

LANGUAGE AND THE OPPORTUNITY TO LEARN SCIENCE  
IN BILINGUAL CLASSROOMS IN THE EASTERN CAPE,  
SOUTH AFRICA

by

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## DECLARATION

I declare that *Language and the opportunity to learn science in bilingual classrooms in the Eastern Cape, South Africa* is my own work, except where indicated, and that it has not been submitted before for any degree or examination at any university.

Signed: 

Signed by candidate
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Signature removed

Margaret Joan Probyn

September 2016

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My dear friends and beloved family have put up with a lot of absences, absent-mindedness and downright neglect. This is my one regret about the whole enterprise. My grandchildren only know a granny who emerges from behind a computer and who has often been 'working' instead of doing fun things with them. My long-suffering husband Bruce has borne the brunt of this with grace and good humour and only occasional exasperation. He really has been a rock of support and has somehow maintained the faith that I WILL FINISH. We all look forward to a PhD-free future.

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Lastly I wish to acknowledge the many, many bright and beautiful children who populate the kinds of schools in which I did my research. So much talent is being squandered and they deserve so much more. We have a long way to go. This research is dedicated to them.

## ABSTRACT

The problem that prompted this research was the general poor performance of South African learners in national and international science assessments, and in particular, the poor achievement levels of Grade 8 learners in successive TIMSS (Trends in International Mathematics and Science Study) science assessments. It was suggested in the TIMSS South Africa reports that the language of the tests, when different to learners' home language, contributed to their poor performance in the assessments. However the reports also noted that language factors were intertwined with other factors such as low socio-economic status.

Large-scale quantitative studies such as TIMSS can tell us the 'what' in an education system; however such studies are not able to tell us much about 'why': for example why South African learners have continued to perform so poorly in assessments such as TIMSS. The notion of 'opportunity to learn' proposes that learners cannot be held accountable for their performance in such assessments if they have not been provided with the opportunity to learn the content assessed. This small-scale qualitative research study therefore set out to drill down from the TIMSS studies to investigate the opportunity to learn science in classrooms in the Eastern Cape where the home language of learners and teachers (isiXhosa) was different to the language of assessment (English).

Opportunity to learn science was conceptualized in terms of the science content of lesson and the language used to construct that science knowledge. Classroom language was further disaggregated into the classroom discourse interaction patterns; and the bilingual languaging practices of teachers and learners. The research thus drew on literature and research from the fields of science teaching, classroom discourse, and bilingual education – fields not usually combined – to develop a complex picture of classroom practices.

A multiple case study was undertaken in eight township and rural schools in the Eastern Cape Province of South Africa, one of the most under-developed and poorest of the nine provinces. Data was collected from five consecutive Grade 8 science lessons that were observed and video-taped for each of eight classes; the teachers were interviewed about their personal histories, attitudes towards teaching and learning science in the context where learners were learning through an additional language; and their classroom practices. In addition, detailed fieldnotes were kept. Transcripts were made of the lessons and interviews; and the isiXhosa in the lessons was translated where it occurred.

The lesson transcripts were analysed using socio-cultural discourse analysis and this included coding and content analysis to arrive at patterns in the data, which were exemplified by extracts from the data; some of these were of necessity fairly long, so as to take account of both the content and language of the lessons and to trace how ideas were developed over time, within and across lessons, though language. The teacher interviews provided the contextual detail; and teachers' practices were probed using simulated recall based on video clips from their lessons.

The fine-grained analysis of the science content of lessons allowed for the elaboration of a hierarchy of necessary conditions that needed to be in place for the opportunity to learn science to be actualized; and a key condition was that the science content should be conceptually coherent, with facts linked to generalized principles and conceptual frameworks and that the generalized principles were supported by factual detail. It appeared that the classroom discourse was important for engaging learners in this process of moving from description of observations, to explanation, to generalizing and concept building. In addition a skilled teacher was able to effect a bridging discourse that supported learners in moving from everyday language and understandings to scientific language and understandings; from practical to theoretical knowledge; and from oral to written modes. These are necessary conditions for all

learners to be afforded the opportunity to learn science. A further condition in the bilingual contexts that these classrooms typified, was the need for the teacher to support learners in developing conceptual understanding in their home language and then teaching for transfer of that understanding into the language of assessment, English.

The analysis was able to demonstrate how the nuanced interplay of content and language in the practice of one teacher appeared to successfully construct the opportunity to learn science; and how in the practices of the other teachers, the opportunity to learn science broke down at different points. This indicated the points of leverage in the enacted curriculum that could be addressed in teacher education to break the logjam of factors contributing to underperformance in science achievement.

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## CHAPTER ONE: LOCATING THE STUDY

In this chapter I locate this research study by outlining my personal interest in the question of language and learning in South Africa; I describe the research problem and the context for this research study; I provide a justification for my use of the framing concept of 'opportunity to learn'; I state the research goals and the research questions; and I provide a brief overview of the chapters that follow.

### Personal interest in language and learning

My own long-standing concerns about language and learning were sparked by my experience as an English teacher in a township secondary school in South Africa in the 1990s and the realization that for many learners, their poor proficiency in English, the language medium for content subjects, created a barrier to learning. Carol Macdonald's research (1990a) into this area vividly documented such problems and provided a theoretical introduction to the issue. It seemed to me that language was a major obstacle to the achievement of educational equity and social justice for many learners in township and rural schools<sup>1</sup>; and yet teachers received little or no training in how to deal with the matter.

In this research I have attempted to probe the matter further, for a more nuanced understanding of the issues around language and learning and to search for possible points of

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<sup>1</sup> 'Township and rural schools' in this study refers to schools that under apartheid were designated for African learners. Under apartheid, schools were segregated according to racial classifications and likewise situated geographically in areas designated for particular racial groupings. Accordingly, African learners were restricted to schools in township areas (dormitory suburbs on the urban peripheries), which fell under the control of the Department of Education and Training; and schools in rural 'homelands' (geographic areas to which the majority of the African population were restricted politically, economically and spatially), which fell under the respective 'homeland' governments. Since 1994 all schools have been open but township and rural schools remain effectively segregated, catering for the African rural and urban poor; and carrying the historic legacies of under-funding and under-development from the apartheid era.

leverage, which might provide the basis for teacher training and more effective classroom practices.

## Research problem

Science is regarded as a key school subject for developing the knowledge and skills necessary to drive economic growth and development (McCarthy and Bernstein, 2011, p. 8); and this is recognized by the South African government as a quotation from a speech by the Minister of Science and Technology, Naledi Pandor, indicates: 'Advances in the science, technology and innovation sector will help to meet the triple challenges of joblessness, poverty and inequality' (Pandor, 2015).

However, despite the obvious need for students qualified in science and mathematics, the majority of South African learners have performed very poorly in international studies such as the TIMSS assessments of Grade 8 mathematics and science: Third International Mathematics and Science Study – Repeat (TIMSS-R) 1998/99 (Howie, 2001); Trends in International Mathematics and Science Study (TIMSS) 2003 (Reddy, 2006); and Trends in International Mathematics and Science Study (TIMSS) 2011 (Reddy et al., n.d.). In these assessments South African learners came last out of 38 and 50 countries respectively in 1998/99 and 2003; and second last to Ghana in 2011, even though in that year South African learners participated at Grade 9 level while Ghana participated at Grade 8. This dismal picture is carried though to Grade 12 physical science and as Table 1 below shows, from 2011 to 2015 there were 37% or less learners writing Physical Science in the Grade 12 public examination (known locally as 'matric'), with the percentages dropping from 36,4% in 2011 to 24,2% in 2015; and over the same period, only 9% or less learners who wrote matric, passed Physical Science with 50% or more – the minimum requirement for university studies.

**Table 1.1. Matric learners who wrote and passed Physical Science with 50% or more 2011-2015**

<b>Year</b>	<b>Percentage matrics wrote Physical Science</b>	<b>Percentage matrics passed Physical Science with 50% or more</b>
<b>2011</b>	36,4	7,5
<b>2012</b>	35,1	8,5
<b>2013</b>	32,8	8,4
<b>2014</b>	31,5	7,1
<b>2015</b>	24,2	6,4

(sources: DBE, n.d.; Equal Education, 2015; Motshekga, 2016)

Unsurprisingly, *Business Day* reported recently that the Human Sciences Research Council had ‘warned that the country’s growth is stifled by a severe skills shortage, particularly in science, technology, engineering, maths and accounting’ (Phakathi, 2015).

Concerns about the poor performance of South African learners in mathematics and science have prompted questions as to the causes – particularly when learners in poorer countries with lower levels of expenditure on education have achieved better results (Howie, 2001). The question that naturally follows is ‘why?’

One factor contributing to poor results in science and mathematics that was identified in the TIMSS South Africa reports was that of *language*:

... the majority of South African pupils cannot communicate their scientific conclusions in the languages used for the test (i.e. English and Afrikaans which were the medium of instruction and are the languages currently used for matriculation examinations). In particular, pupils who study mathematics and science in their second language tend to have difficulty articulating their answers to open-ended questions and apparently had trouble comprehending several of the questions.

(Howie, 2000).

This observation was repeated in the reports of the 2003 and 2011 TIMSS assessments (Reddy, 2006; Reddy et al., n.d.): in TIMSS 2011 it was found that learners who were tested in their home language scored on average 120 points more in the science assessment than learners who were not tested in their home language – this is equivalent to three grade levels (Prinsloo & Rogers, 2013).

What the TIMSS reports were referring to was the *language medium* (or language of learning and teaching [LoLT] as it is referred to in the Language in Education Policy, [LiEP] [Department of Education, R.S.A., 1997]) for teaching and assessing science and how this constituted a barrier to understanding and communicating science knowledge in the tests. As is well known, English is the home language of only 9,6% of the population (Statistics South Africa, 2012), yet the majority of learners in South Africa learn through the medium of English from Grade 4. The opportunities for learners to acquire English language proficiency outside the classroom, particularly in rural schools, are restricted by their lack of exposure to both spoken and written English.

However as Reddy (2006) noted, there is not a straightforward causal link between home language LoLT and learners' achievement in science, as 'there is a complex set of several factors affecting performance in the classroom' (p. xviii) and these include the general co-occurrence of second language (L2) LoLT with lower socio-economic status and attendance at township and rural schools (Spaull, 2013).

Learners' general poor proficiency in the LoLT poses particular problems for science teachers who are faced with the tension between teaching science and teaching language; and the dilemmas of how best to negotiate this tension (see Setati, Adler, Reed & Bapoo, 2002; Probyn, 2009) – for which they receive little or no training. Consequently, a key aspect of this research is

an investigation into teachers' use of the linguistic resources of the classroom and how their languaging (Swain, 2006)<sup>2</sup> practices impact on the opportunity to learn science.

A related aspect of language and the opportunity to learn science, that is less widely debated in South Africa, is the nature of the *classroom discourse*. The related literature draws on socio-cultural perspectives, to examine how language is used by teachers to engage learners in co-constructing knowledge in the classroom, and studies have identified discourse patterns that support learning (for example: Alexander, 2001; Barnes, 1976, 1992; Gibbons, 2006; Mercer, 1995; Wells, 1999). In line with this, others have focused on how science knowledge is constructed through classroom talk and the extent to which this supports or constrains the opportunity to learn science (see Lemke, 1990; Mortimer and Scott, 2003; Sutton, 1992, Wellington and Osborne, 2001).

Since Carol Macdonald's seminal research into language and learning in Grade 4 in African language classrooms in the late 1980s (Macdonald, 1990a), there have been several studies focusing on language practices in such contexts, focusing in particular on classroom codeswitching patterns (see Adendorff, 1996; Chick, 1996; Probyn, 2006; Setati, Adler, Reed & Bapoo, 2002) and the functions thereof – that resonate with similar studies in other post-colonial contexts (for example Arthur, 1996; Clegg & Afitska, 2011; Ferguson, 2003; Martin, 1996; Martin-Jones, 2000; Merritt, Cleghorn, Abagi & Bunyi, 1992) and illustrate the dilemma-filled nature of such practices. However there does not seem to be much research that provides fine-grained analysis of teachers' and learners' languaging practices over several lessons, in terms of how these might support or constrain the opportunity to learn content subjects. There appears to be even less research in South Africa on classroom discourse patterns (an exception

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<sup>2</sup> Swain (2006) refers to 'languaging' to express the Vygotskian notion of making meaning through language.

being Muller (1989)) and how these engage teachers and learners in constructing content knowledge – or not.

My research interest was to investigate the opportunity to learn science in a small sample of eight Grade 8 classes, where teachers and learners shared a common home language that was different from the LoLT (English). In particular I wanted to explore the relationship between the science content and the language of the lessons: the languaging practices of teachers and learners in this bilingual context; and the nature of classroom discourse; and whether these appeared to support or limit opportunities to learn science.

### **Framing the study: ‘Opportunity to learn’**

The ongoing poor performance of South African Grade 8 learners in the TIMSS studies provided the backdrop to this study, which seeks to answer some qualitative ‘why’ questions in response to the quantitative data provided by the TIMSS studies.

