I understand that lessons with content which is sensitive or otherwise unsuitable for the presence of an observer will not be observed.

I realise that no harm will result from my participation in this study, and that the study is being conducted for purposes of improving the preparation of science teachers. I give consent for the material (transcripts / video segments) to be used for research or teaching only. I am not forced to participate and understand that I may withdraw from the study at any time.

Signature: ____

Date: ____

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