The framing concept for this research study is that of ‘opportunity to learn’ (OTL) which holds that ‘students can only be accountable for their academic performance to the extent that the community, broadly defined, has offered them the tools to master the content expected of them’ (McDonnell, 1995, p. 312). In the light of this, and the poor performance of South African learners in the TIMSS assessments, the main research question for this research study is:

What is the nature of the science content and the classroom language practices that support learners’ opportunity to learn science?

The concept of OTL requires some unpacking and justification, particularly as it has been generally used in relation to large-scale quantitative research, rather than small-scale qualitative studies such as this one. According to McDonnell (1995), the concept, ‘opportunity to learn’ was initially developed in the 1960s in relation to large-scale international assessments conducted by the International Association for the Evaluation of Educational Achievement

(IEA). At that time 'opportunity to learn' was conceptualized simply as a measure of curriculum coverage, in order to ensure the reliability of the IEA assessments i.e. to establish whether learners who took the tests, had had the opportunity to learn the content that was being tested.

In the IEA studies, curriculum was conceptualised as functioning at three levels: the 'intended curriculum' – as expressed in official curriculum plans; the 'enacted curriculum' – what happened in classrooms; and the 'attained curriculum' – what learners achieved on standardized tests (Howie, 2001; McDonnell, 1995). So the concept of 'opportunity to learn' related directly to the 'enacted curriculum' – what happened in classrooms.

In the 1980s, the concept of OTL was expanded beyond that of simply curriculum coverage, to include schooling and classroom processes more generally, in order to develop indicators of practices, including instructional strategies, that were associated with higher student achievement levels, (McDonnell, 1995). In addition, the concept of OTL was linked with concerns with equality of educational provision in the face of persistent gaps in achievement between students from different socio-economic backgrounds (see Gee, 2003; McDonnell, 1995).

Given the limits in classroom based research of establishing a direct causal link between teaching and learning, and the wide range of intervening factors that might influence the uptake by learners of teaching input, it seems useful to delink the processes for the purposes of observation and analysis, and consider what teaching content and practices might offer learners a fair *opportunity* to learn particular lesson content, without necessarily making assumptions about what actually *was* learned.

Various studies have defined OTL indicators slightly differently and accordingly collected different kinds of data: for example the TIMSS studies collected data about curriculum coverage, school conditions, learner socio-economic backgrounds and instructional strategies, by means

of learner, teacher and principal questionnaires (McDonnell, 1995; Howie, 2001); Gee (2003) used the concept OTL to identify six principles necessary to provide for equal opportunity for literacy learning. In South Africa, Reeves and McAuliffe (2012) examined curricular coherence as a dimension of OTL in Grade 6 mathematics classrooms in schools serving low income communities, by examining the sequencing of topics in the written work in learners' mathematics notebooks; Carnoy, Chisholm and Chilisa (2012) defined two types of OTL: curriculum coverage which was inferred from students' notebooks; and aspects of the school context (violence, teacher absenteeism) – evidence of which was obtained from questionnaires for school principals, teachers and students (p. 36). Taylor, van der Berg and Mabogoane (2013), also in South Africa, expanded the notion of OTL to include two main components: teacher knowledge (indicator: subject knowledge) and teacher competence (indicators: curriculum coverage, frequency of reading, quantity and quality of writing and frequency and nature of assessment). In Taylor et al.'s large-scale study it was considered too expensive to collect classroom level data by means of observation and so this was collected instead from interviews with teachers, analyses of work done by the best learner in each class, and analyses of teacher planning and assessment records.

The point of providing the above examples is to demonstrate that the notion of OTL has shifted from the initial definition of simply curriculum coverage, to include other aspects of the enacted curriculum that are considered to impact on students' opportunity to learn.

One of the constraints of the above studies is that their large-scale nature has ruled out more detailed, fine-grained studies of classroom interactions. McDonnell (1995 p. 310) makes the point that some aspects of OTL can only be identified through direct observation: 'These include *discourse practices* that evidence the extent of student participation and their role in the learning process, the use of small-group work, and the relative emphasis placed on different

topics within a given lesson and the *coherence* of teachers' presentations' (own emphasis). These are aspects that are given attention in this research study.

The TIMSS 1999 Video Studies of mathematics teaching (Hiebert et al., 2003) and science teaching (Roth et al., 2006) across seven and five countries respectively, attempted to combine quantitative breadth and qualitative depth by using videotapes of lessons to do more fine-grained analyses of classroom interactions. The TIMSS 1999 Video Study for science set out to answer the main research question: 'What opportunities did the lesson provide for students to learn science?' (Roth et al., 2006, p. 5) and a very detailed range of criteria was developed to analyse lessons, from the perspectives of teacher actions, science content and student actions. This then established a precedent for using direct observation - of the videotaped lessons - to identify factors contributing to or constraining OTL science.

So while it has been recognized that there is a need for more fine-grained studies to elaborate OTL, the time and cost constraints have generally mitigated against this for large-scale studies. However, it seems that small-scale fine-grained studies of OTL such as this one, can serve to explore and identify indicators of OTL that could at a later stage be taken to scale; or provide more in depth analyses to elaborate and/or explain findings regarding the attained curriculum from large scale studies. Thus it is intended that this small-scale qualitative study of the opportunity to learn science in eight Grade 8 classrooms, should inform understandings of the enacted curriculum, in the light of the achievement gap between South African students and their Grade 8 counterparts internationally in the TIMSS studies. In this way, the concept of OTL can provide a unifying framework to provide coherence to smaller scale qualitative studies.

### **Research context: The Eastern Cape Province**

The Eastern Cape, where this research study was conducted, is one of the most rural and poor provinces in South Africa: statistics for 2012 showed that over 30% of the population was

illiterate; 42% of the population was unemployed; and 47% of the population living in poverty. So it is no surprise that in 2011, 85% of learners in the Eastern Cape were in no fee schools<sup>3</sup> (Kane-Berman & Holborn, 2012).



**Figure 1.1. Map of South Africa showing Eastern Cape Province (Wikipedia, n.d.)**

The linguistic context of the eastern districts of the Eastern Cape, that are comprised of the former homelands of Ciskei and Transkei, is that the majority of teachers and learners share a common home language, isiXhosa, while the official language of learning, teaching and assessment is English from Grade 4. However there are few opportunities for learners to acquire English outside the classroom as the predominance of isiXhosa in communities means that there is very little interaction with English speakers and there are limited written resources in communities and schools to support literacy development in either isiXhosa or English.

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<sup>3</sup> No fee schools were introduced in 2007 and the Minister of National Education may declare a school exempt from fees, based on poverty levels in the surrounding community.

Education in the Eastern Cape has been bedeviled by political infighting, corruption and mismanagement, and so the fruits of political liberation have not been felt in many township and rural schools, which remain with poor infrastructure and limited resources. According to the South African Survey 2012 of the Institute of Race Relations (Kane-Berman & Holborn, 2012), in 2011, of the 5 676 schools in the Eastern Cape, 10% had no toilets and only 17% had flush toilets; 19% of schools had no water and 20% had no electricity; only 3% of schools had stocked libraries and 2% had stocked laboratories. In 2013 there were still over 400 mud schools<sup>4</sup> in the province, despite an undertaking by the then-president Thabo Mbeki in 2004 that all mud schools would be rebuilt by the end of that year; and in 2012 the Legal Resources Centre brought a court action against the Eastern Cape Education Department for shortages of 500 000 desks and chairs (John, 2013).

Given the above challenges it is hardly surprising that learners in the Eastern Cape Province have fared second last in the country, after Limpopo Province, in science in TIMSS 1999 (Howie, 2001) and 2003 (Reddy, 2006); and lowest of all nine provinces in TIMSS 2011 (Reddy et al., n.d.).

Locating this research study in the Eastern Cape might seem somewhat perverse, in the light of the difficulties outlined. Nevertheless, there were good reasons for this choice: these were partly pragmatic as I was based in the Eastern Cape Province and involved in an in-service development programme for language teachers in three districts: two rural and one urban and peri-urban. This meant I was able to combine data collection and school support visits in one trip and reduce fieldwork costs and time commitments. In addition, from a research perspective, the network of contacts already established with district officials, teachers and

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<sup>4</sup> Mud schools are literally schools made of wattle and daub or mud bricks and as such insecure structures for teaching and learning.

school principals in these districts, assisted greatly with practical matters such as negotiating access, finding the physical locality of schools - an important factor in rural areas where maps and road signs are practically non-existent. This afforded me the opportunity to investigate teaching practices in fairly remote rural schools that are normally inaccessible and where little in-depth classroom-based research has been done; and to find out what competent science teachers are able to achieve in the most challenging of material and linguistic circumstances.

### Research goals

The research goals were to investigate the 'opportunity to learn science' in a sample of eight Grade 8 science classrooms, where the home language of both teachers and learners was isiXhosa and the language medium was English. In order to do this, the science content of the lessons was analysed for types of science knowledge; the sources of the science content; and the accuracy, density and coherence of the presented content. The language of the lessons was analysed in terms of the discourse patterns and the bilingual language practices of teachers and learners. These analyses were merged to attempt to identify which content and language practices appeared most supportive of the opportunity to learn science.

This research aimed to shed some light on the 'black box' of the 'enacted curriculum' in a sample of Grade 8 science lessons where teachers and learners shared a common home language, which was different to the official language of learning and teaching, English. This is the linguistic pattern for the majority of learners in rural and township schools outside the main metropolitan areas.

While there is a growing recognition of the important role of language in the teaching and learning of science, there is sometimes an assumption that simply changing the language medium will solve the problems of access to the curriculum and the poor performance of learners. However, there has been little attention given to the question of classroom discourse,

in particular the kind of public talk that structures and chains knowledge into clear conceptual frameworks; that is contingently responsive to students' contributions to the construction of meaning; that provides a bridge between everyday language and academic language; and enacts a systematically structured and visible curriculum that encodes learners as thinkers and problem solvers.

Thus one hopes that the research might reveal some points of leverage in the enacted curriculum that might contribute to improved opportunities to learn science in such contexts, and that might be of interest and relevance to teacher training and development.

### Research questions

The main research question that was developed to guide this research was as follows:

In what ways did the lesson content and the classroom language practices combine to construct or constrain the opportunity to learn science?

Subsidiary questions that followed were:

- What was the nature of the science content knowledge that was developed in the observed lessons?
  - What types of science content knowledge were presented in the observed lessons?
  - What were the sources of the science content knowledge in the observed lessons?
  - How accurate was the science content knowledge that was presented in the observed lessons?
  - How much science content knowledge was there in the observed lessons?
  - How coherent was the science content knowledge between and within the observed lessons?

- Did the classroom discourse construct or constrain the learners' opportunities to learn science?
  - What was the relative balance of teacher-learner talk?
  - What were the predominant discourse interaction patterns in the lessons and in what ways did they engage learners in developing science knowledge?
  - What bridging discourses did the teacher engage learners in to bridge the gaps between everyday knowledge and language and science knowledge and language; between practical and theoretical knowledge; and between spoken and written language?
- Did the classroom languaging practices of teachers and learners appear to construct or constrain the learners' opportunities to learn science?
  - How did teachers and learners utilize the available linguistic resources of isiXhosa and English to access and develop science knowledge?

## Overview of thesis

Chapter One provides an outline of the research problem; a discussion and justification of the use of the framing concept of 'opportunity to learn'; a description of the research context; a statement of the research goals and questions; and a brief overview of the thesis.

Chapter Two provides a conceptual framework for this study in terms of outlining the theoretical framework for this study and reviewing empirical studies relating to the topic of language and science learning.

Chapter Three describes and justifies the research methodology: the broad research approach, the use of a multiple cases study, data collection methods and data analysis criteria and processes. A brief outline of the research process is also provided, with a discussion of the related ethical issues and the limitations of the study.

Chapter Four presents the findings in terms of a brief description of each teacher and their teaching context.

Chapter Five presents the findings in terms of the analysis of the science content of the lessons to answer the question: what was the nature of the science content in the observed lessons?

Chapter Six presents the findings in terms of the classrooms discourse that was utilised to construct the science content of lessons.

Chapter Seven presents the findings in terms of the bilingual languaging practices of the teachers and learners.

Chapter Eight provides a discussion of the research findings in relation to the literature.

Chapter Nine draws conclusions and makes recommendations based on the research findings.

## CHAPTER TWO: CONCEPTUAL FRAMEWORK

This chapter provides the theoretical and empirical framework for this small scale, qualitative research study which seeks to answer the following question: *In what ways did the lesson content and the classroom language practices combine to construct or constrain the opportunity to learn science?*

The broad theoretical framework is that of a socio-cultural view of language and learning, based on the work of Vygotsky (1962), who held that talk on the social plane is the basis for individual conceptual development. So language is considered to be more than a simple conduit of information but is the means for both engaging in learning, and constructing knowledge within particular socio-cultural-historical contexts. In line with this broad orientation, this research study seeks to investigate the interplay of language and science learning in classrooms where the linguistic context is that the home language of teachers and learners (isiXhosa) differs from the official language of learning and teaching (English); and the socio-economic context is one of poverty and underdevelopment which is directly related to the historic legacies of the policies of apartheid in rural and township schools, in two of the former homelands of South Africa.

A discussion of the concept 'opportunity to learn' has been presented in chapter one: how the concept has been redefined in different ways, using different kinds of evidence; and a justification for its use in this research. For the purpose of this study, 'opportunity to learn' has been conceptualised in terms of the nature of the science content knowledge of lessons and the language used to construct that science content knowledge. The analysis of the classroom language has in turn been framed from two perspectives: that of the classroom discourse - the interaction patterns that engage learners in constructing a coherent understanding of science knowledge (or not); and the use of the bilingual language resources by teachers and learners (or not).

This literature review therefore draws together theories and empirical evidence from the fields of science education, classroom discourse and bilingual classroom practices – fields that more usually have been considered separately.

### **What is involved in learning science?**

What is involved in learning science? The nature of science knowledge is that it seeks to classify and explain the natural and physical world, and develop conceptual frameworks and theories with integrative explanatory power, in a 'hierarchical knowledge structure' (Bernstein, 2000 in O'Halloran 2007) so that all observable phenomena can be explained. The scientific process is one of empirical experimentation, observation and logical reasoning to account for the phenomena observed; and the application of principles and theories to predict, solve problems and control the environment. As such, science knowledge encodes 'an alternative perspective on reality to common sense', (Martin, 1990, p. 86). So learning science involves learning different ways of thinking and seeing: for example that salt has dissolved in water rather than it has disappeared (Sutton, 1992, p. 41). In terms of constructivist views, learners' existing commonsense schemata or conceptual frameworks accounting for the natural and physical world need to change to accommodate alternative uncommonsense scientific explanations and conceptual frameworks.

Learning science also requires a range of cognitive skills, identified by Lemke (1990, p. ix) as 'observing, describing, comparing, classifying, analyzing, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting, writing.' According to socio-cultural views, language and cognition are closely intertwined, and so many of these cognitive skills could as well be described as language skills, constituting an 'elaborated code' (Bernstein, 1990) or 'school code' (Taylor, Muller & Vinjevold, 2003); or 'cognitive academic language proficiency' (Cummins, 2000), and as such, necessary for academic learning in general.

In addition, learning science involves learning the particular language of science (see Halliday & Martin, 1993; Lemke, 1990; Martin, 1990; Mortimer & Scott, 2003; Ogborn, Kress, Martins & McGillicuddy, 1996; Sutton, 1992; Wellington & Osborne, 2001), which is distinguished from everyday language by new technical terms such as *photosynthesis*, *molecule*, *carbon dioxide*, as well as technical scientific meanings attached to everyday terms, for example *table*, *current*, *force*, *cell* - in fact it is the latter which learners tend to find more challenging (Cassels & Johnstone, 1985, cited in Wellington & Osborne, 2001, p. 11). However it is concept words in science such as *work*, *energy*, *pressure*, *food web* that pose the greatest learning challenges as their meaning is at a higher level of abstraction, and dependent on a prior understanding of a network of other words, all related in a vertical knowledge structure; so without these prior understandings, the structure of the concept will collapse (Wellington & Osborne, 2001, p. 21). So for example, the concept of a 'food web' is dependent on understanding the meaning of categories such as plants, herbivores, carnivores, omnivores; how these categories are linked hierarchically in 'food chains'; and how food chains combine to form food webs. If the underlying term 'food chain' were not clearly understood, then understanding of the higher level concept of 'food web' would also be incomplete. Wellington and Osborne (2001) make the point that these specialized meanings need to be explicitly taught: meaning has to be taught not 'caught' (p. 17). These challenges would be amplified in a bilingual context where the learners' home language was different to that of the official language of learning and teaching.

The discourse of science also has particular grammatical features which are shared with academic writing in general, but are particularly evident in science texts and these include lexical density through nominalization - where verbs or processes are turned into nouns (for example *evaporation*) so that clauses can be loaded with more meaning; the use of the impersonal, passive voice and the use of analogies and metaphors to represent processes which cannot be directly observed. All of these pose challenges for learners when reading and writing

science texts. In addition, the discourse of science makes use of particular written genres such as explanations, procedures, recounts, reports, arguments, discussions, all of which have particular structures and grammatical features.

As with the specialized vocabulary of science, genre theorists propose that the grammar and genres of science need to be made visible and explicitly taught. They claim that 'progressivist' pedagogies tend to leave such powerful knowledge implicit, thus privileging learners from well-resourced, highly literate homes where such knowledge may be incidentally acquired (Christie, 2002; Martin, 1990).

Thus science content and language are closely intertwined in the process of learning science, both from the perspective of socio-cultural theories of language and learning; and from the perspective of learning the specialised language of science. Teaching science then involves mediating learners' conceptual shifts, through language, in terms of understanding the physical and natural world in alternative, un-commonsense ways; as well being able to expressing these understandings, both orally and in writing in the specialised language of science.

## **Learning science: the 'what' of the curriculum**

### **Types of science knowledge**

The content of school science is described in the literature (see Mortimer & Scott, 2003; Roth et al, 2006) as concerned with three inter-related aspects: learning facts about the natural and physical world and how it is constructed, and how these facts are linked into conceptual frameworks; that science knowledge is enquiry based and subject to a process of validation against empirical evidence; and the application of science knowledge to problem solving in everyday life. These three aspects are reflected in the three learning outcomes in the revised curriculum, introduced in 2002 (Department of Education, RSA, 2002):

#### Learning Outcome 1: Scientific Investigations

The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts.

Learning Outcome 2: Constructing Science Knowledge

The learner will know and be able to interpret and apply scientific, technological and environmental knowledge.

Learning Outcome 3: Science, Society and the Environment

The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment.

The above Learning Outcomes have been replaced with 'Specific Aims' in the latest version of the curriculum (Department of Basic Education, RSA, 2011), but these remain very similar:

Specific Aim 1: 'Doing Science'

Learners should be able to complete investigations, analyse problems and use practical processes and skills on evaluating solutions.

Specific Aim 2: 'Knowing the subject content and making connections'

Learners should have a grasp of scientific, technological and environmental knowledge and be able to apply it in new contexts.

Specific Aim 3: 'Understanding the uses of Science'

Learners should understand the uses of Natural Sciences and indigenous knowledge in society and the environment.

In the TIMSS 1999 video study, these three forms of science knowledge were described as

- canonical knowledge, which includes propositional knowledge about 'science facts, concepts, ideas, processes, or theories' and includes observations from practical work;
- procedural and experimental knowledge, described as 'how to do science-related practices such as manipulating materials, and performing experimental processes'; and
- real-life issues - 'how science knowledge is used, applied or related to societal issues or to learners' personal lives'

(Roth et al, 2006, p. 48).

It would seem obvious that in order for learners to have the opportunity to learn science they should have exposure to the different forms of science knowledge as outlined above and reflected in the learning outcomes and aims in the curriculum: knowing science, doing science and applying or using science; but that doing science and using science are in fact in support of developing an understanding of science as an empirically based, hierarchically structured body of knowledge with real life application. However, in the TIMSS video study report it was noted that in some classrooms learners were very busy doing practical activities but that these appeared to be ends in themselves, rather than the basis for developing science knowledge (Roth et al, 2006, p. 61); and in a similar vein, Blank (2000, cited in Yore & Treagust, 2006, p. 294) was critical of 'activitymania' where teachers and learners equated learning of science with simply 'doing'. In relation to South African classrooms, Fleisch (2008) referred to Schollar's (2004, cited in Fleisch, 2008) observations of many lessons where there was little content and 'pure social and/or physical activity ... (was) valued for its own sake'; this Schollar suggested was a result of a misinterpretation of the new teaching methods introduced with curriculum.

The point is, that science lessons might keep learners busy doing practical activities, but it does not necessarily follow that they provide learners with the opportunity to learn science. So an analysis of opportunity to learn science would need to investigate to what extent learners were exposed to all three forms of science knowledge, with canonical knowledge underpinned by both empirical evidence and real life applications.

### **Sources of science lesson content**

In order for learners to learn the language of science, there should be plenty of opportunities for learners to discuss scientific ideas and read science and write science texts; this much is increasingly argued in the literature, both internationally (see for example Gibbons, 2006; Hand & Prain, 2006; Ogborn et al, 1996; Wellington & Osborne, 2001; Yore et al, 2004; Yore &

Treagust, 2006) and in South Africa (see for example Rollnick, 2000; Mayaba, Otterup & Webb, 2013). However, South African research also has shown that too little reading and writing happens in classrooms in general and that even when textbooks are available, they are under-utilised (Fleisch, 2006; Taylor, 2011). This was corroborated in the South African TIMSS 2003 study (Reddy, 2006), where it was reported that only one third of teachers said that they used textbooks as the primary basis for lessons (p. 105). Taylor et al (2013) suggested that teachers' apparent resistance to using textbooks was a hangover from the curriculum reforms of the late 1990s when teachers were strongly encouraged to produce their own learning materials. So in South Africa, research indicates that in many classrooms lessons are largely oral with the teacher being the main source of lesson content.

#### **Accuracy of science lesson content**

If teachers are the main source of lesson content, then that raises the question of the accuracy of teachers' subject knowledge, and accordingly the accuracy of the science content presented in lessons - a factor that would quite obviously impact on learners' opportunity to learn science. While the accuracy of teachers' science content knowledge might be taken for granted assumption in developed countries such as those that participated in the TIMSS video study (and presumably the reason it was not included as a factor in the TIMSS video study analysis of opportunity to learn), this cannot necessarily be taken for granted in developing countries such as South Africa. As successive research findings have shown, the poor subject knowledge of teachers continues to be identified as a problem in South African education (Carnoy, Chisholm & Chilisa, 2012; Fleisch, 2008; McCarthy & Bernstein, 2011; Spaul, 2013; Taylor, van der Berg & Mabogoane, 2013; Taylor & Muller, 2014).

In relation to science teachers in particular, Selveratnam (2011) for example, found that only 42% of a group of 73 matric physical science teachers from Dinaledi schools<sup>5</sup> could solve basic problems correctly. The Department of Education has recognized this as a problem; and 'poor content and conceptual knowledge' has been identified as a critical challenge facing education in South Africa today - one that higher education institutions are tasked with addressing in teacher education programmes (Department of Higher Education and Training, RSA, 2011, p. 6). The negative effects of the poor subject knowledge of many teachers are compounded by the under-utilisation of textbooks, as this deprives learners of reliable alternative sources of science content knowledge.

### **Density of science lesson content**

One of the ongoing and unresolved debates in science education has been between breadth and depth of science content: those advocating that fewer topics should be covered in more depth – 'less is more' - versus those advocating broad coverage and who counter with 'less is less' (Roth et al, 2006; Schwartz, Sadler, Sonnert & Tai, 2009). In line with these concerns, the density of science ideas in lessons was an aspect of learning science that was included in the TIMSS video study analysis; and this was measured by means of a count of canonical science ideas per lesson.

Advocates of teaching science in depth claim that learners need to thoroughly engage with new ideas in order to dislodge their common sense understandings and that this takes time. Advocates of following a curriculum that provides breadth argue that learners' need a broad understanding in order to appreciate the generalized big ideas in science. The density of science content is clearly related to lesson pacing and curriculum coverage and is an issue that relates in

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<sup>5</sup> In 2001 the Department of Education established the Dinaledi School Project to increase the number of matriculants with university entrance mathematics and science passes. Schools with potential to improve were selected and provided with extra resources and support. Initially 102 schools were selected and by 2008 this number had grown to 500.

part to the intended curriculum; but at a classroom level teachers are also faced with decisions about breadth and depth within the constraints of lesson time allocations. However, it appears that there is little agreement as to the optimal density of science content in lessons; and in any event, measurement of the density of lesson content in individual lessons on different topics might not be the basis for valid comparisons and evaluations of opportunity to learn, given the obvious differences in complexity, abstraction, cognitive challenge and so on – the ‘learning demand’ (Mortimer & Scott, 2003, p. 108) - between different science topics.

South African research has indicated that in many township and rural schools, the pacing of lesson content by teachers is slow (Chisholm et al, 2005; Reeves, 2000), matching the pace of the slowest learner (Hoadley, 2003). The fact that learners in these schools are learning through the medium of a second language also contributes to slow lesson pacing; in fact Short and Fitzsimmons (2007) in referring to second language learners of English in the US, make the point that these learners must perform ‘double the work’ of students learning through their home language, as they are learning language while at the same time learning the content, and yet they are judged on the same assessment standards English speakers as home language speakers of English (p. 1); Gibbons makes much the same point in the context of Australia (Gibbons, 2006, p. 106).

So in South Africa, slow lesson pacing, combined with poor time on task has meant that frequently the curriculum is not completed in any one year and cumulative backlogs have left learners with serious gaps in their knowledge (Chisholm et al, 2005; Reeves, 2000). The question remains as to how the density of ideas in science lessons might impact on the opportunity to learn science. It seems that it is hard to determine what is ‘just right’. A count of ideas per lessons is a fairly crude measure, but does give some sense of the density of lesson content; and certainly provides an indication of extremes at either end of the scale, both of which are likely to limit rather than support the opportunity to learn science.

### Coherence of science lesson content

Even if the above necessary conditions – that there was science content in lessons that was correct; that there was not too much or too little; and that it was supported by written sources - were met, these would not constitute sufficient conditions for the opportunity to learn science. A key aspect of learning science with understanding is that facts should be linked to generalised conceptual frameworks; and that conceptual frameworks themselves should be supported by rich factual detail (Donovan & Bransford, 2005).

Shalem and Slonimsky (2010) writing in the context of South Africa, come to much the same conclusion. They have drawn on Vygotsky's work on concept development and Bernstein's work on knowledge structures, to argue that generalization and hierarchy are central in knowledge acquisition and therefore need to be explicitly taught: according to Vygotsky, 'concepts generalise phenomena; they extend them in time and space' and 'in theoretical thinking, the relations between concepts form a vertical order, whereby the more general concept frames the relations between the subordinate concepts' (Shalem & Slonimsky, p. 757) This relates to Bernstein's classification of knowledge structures, with 'disciplines in the natural sciences achieving high levels of integration of propositional knowledge ... [in] a hierarchical knowledge structure' (p. 757). Consequently pedagogy that is necessary to move learners from a restricted to an elaborated code, should make explicit the generalized structure of ideas as well as teaching learners to instantiate abstractions (p. 761).

In the TIMSS video study, the linking of the facts presented in lessons to generalized conceptual frameworks was identified as an important indicator of lesson coherence (Roth et al, 2006 pp. 64 – 70). It would seem that this would be an essential aspect of developing a hierarchical knowledge structure such as science.

The question of coherence in science and mathematics education has also been defined somewhat differently at different levels in the curriculum in various research studies: at the level of the intended curriculum, Schmidt, Wang and McKnight (2005) investigated curricular coherence in mathematics and science in the USA as compared to other high-achieving countries, in terms of the introduction and sequencing of topics. In South Africa, Reeves and McAuliffe (2012) and Stols (2013) investigated curricular coherence in the implemented curriculum, as an aspect of opportunity to learn mathematics: curricular coherence was measured in terms of the sequencing of mathematics topics and sub-topics by teachers over the course of one year, on the basis of evidence in learners' work books. So these definitions of coherence are on a different scale to that of this study, which in line with the TIMSS Video Study, investigated coherence in the implemented curriculum at the level of lesson content. Naidoo and Green (2011) and Venkat and Naidoo (2013) analysed science and mathematics classroom discourse respectively, for evidence of grammatical coherence in terms of systemic functional linguistics. So while these research studies were also on the scale of single lessons, the focus was on grammatical features such as grammatical and lexical cohesion, rather than on the coherence of the lesson content itself.

In the literature on science teaching and learning, and language, there is considerable reference to 'argumentation' and the need for teachers to teach such cognitive-language skills in science (for examples see Newton, Driver & Osborne, 1999; Sadler, 2006; Yore et al, 2004). This has also been taken up in South African research (for example see Msimanga & Lelliott, 2012). The literature in this area has tended to focus on discursive moves in arguments such as claims, grounds, warrants and backings (Newton et al, 1999) and generally has not made specific reference to developing coherence in the science content of lessons.

However, the linking of facts to generalized conceptual frameworks and the development of a hierarchical knowledge structure, would necessarily have to be done through logical argument.

In line with this, Wellington and Osborne (2001, p. 83) emphasised the importance of discussion in science lessons, in order to '[link] evidence and empirical data to ideas and theories'; and Scott, Mortimer and Ametller (2011) pointed to the importance of learning how 'scientific concepts themselves fit together in an interlinking system' as an aspect of 'pedagogical link-making' (p. 8).

Thus in considering the opportunity to learn science from the perspective of the science content of lessons, it seems important to examine to what extent the knowledge presented in the observed science lessons is clearly, systematically and cumulatively linked to generalisable principles and structured into conceptual frameworks; whether learners are inducted into the scientific process of observation, deduction and application; and the extent to which the reasoning processes are modeled and made visible, rather than being left implicit.

## Summary

The nature of the science content in lessons has been considered from the perspectives of the types of science content in lessons, the sources of science content, and the accuracy, density, and coherence of the science content presented.

In this study, the analysis of the opportunity to learn science was based on the factors that have been discussed, to arrive at a conclusion as to whether the science content in the lessons supported or constrained the learners' opportunity to learn science. What follows next is a consideration of theoretical positions and empirical evidence on the question of language and learning science.

## Language and the teaching and learning of science: the 'how' of the curriculum

This research study set out to understand how science knowledge was constructed through language in the observed classrooms, and which language practices seemed to support opportunities to learn science. The specialised language of science is a part of what learners

need to learn about science; and language is also the means through which science knowledge is constructed in the classroom; so language and the science content of lessons are closely intertwined. However for the purposes of this analysis they are teased out.

The classroom language has been further disaggregated and considered from two perspectives: that of the bilingual practices of the teachers and learners; and that of the interaction patterns in the classroom discourse. These two perspectives draw on different literature and research, which are discussed in the following sections.

### **Teaching and learning in multilingual contexts**

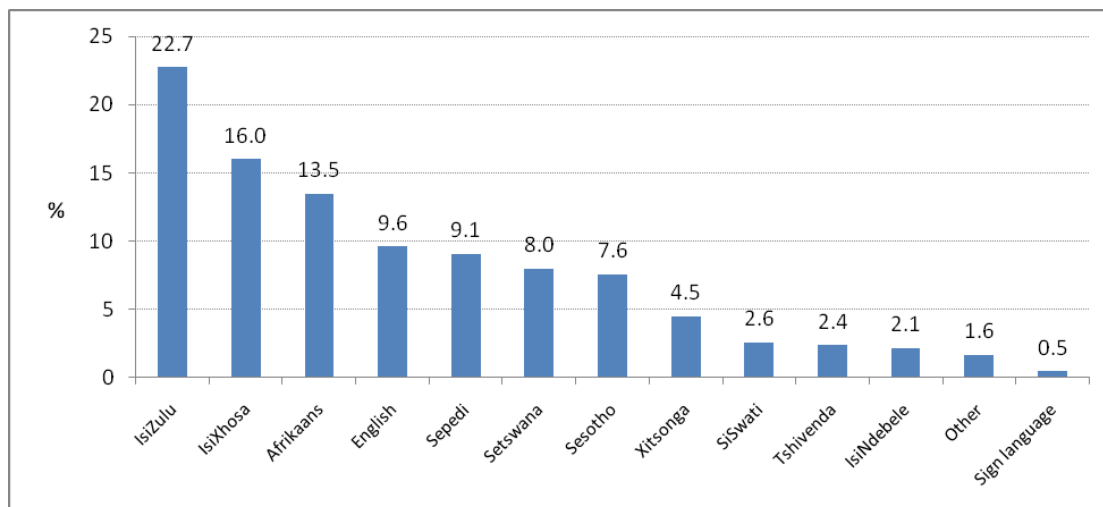
There is a rich literature and research into teaching and learning in multilingual contexts, (for example Adendorff, 1996; Baker, 2001, 2011; Blackledge & Creese, 2010; Canagarajah, 2011; Chick, 1996; Cummins, 2000; Ferguson, 2003; Garcia, 2009; Heugh, 2002, 2011; Hornberger, 1989; Macdonald, 1990a, 1990b; Lin & Martin, 2005; Makalela, 2015; McKinney, 2017; Rubagumya, 1994; Setati, Adler, Reed & Bapoo, 2002) much of which argues in favour of children learning through their home language or mother tongue – against predominant political forces and opinions – both in the north where societal multilingualism frequently results from immigration and speakers of languages other than the dominant social languages are often minority groups; and in the south in post-colonial contexts, where the speakers of languages other than the dominant societal and educational languages are in fact numerically in the majority. These voices in favour of children learning through their home languages base their arguments on the cognitive and affective benefits, which are backed by research. This literature and research is discussed in the following sections, in relation to the research problem.

### **South African linguistic context**

Classroom language practices in multilingual settings are nested within and shaped by particular language ecologies (Creese & Martin, 2008) including language policies, perceptions

and practices, which in turn have their roots in history, political contestation, social practices and economic realities. South Africa is no different in this respect.

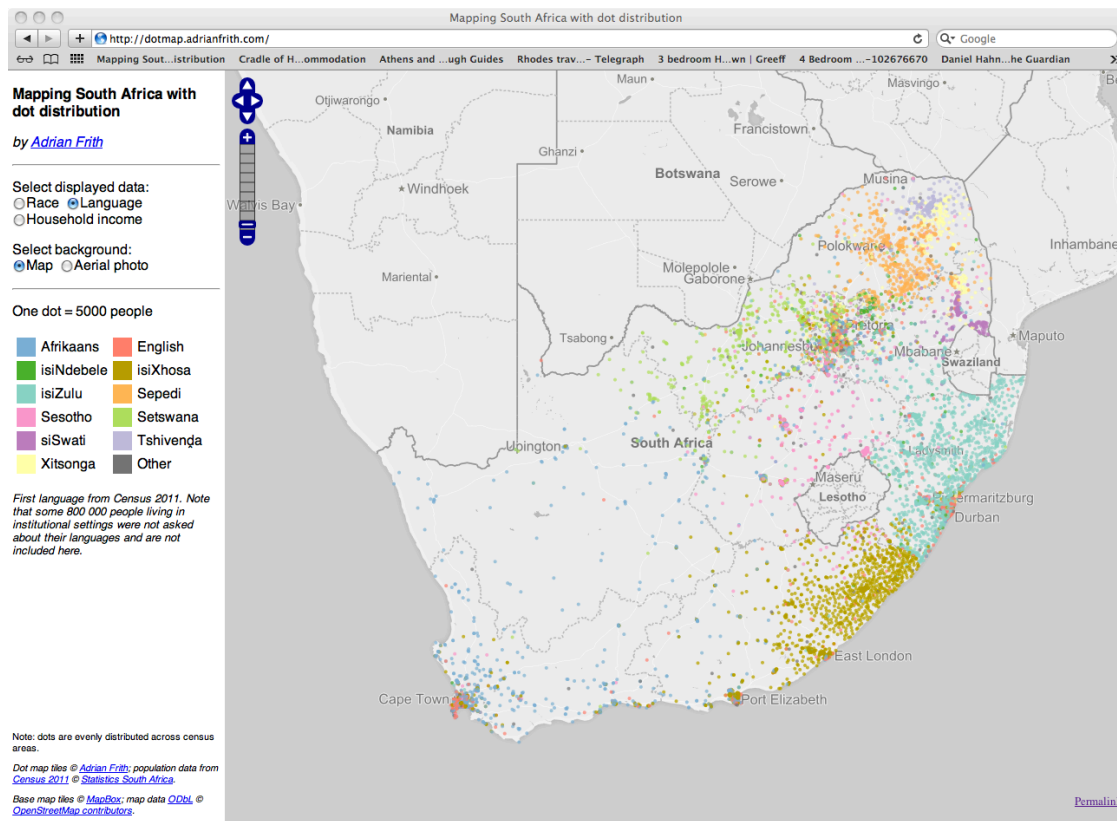
In South Africa, languages have been linked to historic political contestations and so language policies have reflected shifting power relations. Today, English is the home language of only 9,6% of the population (Statistics South Africa, 2012) (see Figure 2.1.) and yet, it is the language which dominates the political economy – despite the provisions of the South African Constitution of 1996 (Republic of South Africa, 1996) that conferred official language status on nine indigenous African languages, in addition to the former official languages of English and Afrikaans.



**Figure 2.1. Home languages of South African population, Census 2011 (Statistics South Africa, 2012)**

As the map in Figure 2.2. shows, the geographic distribution of languages today also retains much of the imprint of apartheid policies which restricted the movement of African language speakers – apart from those whose labour was required in the cities - to racially and linguistically defined homelands in rural areas. As a result, in rural and township areas such as in the Eastern Cape province where this research was conducted, communities are often still

relatively monolingual (Dempster & Reddy, 2007; Heugh, 2002), and learners have very little exposure to English outside the classroom, either in oral or written form. It is only in metropolitan areas that learners live in truly multilingual communities.



**Figure 2.2. Geographic distribution of languages, based on Census 2011 (Frith, n.d.)**

### Language-in-education policies and paradoxes

Hartshorne (1995) and Heugh (2008) have both provided detailed accounts of the development of current language in education policies and perceptions in South Africa, which carry the imprint of both colonial and apartheid histories and political struggles (see also Probyn, 2005).

Under apartheid, the different language policies for different race and linguistic groups meant that most English and Afrikaans speakers learned through the medium of their home language,

whereas African language speakers learned through the medium of their home language only for the initial years of schooling and then switched to English medium instruction.

As is well known, the Soweto Uprising of 1976, a watershed point in South African history, was sparked by student protests against proposals by the apartheid government to enforce the use of Afrikaans as a language of instruction alongside English from year seven (Standard 5). As a result of the protests, the government was forced to back down and the proposals for Afrikaans medium instruction were scrapped; and thereafter the switch from home language to English medium was set at the beginning of year five (Standard 3).

However Macdonald's (1990a) seminal research showed that learners in Standard 3 did not have the requisite English language skills in order to cope with learning through the medium of English: for example, by the end of Standard 2, after learning English as a subject for three years, learners could at best be expected to have an English vocabulary of 800 words; but in Standard 3 they would need a core vocabulary of about 5 000 words to cope with learning all their subjects through the medium of English (Macdonald and Burroughs, 1991, p. 15). This proficiency gap meant that the language medium became an obstacle to learning, one that Macdonald likened to 'swimming up the waterfall' (Macdonald, 1990b). The effect of this on teaching and learning was that teachers resorted to translating lesson content into the learners' home language and then giving them simplified notes in English to learn off by heart and regurgitate in tests. This was illustrated in a group interview with Grade 12 students about their experiences of switching to English medium instruction in Grade 5 (Probyn, 1995) (names have been changed):

Asanda: ... our teachers were not reading the textbook, they were writing notes for us with the simple English. Then after finish writing notes, they would explain those notes so that we can read the notes from our notebook, so that we understand it.

Interviewer: OK. Then how did you come to write your exams? 'Cause you had to write your exams in English? ....

Luvuyo: When I was in Std 3, we used to memorise the notes and we didn't know what, sort of the meaning of the words, we just memorised and closed the book...

Nomsa: Most of us done it.

Asanda: And the other thing, when you are going to write an exam, you see the question paper; when they give you the question paper, they [the teachers] translate the question paper into Xhosa so that you can know what is needed there so you can just rewind your memory and think of when the teacher explained those words to you, so that you can remember those things.

Luvuyo: We didn't write ... when they asked us a question and we are writing an exam, we just copy all ... we didn't write on our own to explain in our own words we just took the words from our notes.

The metaphor 'rewind your memory' seems to capture the process of rote learning particularly vividly.

The Language-in-Education Policy (LiEP) of 1997 (Department of Education, RSA, 1997) set out to address these problems and in line with the constitutional recognition of eleven official languages (Republic of South Africa, 1996), it sought to promote multilingualism as a means to inter-group communication and nation building. The LiEP stipulated that learners should study two of the official languages as subjects and one of these should be the language of learning and teaching (LoLT); it advocated an 'additive approach' to multilingualism in order that learners' home languages should be strongly maintained, preferably as the language of learning and teaching; and it suggested that this would be the policy most supportive of 'general conceptual growth amongst learners'.

The theoretical arguments in support of this position were drawn from the field of psycholinguistics – most notably in the work of Jim Cummins dating from the mid-1970s (see Cummins, 2000) who claimed that successful second/additional language learning should be based on strong proficiency in the learner's home language. Cummins argued that learning an additional language is different to learning a first language as generic language skills - such as understanding how to decode print – that are already in place in the home language, can be *transferred* to the additional language (Cummins, 2000); and that learners' prior knowledge was

likely to be encoded in their home language. So a sound grounding of both concepts and linguistic skills could be transferred from the learners' home language to the additional language; and learning in the home language would benefit the development of understanding and language skills in the additional language.

These ideas were supported by research evidence from Africa and the USA: in the 'Six-year Primary Project' in Nigeria (Bamgbose, 1991) where the use of the learners' Home Language as language of learning and teaching was extended from three to six years, this resulted in improved learning outcomes for learners in the six year programme, in their content knowledge *as well as their proficiency in English*, although English was learned as a subject, and not used as a LoLT (Heugh, 2011, p. 125).

In the USA, large-scale, longitudinal research by Thomas and Collier (2002) investigated the effects of different models of bilingual education on content and language learning. They found that the bilingual programmes that resulted in greatest learning achievement in terms of *both language and content*, were dual language programmes where learners learned through the medium of two languages.

More recent research in South Africa by Taylor and Coetzee (2013) came to similar conclusions: in a large scale longitudinal study covering the population of South African primary schools, it was found that learners who studied through the medium of their mother tongue for the first three years of school, performed better in English as an additional language in Grades 4, 5 and 6, than learners who had studied through the medium of English from Grade 1.

What is somewhat counter-intuitive in these findings is that although learners in these late exit transitional and dual language models spent *less time* learning through the medium of English than learners in the straight for English or early exit transitional models (three years or less of learning through their home language, followed by a switch to the majority language, English),

they achieved *higher levels of proficiency in English* as well as in their content subjects; and in the South African example, even learners who had been in the early exit transitional programmes, performed better in English than learners who had been in straight-for-English programmes. These findings appear to demolish the argument for learning through the medium of English from as early as possible so as to ensure higher levels of proficiency in English (time on task argument); and likewise to support Cummins' position on language transfer.

However in South Africa, the concept of additive bilingualism has not really been debated or well understood beyond the confines of academia. In terms of the Language in Education policy (Department of Education, RSA. 1997), decisions about school language policies have been devolved to school governing bodies, composed of parents and teachers, the trend in township and rural schools has been to introduce English as LoLT earlier (Probyn, Murray, Botha, Botya, Brooks & Westphal, 2002). It appears that the instrumental need to acquire English, and the assumption that time on task is the way to achieve this, paradoxically overrides a consideration of how this might limit learners' access to the curriculum and their academic success as a whole.

The result is that although only 7% of learners speak English at home, it is the chosen language of learning and teaching (LoLT) for 81% of learners from Grade 4 onwards, (Department of Basic Education, RSA, 2010, p. 16), with the majority of learners switching to English after an initial period of up to three years of learning in their home language. Yet for many African learners in township and rural schools, exposure to spoken and written English outside the classroom is limited; and the historic legacies of apartheid mean that few such schools have libraries and the necessary resources to support English learning.

As noted earlier, the South African TIMSS reports have suggested that the poor performance of the majority of learners was at least in part because of their poor proficiency in the language of the test when it was not their home language (Howie, 2001; Reddy, 2006, Prinsloo & Rogers, 2013). However, the poor reading literacy levels of Grade 4 and 5 learners *in their home*

*languages*, in the international PIRLS studies (Howie et al, 2008; Howie, van Staden, Tshele, Dowse & Zimmerman, 2012) point to the problem of literacy in general and the difficulties of disentangling causal factors for poor academic performance.

Public opinion as to the most suitable languages for learning and teaching are frequently expressed in the wake of poor results in national and international assessments (see for example, “Hobbled by inadequate English,” 2014). However academic opinion has remained divided on the issue with some advocating a straight for English approach on pragmatic grounds, particularly in the more multilingual urban contexts (for example, Vinjevold, 1999) while others have strongly argued for the benefits of home language LoLT - at least six years - followed by dual medium LoLT, in what has been termed ‘mother tongue based bilingual education’ (Heugh, 2002, 2011).

So the question of which language policies – and practices – are most supportive of the opportunity to learn, and/or pragmatically possible, remains highly contested and as yet unresolved.

#### **Classroom language practices: policy-practice gaps**

While much of the literature and language policy recommendations in multilingual contexts have been in favour of mother tongue based and bilingual education models, advocates of such policies and programmes have tended to adopt a negative view of codeswitching, or alternating between languages within the same lesson.

So in the literature on ‘dual language’ bilingual programmes, the recommendation is that languages should be strictly separated (Thomas & Collier, 2002, p. 126). This quite clearly relates to the negative effect that codeswitching might have on *language* learning as bilingualism is one of the principle goals of dual language programmes. The reasons given are that if learners anticipate that lesson content will be repeated in their home language, they will

tend to switch off when the teacher is explaining concepts in the additional language; and teachers will not develop language support strategies such as modifying their language use and using extra-linguistic support (Wong Fillmore, 1985); so this will compromise the very purpose for learning through the additional language, that is, acquisition of the additional language. Lindholm-Leary (2005) in a review of research and best practices in dual language programmes found in favour of monolingual lesson delivery (p. 14) and noted rather tartly: 'Some children in partial immersion programs have developed the strategy of looking confused when they have to respond in the second language because they have been reinforced for their confusion with some well-meaning adult who translates for the "poor child". Instructors who react in this manner discourage students from developing listening strategies in the second language.' (p. 18)

Recommendations for language in education policies in post-colonial Africa (Ouane & Glanz, 2011; UNESCO, 1953) have been in favour of mother tongue or home language LoLT, plus learning an international language of wider communication. Along with this has gone a negative view of classroom codeswitching – seen as an undesirable by-product of learning though an additional language; for example Benson (2004, p. 208) referred to 'unsystematic codeswitching i.e. bouncing between languages without clear goals.'

An objection to codeswitching frequently given in relation to *content* learning in transitional programmes has been that learners are assessed in the additional language and need to be able to understand and express the content in the language of assessment and the assumption is that learning concepts in their home language will undermine this process (see for example Alidou & Brock-Utne, 2011).

However there have been some counter voices in relation to dual language programmes such as Tikunoff (1985) who found that alternating between languages for clarity when students appeared puzzled, was one of five significant features of successful bilingual education. Genesee

(1987) also supported the use of the learners' 'native language' by both teachers and students, when necessary to clarify their message and when all else failed, but cautioned against overuse of this strategy 'as ultimately the success of second language learning depends on the learners having to rely exclusively on the target language for communication' (p. 182).

Nevertheless, as has been widely reported in the literature, in post-colonial contexts where a former colonial language is used as language medium in education, there is frequently a gap between the demands of the curriculum and learners' proficiency on the LoLT; and a resultant gap between policy expectations and practical classroom realities. In these contexts, teachers are very conscious of their responsibility to teach both lesson content and language; and of the tension between these objectives: Setati, Adler, Reed & Bapoo, (2002, p. 84) in the South African context referred to 'the dilemma between access to meaning and access to English'. Similarly, Wong Fillmore and Valadez (1986, p. 653), writing in the context of the USA, observed that two goals of bilingual education programmes - namely that of content and language learning - are, from a strictly practical perspective, in conflict; and that 'to accomplish both these goals at the same time ... requires that the competition between (them) ... be recognised and resolved.'

In such classrooms, as Macdonald (1990b) noted, the teacher's practice is moulded by the language proficiency of the learners; and a common pragmatic response is for teachers to switch to the learners' home language during classroom talk, to achieve a range of cognitive and affective goals, while reading, writing and assessment are conducted solely in the additional language - most commonly, English. Such policy-practice gaps and resultant bilingual practices have been described in the literature both internationally (see for example: Arthur, 1996 in Botswana; Lin, 1996, in Hong Kong; Clegg & Afitska, 2011 in sub-Saharan Africa; Martin, 1996, in Brunei; Merritt, Cleghorn, Abagi & Bunyi, 1992, in Kenya; and Martin-Jones, 2000 and Ferguson, 2003, for overviews); and in South Africa (see for example, 6, 1993; Probyn, 2001, 2006, 2009; Setati et al, 2002).

Despite such practices being widespread, classroom codeswitching has also tended to be regarded as a deficit classroom practice by educational authorities, and stigmatized as an indication of failure (Adendorff, 1996; Baker, 2001; Garcia, 2009; Setati et al, 2002; Probyn, 2009; Wei & Martin, 2009). Consequently codeswitching practices are frequently covert: for example in my own research a teacher referred to ‘smuggling the vernacular into the classroom’ (Probyn, 2009, p. 123) – an issue that was explored from an international perspective by Wei and Martin (2009).

Set against these largely negative attitudes towards codeswitching in the literature on bilingual education, is another body of literature coming from socio- and psycholinguistics that considered the naturally occurring language use in multilingual social settings, including classrooms in post-colonial contexts (for example: Adendorff, 1996; Canagarajah, 2011; Creese and Blackledge, 2010; Ferguson, 2003; Garcia, 2009; Hornberger, 1989; Lin, 2005; Martin, 2005; Martin-Jones, 2000; Probyn, 2005, 2009; Setati et al, 2002). Rather than taking a prescriptive view of what teachers should do in the classroom, these writers have examined how teachers and learners exploit the linguistic resources available to them to engage students in learning. Central to this research has been the study of classroom codeswitching, which has been regarded as a ‘communicative and pedagogic resource in bilingual contexts’ (Ferguson, 2009, p. 231). This marks a shift in attitude towards learners’ home languages in bilingual contexts, from that of a problem to that of a resource (Cummins, 2001).

In this field of research the focus has been on the documentation of the different patterns and functions of classroom codeswitching and responses of teachers to the tensions between policy demands and the learners’ language proficiency – most frequently in post-colonial settings (see for example Wei and Martin, 2009). In the same volume, Ferguson (2009, p. 232) summarized the main functional categories of classroom codeswitching in such contexts as broadly relating to:

- constructing and transmitting knowledge
- classroom management
- interpersonal relations

Recent writing in the field of bilingual education, reflecting the ‘multilingual turn’ (May, 2013), has challenged the monolingual assumptions underpinning the notion of bilingualism as the sum of two separate languages or ‘two solitudes’, as Cummins put it (Cummins, 2008, p. 588), but has instead taken the view that languages comprise a common linguistic resource that can be drawn on flexibly, including in classrooms. Accompanying this has been an acknowledgement of ‘the fluid ways in which languages are used’ in multilingual contexts – what Garcia (2009) has described as ‘linguaging’ (p. 23) and ‘translanguaging’ when it refers to moving between languages (see also for example Canagarajah, 2011; Creese and Blackledge, 2010; Makalela, 2015; McKinney, 2017). These ideas have parallels in the South African context with proposals for a ‘modified dual medium’ multilingual model made by Heugh (1995) in which she suggested that ‘teachers need to be flexible about when and where they alternate between the two languages of learning’ (p. 85). Unfortunately the models for bilingual education proposed by Heugh and others (see Heugh, Siegruhn & Pluddemann, 1995) have not been taken up by education authorities in South Africa.

As mentioned previously, Cummins has contributed the idea that language skills and ideas learned in the learner’s home language, can be transferred across languages to the additional language (Cummins, 2000, 2007):

(W)hen students’ L1 is involved as a cognitive and linguistic resource through bilingual instructional strategies, it can function as a stepping stone to scaffold more accomplished performance in the L2 (2007, p. 238).

Thus classroom translanguaging practices have come to be regarded as not only mirroring the authentic language practices outside the classroom, but also as cognitively sound practices within classrooms.

However, as Ferguson (2009) has pointed out, there is little research that examines the *learning effects* of such flexible bilingual practices in the classroom. He argued that if such research were to show that translanguaging/codeswitching practices at least did not have negative effects on additional language acquisition, it would defeat the arguments against such practices i.e. the 'time on task' argument against the use of learners' home language when the LoLT is an additional language.

In addition, Ferguson (2009) made the point that translanguaging/codeswitching practices vary widely in terms of the balance of languages used, the base-language, and direction of switches; and claims that these variables would make for different learning effects.

The consensus appears to be that although codeswitching is a common practice in bilingual classrooms, it is rarely a pre-determined teaching and learning strategy (Adendorff, 1996; Baker, 2001, p. 279; Clegg & Afitska, 2011; Ferguson, 2003; Probyn, 2001), but rather a 'pragmatic response to the local classroom context' (Blackledge & Creese, 2010, p. 203); and so there have been calls for such flexible bilingual language use to be developed into a systematic and planned pedagogical strategy and for such language strategies to be included in teacher training programmes (Alidou & Brock-Utne, 2011; Benson, 2004; Ferguson, 2009; Probyn, 2006; Setati et al, 2002).

#### **Language practices in bilingual classrooms: clarifying terminology**

At this point it seems useful to attempt to clarify the various terms used to describe language use in the classroom and to fix the meanings, at least for the purposes of this research. Up to this point, the terms have been used as they appear in the literature.

As is widely reported in the literature, in multilingual classrooms teachers and learners frequently draw on more than one language for a range of functions; and these practices may be part of a planned bilingual curriculum or may arise fairly spontaneously in response to particular needs. It seems that the term *language alternation* as used by Clegg & Afitska (2011, p. 62) is a useful way of describing switches between languages in general.

Lewis, Jones & Baker (2012a. and 2012b.) explored more recent developments in the literature on bilingualism, in terms of both terminology and ideology; and usefully distinguished between the terms '*codeswitching*,' and '*translation*;' and the more recent concept of '*translanguaging*.'

Classroom '*codeswitching*' has generally referred to relatively short switches from the official LoLT to another language, usually the learners' home language, and back again (Clegg & Afitska, p. 62). However it has also on occasion been used fairly loosely to refer to all forms of language alternation in bilingual contexts, not only in classrooms. In this research, the term is limited to the former meaning: switches between languages of relatively short duration. '*Translation*' in the bilingual classroom refers to repetition by the teacher of lesson content or instructions in the learners' home language. Both these forms of language alternation may occur in bilingual educational settings where they have been regarded, at best, as temporary deviations from a monolingual ideal, in contexts where '*monolingual ideologies hover over the classroom*' (Wei & Martin 2009, p. 119).

As mentioned, more recent literature on the matter has reframed bilingual classroom practices in terms of '*translanguaging*,' defined by Baker (2011) as '*the process of making meaning, shaping experiences, understandings and knowledge through two languages. Both languages are used in an *integrated and coherent* way to organize and mediate mental processes in learning*' (p. 288) (own emphasis). The term '*translanguaging*' was originally used in relation to Welsh bilingual education programmes, where the teacher used both English and Welsh in the classroom and varied the two languages for input and output activities, in the interests of

developing bilingual language proficiency as well as for the perceived cognitive benefits (Williams, 1996 in Lewis et al 2012a).

However as Lewis et al (2012a) noted, the original term ‘translanguaging’ has been taken ‘from school to street and beyond’ by Baker (2011) Canagarajah (2011), Creese and Blackledge (2010) Garcia (2009), Hornberger and Link (2012) and others, to encompass societal bilingual practices more generally, as well as to refer to a range of bilingual practices in the classroom.

Clegg and Afitska (2011), in writing about language alternation in African classrooms, made a very useful distinction between codeswitching, translation as well as longer stretches of monolingual talk by teachers or learners in either language, which might vary according to the learning activity, with the learners’ home language frequently used for exploratory talk and the official LoLT for presentational talk. I propose to term the latter form of language alternation in classrooms as translanguaging, as it seems to me to be distinguished in form, function and ideological orientation from classroom codeswitching and translation. Whereas codeswitching and translation reflect a temporary deviation from a monolingual ideal, the notion of translanguaging reflects acceptance of a heteroglossic, multilingual reality and a more comprehensive and flexible use of the classroom language resources to mediate learning. As Lewis et al, (2012 b) note, the difference between codeswitching and translanguaging is in part ideological as

code-switching has associations with language separation, while translanguaging celebrates and approves flexibility in language use and the permeability of learning through two or more languages. Particularly in the bilingual classrooms, translanguaging as a concept tries to move acceptable practice away from language separation, and thus has ideological – even political – associations’ (p. 659).

What the concept translanguaging usefully allows is to pull together concepts from the field of bilingualism and map them onto concepts from the field of classroom discourse; to examine

longer stretches of classroom discourse and the bilingual practices within them; and to explore the possible learning benefits of such practices.

Lewis et al (2012b) noted too that translanguaging is ‘an emergent educational concept’ (p. 667) and that ‘a wealth of future research is needed to establish when, where, and how translanguaging is a suitable teaching approach.’ (2012a. p. 651). The concept of translanguaging is one that has recently been taken up in South African classroom-based research (see Makalela, 2015; McKinney, 2017, Probyn, 2015). This research study is a further contribution to such to the development of the emergent educational concept of translanguaging and what it might mean in classroom practice.

## Summary

While language policies and paradoxes in the South African context frame this research, it is beyond the scope of this study to explore and/or recommend alternative policies, so the discussion has been confined to exploring teachers’ practices within these policy constraints. The situation is that in Grade 8, the majority of learners learn through the medium of an additional language; and very many learners do not have the necessary proficiency in the LoLT to adequately access the curriculum. So the question how teachers mediate learning under such conditions, looms large in a consideration of opportunity to learn in Grade 8 science classrooms.

It appears that a reorientation from a view of bilingualism as ‘monolingualism times two’, (Garcia, 2009, p. 71) along with the notion of the ideal of the strict separation of languages in the classroom, to a more heteroglossic view of languages as resources to be used flexibly in response to learners’ needs, might open up pathways to more effective practices.

Debates and research on language and learning in South Africa have been dominated by these questions of language policies and practices in terms of the language/s of learning and teaching. This has tended to overshadow a related aspect of language and learning, namely the nature of

the classroom discourse and how teachers and learners engage in constructing knowledge through classroom talk – an aspect that has received considerable attention in contexts that are generally more linguistically homogenous. What this study of language and the opportunity to learn science attempts to do is to draw together these two different perspectives in the literature on language and learning: those of classroom discourse and of bilingual/multilingual classroom practices.

What follows in the next section therefore, is a discussion of the theories and research relating to classroom discourse and the construction of science knowledge.

### **Classroom discourse**

As stated, the broad theoretical framework for this research is that of a socio-cultural approach to language and learning that encompasses learning in general (see Alexander, 2001, 2006; Barnes, 1976, 1992; Mercer, 1995; Wells, 1999) and learning science in particular (see Lemke, 1990; Martin, 1990; Ogborn, Kress, Martins & McGillicuddy, 1996; Mortimer & Scott, 2003; Sutton, 1992; Wellington & Osborne, 2001).

The literature on classroom discourse covers a wide range of perspectives: linguistic, psychological, sociological and educational and there have also been useful cross-disciplinary perspectives: for example Wells has drawn on both socio-cultural theory and systemic functional linguistics in the work of Vygotsky and Halliday to argue for the complementary contribution of these theories to a 'language-based theory of learning' (Wells, 1999); Christie and others in the systemic functional linguistics field have engaged with the sociology of Basil Bernstein in examining and explaining classroom discourse and learning (Christie, 2002); and Gibbons draws on the complementary insights of systemic functional linguistics, Bernsteinian theory, socio-cultural theory and second language acquisition theory in analyzing classroom discourse and the process of learning (Gibbons, 2006).

The focus of this research is primarily educational rather than linguistic: how science knowledge is constructed by teachers and learners through the classroom discourse and whether the discourse practices of teachers and learners appear to increase or diminish the opportunity to learn science. As Edwards and Mercer (1987) have noted: 'it is essentially in the discourse between teacher and pupils that education is done, or fails to be done' (p. 101). This means too that the focus of the analysis is on both the science content and the discourse patterns.

### Teacher-learner talk

Ground breaking work by Barnes (1976, 1992), from a socio-cultural perspective, arose from concerns about the domination of teacher talk in lessons; and argued for the importance of pupil talk in learning. Barnes drew an important distinction between the functions of 'exploratory talk' by learners where the focus is on sorting out their own ideas, and 'presentational talk' when they offer a 'final draft' for display and evaluation; and pointed out the importance of both at different stages in a lesson. Later work in this line (see for example: Alexander, 2001; Gibbons, 2006; Mercer, 1995, Mortimer & Scott, 2003; Wells, 1999) meshed with work from linguistics on classroom discourse interaction patterns, to identify patterns of interaction that appeared most supportive of learning.

### Patterns of classroom interaction

Linguistic research that was primarily interested in the structure and turn taking patterns in the particular context of classrooms, identified the dominant pattern of classroom interaction as that of teacher-led question and answer, with an 'initiation (question by teacher), response (by learner) and evaluation (by teacher) - commonly known as IRE exchanges (Mehan, 1979), sometimes as initiation, response, feedback (IRF) from Sinclair and Coulthard (1975); and as 'triadic dialogue' by Lemke (1990). An example might be:

- (1) Teacher: What are the elements making up water?

(R) Learner: Hydrogen and oxygen.

(E) Teacher: Right.

This tightly controlled pattern of classroom interaction has been strongly criticised by some education researchers for limiting learners' participation and thinking (see Wells, 1999 p. 167-168 for a discussion of this).

A reevaluation of the negative perceptions of the dominant IRE pattern of classroom interaction was proposed by Wells (1999) who suggested that the third turn in such triadic dialogue - the 'evaluation' (E) move - could be modified as 'feedback' (F); so that rather than closing down a student's participation with an evaluation, the teacher could instead utilize this move to build on the student's response by requesting the student to clarify, exemplify, expand, explain or justify their response, and so provide the point of departure for the next IRF triad (e.g. IRFRFRF ...). It is through this 'contingent responsiveness' to learners' contributions, that the feedback move functions as a pivot in chaining and expanding the basic IRF exchange into a 'genuine dialogic co-construction of meaning'. In this way the teacher could be regarded as 'working on understanding within the student's Zone of Proximal Development' (p. 86).

Subsequently, Alexander's work on dialogic teaching (2006) has prompted a reappraisal of such whole class dialogue that 'chains ideas into coherent lines of thinking', enabling teachers to engage learners in linking of facts and observations through argument into conceptual frameworks in what amounts to reasoning aloud - a critical aspect of content coherence. Alexander described the dialogic classroom talk as 'collective, reciprocal and supportive' and 'concerned with the *conduct* and *ethos* of classroom talk', as well as being 'purposeful and cumulative' in terms of the lesson content (Alexander, 2006 p. 49).

Alexander referred to this kind of classroom discourse as 'scaffolded dialogue' (2000, pp. 526-527); Gibbons as 'dialogic exchanges' (2006 pp. 116-117); Mercer and Littleton as 'reasoned

dialogue' (2007, p. 133); and Mortimer and Scott as 'interactive-dialogic' approaches (2003, p. 105). Such structured whole class talk enacts a visible pedagogy that is convergent; the class is treated as a single unit and the responses of individual learners are taken to represent the levels of understanding of the whole class (Alexander 2001, p. 428).

Alexander along with prominent educational researchers in the field of classroom discourse (see for example, Gibbons, 2006; Mercer & Littleton, 2007; Mortimer & Scott 2003) have rejected simplistic dichotomies between teacher-centred and learner-centred approaches, instead claiming that teachers need to develop a range of discourse repertoires; and that in science lessons for example, different patterns of classroom discourse and interaction function for different purposes at different points in a lesson – and the key question is whether interaction patterns in the discourse are appropriate for the stage and learning purpose in a lesson.

In the context of science lessons, Mortimer and Scott (2003) pointed out that practical work does not speak for itself, and it is in the interactive talk during and following practical activities that the learning of the science concepts takes place (p. 1). However, while it is important for learners to have the opportunity to discuss their own ideas, they 'will not stumble upon, or discover, the key concepts ... of science for themselves' and they need an 'authoritative introduction to the scientific point of view' (p. 106). So 'there will always be a tension between dialogic and authoritative discourse and a key part of the teacher's role is to strike an effective balance between [the two]' (pp. 106–107).

Based on the above understandings, Gibbons (2006, p. 114) proposed a range of possible classroom discourse interaction patterns on a cline from least to most learner participation:

- teacher monologue where the teacher does not seek verbal responses from students;

- IRF (Initiation-response-feedback) where the teacher seeks one word or brief answers from students;
- dialogic exchanges where IRF exchanges are chained into semantically linked sequences and depend on the contingent responses of the teacher;
- participatory exchanges where agenda is shaped by all participants – mainly in group work.

Another form of classroom interaction that is particularly prevalent in post-colonial contexts where the language of learning and teaching is an additional language (usually the formerly colonial language), has been described as 'oral cloze' (Cath & McLellan, 1993 cited in Martin, 1996): that is, when a teacher asks a class a question and cues the response - very often by leaving out a word for a learner or the whole class to fill in and signaled by a rising, questioning tone. This functions as part of 'ritualised participation strategies, designed to keep the students involved rather than requiring an answer to a question' (Hardman, 2008 p. 139); and as Macdonald (1990a) and Chick (1996) have pointed out, it enables learners to participate in a lesson without necessarily understanding the lesson content; for this reason Chick referred to this kind of classroom interaction as 'safe-talk' as he claimed it allowed teachers and learners to maintain an appearance of participating in teaching and learning, without exposing their lack of subject knowledge or language proficiency. There are some differences in the literature as to the term used for this type of practice: for example Macdonald referred to 'Rote Rhythm' (1990a. p. 143); and Gibbons (2006) and Hardman (2008) have referred to it as a form of 'cued elicitation'; I propose to stick to the term used by Martin (1996) and others, namely 'oral cloze' as it seems to capture the purpose more accurately. On Gibbons' cline it would fit in between 'teacher monologue' and IRF.

As Gibbons (2006) pointed out, a science lesson would follow fairly predictable stages, in what she referred to as a 'curriculum macro-genre' (p. 101, following Christie, 1995), with different forms of classroom organization and patterns of interaction at different stages:

Stage 1: review and orientation (whole class activity)

Stage 2: setting up new task (whole class activity)

Stage 3: carrying out task (group activity)

Stage 4: reflection on task and making sense of what has been done - identifying scientific principles (whole class activity)

Stage 5: (optional stage) Written work based on 4. (individual or group activity)

So in Stage 1, the predominant discourse structure might well be that of a brisk IRE/F exchange, as the teacher reviews and checks on prior understandings; in Stage 2, a teacher monologue might predominate as the teacher gives instructions; Stage 3 would mainly involve learners in participatory exchanges, with some input from the teacher; and the fourth stage - reflecting on the practical task - is where the dialogic exchanges would engage learners in making sense of the practical experience and recontextualising it in terms of science knowledge, following an explanatory arc of description - explanation - generalization (Mortimer and Scott, 2003, p. 26). The final writing stage of the lesson, would involve learners in a shift across the mode continuum, in consolidating and applying the ideas that had been developed orally.

### **Building conceptual coherence through the discourse**

In the section on science content, reference was made to the importance of lesson coherence in learning with understanding: that is, linking and organizing of facts into generalized conceptual frameworks, and the supporting of conceptual frameworks with rich factual detail (Donovan & Bransford, 2005). It would seem that this coherence of lesson content, would be achieved at the

fourth stage of the lesson, when the teacher engaged and guided learners in developing the scientific argument, through dialogic exchanges. Likewise, it would seem that in classrooms where there is not evidence of dialogic discourse at this point in the lesson, it is likely that lesson content would be left as fragmented bits of information: one can conclude therefore that dialogic discourse would be a necessary condition for engaging learners in developing conceptual frameworks and understanding; and developing a vertical knowledge structure in science lessons.

Alexander (2006) makes the additional point about such classroom discourse that forms the basis of what he terms dialogic teaching, namely that it is *cumulative*, with ideas and meaning linked both within and across lessons – referring to what Mercer and Littleton (2007) have identified as the temporal nature of classroom discourse. This means that in order to investigate the development and cumulation of ideas within and across lessons, it is necessary to study stretches of discourse that are long enough to encompass a teaching-learning cycle, or ‘coherent acts of *teaching*’ (Alexander, 2000, p. 439) starting with the introduction of a new concept, to an assessment of what has been learned (see also Christie, 2002, p. 23; Gibbons, 2006; Mercer & Littleton, 2007; Mortimer & Scott, 2003).

For teachers to engage learners in such classroom discourse practices, it is necessary that teachers have in-depth subject knowledge, so as to be able to deviate from a narrow lesson script when required, in order to be contingently responsive to learners’ contributions. Carlsen (1992) for example, showed that when teachers did not have sufficient subject knowledge they were not able to develop concepts in a dialogic and interactive manner.

### **Bridging discourses**

So, on the one hand, classroom discourse is the means through which the vertical knowledge structure of science may be constructed by teachers and learners; but also, it may serve to

bridge the gap between the learners' home language and school language in general; and the language of school science in particular. Lin (2012) provides a useful summary

As described earlier, science knowledge constitutes an uncommonsense view of the world; and the language knowledge and skills necessary for learning in school in general, and for learning science in particular, are generally very different to the everyday knowledge and language that learners bring with them to school.

Bernstein and others have shown that the gap between 'community code' and 'school code' (Taylor, Muller and Vinjevd, 2003) is generally greater for learners from poorer socio-economic backgrounds than those from middle-class backgrounds. Cummins (2000) has usefully described the kind of oral language knowledge and skills that learners bring to school as 'Basic Interpersonal Communication Skills (BICS)' – which operate in a face-to-face situation and as such are 'context-embedded'; and contrasts these with the 'Cognitive Academic Language Proficiency (CALP)' that is required by schooling and which operates in a situation that is abstracted from immediate experience – 'context-reduced' – and marks a shift along the mode from a more spoken-like form, along a continuum to a more written-like form.

In addition to this general shift from 'BICS' to 'CALP,' learners have to master the particular discourse of science, which (as described earlier) is different to everyday language in that it employs a wide range of specialized terminology, as well as utilizing everyday terms with new specialized meanings. Science discourse is also lexically dense, partly through the grammatical process of nominalization, which makes it particularly challenging for learners to read and write (Lemke, 1990; Martin, 1990; Mortimer & Scott, 2003; Ogborn et al, 1996; Sutton, 1992; Wellington & Osborne, 2001). In addition science is expressed through particular written genres such as procedures, explanations, reports and arguments, which are structured differently to the written genres that children are most familiar with such as recounts and narratives (Martin, 1990).

The nature of science knowledge is that it is empirically based and so learners also need to bridge the gap between observation of particular phenomena, to understanding how these observations relate to generalised principles and broader conceptual frameworks and are linked into a vertically structured body of knowledge. These scientific concepts are frequently at odds with learners' existing common sense understandings, which are sometimes hard to displace (Mortimer & Scott, 2003).

The challenges of bridging the gap between community language and school language; and everyday language and science language apply to all learners, irrespective of their particular home language. But when learners are learning through the medium of a language that is not their home language, there is an additional linguistic challenge – as is the case for the majority of learners in South Africa.

Research by Gibbons (2006) has shown how good teachers orchestrate a 'bridging discourse' in order to support learners as they move along the oral to written mode continuum: from face-to-face, context-embedded talk around practical activities, that utilises everyday knowledge and language – what Bernstein has referred to as *horizontal discourse* - to using more abstract, context-reduced, generalised, scientific knowledge and language – Bernstein's *vertical discourse* (O'Halloran, 2007).

In addition, in the multilingual South African context, many teachers utilize the learners' home language as a bridge to understanding the lesson content in English. Setati et al (2002) described this 'journey' from 'informal' exploratory talk in the learners' home language to 'formal written science discourse in English, as following a range of possible paths. This is closely echoed by Lin (2012, p. 93) in the multilingual context of Hong Kong, where she refers to the notion of 'bridging resources' in multilingual classrooms and different possible pathways from L1 everyday oral language to L2 academic written language.

As already discussed, language in education policies and practices are an important and fiercely debated issue in South Africa, and so the bilingual aspects of bridging discourses have been dealt with separately in the analysis of the data.

### Research into language and learning

Much of the research on classroom discourse and learning has been based in the UK, building on the work of Barnes (1976, 1992) (see Mercer & Hodgkinson, 2008; Mercer, 1995; Scott, 1998; Wells, 1999). Alexander's magnum opus – a comparative cross cultural study of teaching in classrooms in five countries (2001) led to a renewed focus on 'dialogic' whole class teaching.

Gibbons (2006) in Australia provided a very useful research model in that she analysed the discourse patterns and science content across whole lessons, with a particular focus on what she termed 'bridging discourses' that supported learners in bridging the gap between everyday knowledge and language; and science knowledge and language, while also moving across the mode continuum from speaking to writing.

However, although many of the learners in the UK studies, and Gibbons' study were second language speakers of English, there was not a specific focus in these studies of the learners' home language and its role in learning. Research studies with a specific bilingual focus (for example: Benson, 2004; Canagarajah, 2011; Creese & Blackledge, 2010; Cummins, 2000, 2008; Ferguson, 2003, 2009; Garcia, 2009; Hornberger, 1989; Martin, 1996) have also tended not to take the structure of classroom discourse into account.

In South Africa, there has been much research on classroom codeswitching (for example: Adendorff, 1996; Macdonald 1990a & b, 1991; Probyn, 2001, 2006, 2009; Setati, et al., 2002, Rollnick, 2000) but less on classroom discourse that has looked explicitly at the construction of knowledge. Macdonald's focus was on the limitations that the switch to English in Grade 5 placed on teaching and learning and she identified a discourse structure – Rote Rhythm - that

appeared common in South Africa as well as other post-colonial contexts where learners learn through the medium of a poorly acquired former colonial language (Arthur, 1996; Benson, 2004, Chick, 1996). Setati et al (2002) described classroom codeswitching as a 'dilemma-filled' practice and also noted that teachers needed to bridge the gap between home language/everyday language and the particular subject discourses of schooling; and that this 'journey' might proceed along a range of possible paths. However this research did not include a detailed analysis of classroom discourse, except to note that the journey from oral everyday knowledge in the learners' home language to written, subject specific discourse in English was rarely completed, with lessons most often shifting abruptly from group discussion in the learners' home language to teacher exposition in English. So it appears that there is a gap in terms of research in South Africa and internationally, that examines the construction of science knowledge through the classroom discourse in bilingual contexts; and what language practices might offer the best opportunities to learn science – a gap that this research seeks to fill.

## Summary

Necessary conditions for the opportunity to learn OTL science are that the science content presented in lessons, should be empirically based, with real world application; and that it should be accurate, and appropriately paced. However, these factors are not sufficient; and for learning with understanding, the science content of lessons also needs to be coherent: that is, science facts need to be linked through argument into conceptual frameworks; and conceptual frameworks need to be supported by rich factual detail (Donovan & Bransford, 2005; Shalem & Slonimsky, 2010).

This vertical structuring of science facts into coherent conceptual frameworks seems best achieved through engaging learners in extended stretches of dialogic discourse, at the point in the lesson when making sense of empirical observations and evidence, and making links to everyday applications. But as Alexander (2006), Gibbons (2006) and Mortimer and Scott (2003)

have noted, dialogic discourse is appropriate at the sense-making stage of a lesson; but it is one of a range of possible discourse strategies; and teachers will shift between authoritative and dialogic discourse patterns at different stages in a lesson.

In addition to constructing with learners the vertical content knowledge of science, teachers need to help learners to make links between the language of home and the language of schooling in general, and the language of science in particular. In the complex bilingual contexts such as exist in township and rural schools in South Africa, the challenges of bridging knowledge and discourses from home to school are greatly increased. A distinction between the notions of codeswitching and translanguaging seems helpful in a consideration of the opportunity to learn in these classrooms.

The theories and research from the literature form the framework for the analysis of language and the opportunity to learn science in the observed classrooms, and the discussion of the research findings, in the chapters that follow.

## CHAPTER THREE: RESEARCH METHODOLOGY

This chapter describes the research methodology employed to answer the research questions presented in chapter one. The questions are reiterated below for ease of reference:

The main research question that guided this research was as follows:

In what ways did the lesson content and the classroom language practices combine to construct or constrain the opportunity to learn science?

Subsidiary questions that followed were:

- What was the nature of the science content knowledge that was developed in the observed lessons?
  - What types of science content knowledge were presented in the observed lessons?
  - What were the sources of the science content knowledge in the observed lessons?
  - How accurate was the science content knowledge that was presented in the observed lessons?
  - How much science content knowledge was there in the observed lessons?
  - How coherent was the science content knowledge between and within the observed lessons?
- Did the classroom discourse appear to support or constrain the learners' opportunities to learn science?
  - What was the relative balance of teacher-learner talk?
  - What were the predominant discourse interaction patterns in the lessons and in what ways did they engage learners in developing science knowledge?

- What bridging discourses did the teacher engage learners in to bridge the gaps between everyday knowledge and language and science knowledge and language; between practical and theoretical knowledge; and between spoken and written language?
- Did the languaging practices of teachers and learners appear to support or constrain the learners' opportunities to learn science?
  - How did teachers and learners utilize the available linguistic resources of isiXhosa and English to access and develop science knowledge?

### Research approach

The large-scale TIMSS studies of 1998/99 (Howie, 2001) and 2003 (Reddy, 2006) provided the backdrop to this research study in that they assessed South African Grade 8 learners in mathematics and science, in comparison to learners internationally. The poor performance of South African learners in these and successive assessment studies has been cause for much concern; and questions have been raised as to the possible causes. An obvious question to ask, in line with a key concept coming out of the successive IEA studies such as TIMMS (see McDonnell, 1995), is: did the South African Grade 8 learners in fact have the opportunity to learn science? Although the TIMSS studies internationally provided data about the contexts of teachers, learners and schools, which provided some indication of opportunity to learn, this data was collected by means of questionnaires and there was no direct observation of classroom practices to shed light on the 'black box' of the implemented curriculum.

This shortcoming prompted the TIMSS Video Studies for mathematics (Hiebert et al, 2003) and science (Roth et al, 2006), which as their titles suggest, used videotapes of mathematics and science lessons in seven and five countries respectively, to identify and compare opportunity to learn mathematics and science. These studies provided a stimulus and starting point for my own research and analysis, as discussed later.

As Cohen, Manion and Morrison (2007) have noted, case studies can provide the kind of fine-grained analysis to complement large-scale quantitative studies (p. 255; see also Robson, 2007 p. 255). On account of their small-scale, in-depth nature, case studies fall into the broad qualitative research paradigm. The term case study has been used to describe a wide range of research purposes and designs (Bassegy, 1999 p. 57): these include what Bassegy refers to as 'educational' case studies - those concerned with the understanding of educational action; and 'explanatory' case studies that 'present(s) data bearing on cause-effect relationships' (Yin, 1993 in Bassegy, 1999 p. 29). Bassegy (1999) has argued for educational case studies as a 'prime strategy for developing educational theory which illuminates educational policy and enhances educational practice' (p. 57), and according to Adelman et al (in Cohen, Manion & Morrison, 2007 p. 256) case studies can be 'a step to action.'

As my concerns were to understand educational action and the effects thereof; and to enhance educational practice through this understanding, an educational, explanatory case study seemed the most appropriate research strategy. In addition, as Stake (1994 in Cohen, Manion & Morrison, 2007) has pointed out, case studies may be concerned with individual cases, or with multiple cases to gain a fuller picture; and as the latter was my intention, I decided to undertake a multiple case study of eight Grade 8 science classes.

Accordingly, this research study could be best be described as a multiple, educational, explanatory case study, aimed at providing a fine-grained analysis of eight Grade 8 science classrooms in bilingual rural and township schools in the Eastern Cape Province, in order to investigate the opportunity to learn science in these classrooms.

The concept 'opportunity to learn' has been discussed and justified in chapter one; this concept provided the overarching theoretical framework for this study. In this study, 'opportunity to learn' has been analysed from two complementary perspectives: the *science content* of the observed lessons, and the *language* used to construct this science knowledge. In turn, the

classroom language has been considered from two further perspectives: that of the interaction patterns in the *classroom discourse*, and the teachers' and learners' use of the *bilingual linguistic resources* available to them.

This dual focus on lesson content and language used to construct that content, falls into the broad socio-cultural framework that draws on the original work of Vygotsky (1962) and is centred on language and learning in social contexts. Researchers in this field such as Alexander (2000), Christie (2002), Gibbons (2006), Mercer and Littleton (2007), Mortimer and Scott (2003), all have made the point that much of the linguistic research on classroom discourse has tended to focus on pedagogy and the surface patterns of classroom interactions, based on relatively short extracts from lesson transcripts, while glossing over the meaning or content of lessons. This has prompted calls for the study of longer stretches of classroom discourse, where meanings are constructed over time and across lessons. Hence in this study, the main - set consisted of a series of five consecutive science lessons per teacher; and the analysis has made use of fairly lengthy extracts from lesson transcriptions 'which allows them to be read and understood as coherent acts of *teaching*, not disembodied instances of pedagogical talk ... ' (Alexander, 2000, p. 439; original emphasis).

Mercer (2010) coined the term 'socio-cultural discourse analysis' which he described as being concerned with the 'content and function' of spoken language, and the 'ways shared understanding is developed, in social context, over time'. Reports of such research are usually illustrated by selected transcripts of talk, to which the analyst provides a commentary; and this qualitative data is then integrated with quantitative analysis (p. 9). Similarly, this study includes both qualitative and quantitative analysis of data, with examples drawn from lesson transcripts used to illustrate frequency counts of particular indicators, so as to be able to draw some comparisons between cases.

So, to sum up, this research study can be described as a qualitative, educational, exploratory, multiple case study of eight Grade 8 science classrooms, utilising 'socio-cultural discourse analysis' (Mercer, 2010) of classroom interactions in the observed lessons, to arrive at some understanding of the intersection of language and science content as aspects of the 'opportunity to learn science'.

## Research design

### Research sites and sampling

As outlined in chapter one, The Eastern Cape Province, where this research was conducted, is one of the poorest and most populous rural provinces in South Africa, with one of the weakest performances in the TIMSS studies in both mathematics and science (Howie, 2001; Reddy, 2006).

As described, my particular focus on classrooms in the two rural districts and one peri-urban one in the Eastern Cape Province was a pragmatic choice, as I was already working with in-service English teachers in these districts and so had an established network of contacts I could call upon. At the same time, my entree to these districts provided a unique opportunity to investigate teaching and learning in contexts which are the most challenging and least researched; and to find out what competent teachers *can* do in such contexts.

As the TIMSS studies of Grade 8 science and mathematics (Howie, 2001; Reddy, 2006), provided the quantitative contextual data for this research, Grade 8 science teachers were chosen for this study. A further criterion was that teachers should be fluent speakers of isiXhosa as this matched the provincial linguistic profile, where the majority of teachers and learners share a common home language, isiXhosa, while the language of learning and teaching is most often English from at least Grade 4. This is also a typical linguistic situation in many parts of the country, particularly in rural areas (Heugh, 2002; Setati et al, 2002).

The decision to include eight teachers in the study was a pragmatic one based on what was considered doable in terms of data collection over the course of one year, given work and time constraints, as the research was conducted on a part-time basis. I considered that eight case studies would provide enough data to provide a fairly solid basis for the research.

My selection of teachers was purposeful as I attempted to identify 'excellent' teachers, through the science subject advisors in the district offices. The decision to use 'excellence' as a criterion was intended to steer the research away from classrooms where teaching and learning had broken down and thus to reduce variables related to teacher proficiency, that might impact negatively on 'opportunities to learn' science. I recognize that the definition of 'excellent' is somewhat problematic, but I anticipated that the recommended teachers would be those at least recognized as competent and committed by the subject advisors and their colleagues; and so it could be claimed that they were selected on the basis of their good reputations.

As is often the case, the research design was a compromise between the ideal and the possible.

#### **Access to research sites**

I negotiated access to the districts by getting written permission from the Eastern Cape Department of Education at a provincial level. Then at district level, I made appointments with the respective district managers to explain the purpose and scope of the proposed research and I provided them with an outline of the research purposes and intended processes. The district managers in turn referred me to the district science subject advisors, whom I also met and I again explained the purpose and scope of the research and provided the same research outline. They were all interested and supportive of the research; and I requested them to nominate 'excellent' science teachers in their districts. I then approached the school principals and teachers concerned with letters requesting their participation and copies of the research outline; and arranged to meet with them to discuss the contents of the documents, before

requesting their participation, in line with the ethical requirement of informed consent. The research proposal received ethical clearance from the University of Cape Town.

All the teachers who were approached, graciously agreed to participate in the research and claimed to welcome the opportunity to be observed and discuss their teaching practices. In line with the ethical principal of anonymity, teachers were allocated pseudonyms and were located as follows: Teachers A, B, C, D, and G were located in rural schools and Teachers E, F and H in township schools.

### **Data collection methods**

In order to answer the research questions, different kinds of data were collected through various data collection methods.

### ***Lesson observation***

In order to investigate how science knowledge was developed through language over time, I decided to observe a series of five consecutive lessons for each teacher, so as to gain a sense of the development of science concepts over the five lessons, and the coherence thereof both within and across lessons; as well as the shifts in the discourse patterns and the bilingual language use in the classrooms.

The lessons were videotaped with the agreement of the teachers and this was negotiated at the outset, when discussing the research and inviting the teachers' participation. Videotaping in classrooms has clear advantages in that it provides a permanent record of lessons that can be reviewed multiple times if required and this allows for more detailed and nuanced analysis (Stigler, Gonzales, Kawanaka, Knoll & Serrano, 1999). The obvious disadvantage is that a camera is more intrusive than a human observer alone, and may increase reactivity on the part of both teachers and learners; and this might pose a threat to the validity of the research. However, Stigler et al (1999) have claimed that teaching behaviour and aspects of classroom discourse are

so highly socialised that they are unlikely to change, even in the presence of a camera; and in the case of this research, any unnatural behaviour on the part of teachers and/or learners would have been difficult to sustain over the course of five lessons. However, aspects that were more likely to change were that teachers might prepare more thoroughly than usual; and that learners might be on their best behaviour. In addition, in the kind of bilingual classrooms that were the subject of this study, as discussed in the literature review, teachers and learners might be inhibited in terms of their use of their shared home language when this did not have official sanction (see for example, Probyn, 2009; Setati et al, 2002).

Suggestions to minimize some of the problems of reactivity generally and to a video camera in particular, include spending some time in the classroom with the video camera prior to the actual data collection, to acclimatize participants. However in the case of this research, acclimatisation procedures were not possible given the multiple sites and fairly tight data collection schedules. In any event, Alexander (2001) has claimed that such procedures were found to have negligible effect and that in fact teachers and learners adapted remarkably quickly to a video camera, especially if it was left on a tripod rather than being carried around the classroom (Alexander, 2001). Nevertheless, as Stigler et al (1999) have suggested, the observed lessons should be regarded as an idealized version of everyday practice.

As Stigler et al (2003, p. 6) have pointed out, 'deciding exactly what to film during a lesson is a non-trivial issue.' A video camera is a much clumsier instrument than the human eye, and so it is important to decide beforehand where to point and focus the camera and to follow standard procedures so as to capture comparable data. As with the TIMSS video studies, my aim was to 'follow what an attentive student would be looking at during times of public discussion, usually the teacher, and then follow(ed) the teacher and sampled student activities during private work time' (p. 6).

The videotaped lessons were transcribed for the whole-class talk and talk between the teacher and individual learners and groups that was loud enough for the class to hear. The transcriptions were translated from isiXhosa to English where necessary. The initial transcriptions and translations were done by isiXhosa speaking linguistics students. I am able to follow isiXhosa and so was able to check the transcriptions against the videotapes for obvious errors and gaps which I noted; and then the transcriptions were checked and gaps corrected by one isiXhosa speaking translator.

Thus the primary source of data for this research was the transcriptions of a series of five consecutive lessons for each of the eight 'reputable' Grade 8 science teachers, in the context where the teachers and learners shared a common home language, isiXhosa. The lesson transcriptions were backed by the digitized videos of the lessons, which were used in conjunction with the transcriptions for the data analysis.

### *Interviews*

Teachers were interviewed immediately after the observation period, to obtain contextual information, including their qualifications and training as science teachers, the school context (for example: numbers of teachers and learners; socio-economic status of learners), resources for teaching science (science equipment and textbooks), and their views on language and learning and the language medium in particular.

Teachers were also interviewed about their classroom language practices, using extracts from the videotaped lessons for the purpose of 'stimulated recall' - in particular about their use of English and isiXhosa and the functions of their bilingual classroom practices, which were not necessarily directly observable. These interviews were semi-structured to allow for systematic collection of data that was comparable, but also to allow for the individual practices and views

of teachers to emerge. A copy of the semi-structured interview questions is attached in Appendix 1.

The interviews were recorded and transcribed.

### *Learners' written work*

Copies were made of a sample of learners' classwork for each class, where written work was done in the observed science lessons. This was to provide evidence of how much written work was done in lessons and to what extent the oral teaching and learning was consolidated in writing.

### *Field journal*

A field journal was kept to record dates of school visits, observations about the school contexts, classroom observations not necessarily captured on video, and emerging thoughts as the data collection proceeded.

### *Ethical issues*

There were four key guiding principles to ensure that the research was conducted ethically: respect and empathy for the participants, informed consent, protection of the identity of the participants and protection from harm of the participants (University of Cape Town, School of Education n.d.).

### *Respect and empathy for participants*

In line with the first principle – respect and empathy for participants - I attempted to identify 'excellent' science teachers, in the hope that they might be able to provide useful insights into how to deal with the challenges faced by many teachers who teach through the medium of English, in contexts where English is not the home language of the learners; but I also wished to work with 'excellent' teachers to avoid deficit assumptions about their classroom practices. In my interactions with the teachers, I related to them with respect, as competent professionals,

and empathised with the challenges they faced; and expressed appreciation for their willingness to open up their classrooms to me.

### *Informed consent*

In order to obtain the informed consent of the participants, I drew up an outline of the research proposal with the purposes and intended processes spelt out (see Appendix 2). The research outline formed the basis for face-to-face discussions with the district managers and science subject advisors; and then with the principals and teachers nominated by the subject advisors, when discussing their possible participation in the research. It was made clear to teachers that their participation would be entirely voluntary and that they would be free to withdraw at any stage should they wish to.

The feasibility of obtaining written permission from the learners' parents or caregivers/guardians was discussed with the teachers and school principals concerned. However in their opinion, this would have been a problem given the low levels of functional literacy of many caregivers/guardians (frequently grandparents), particularly in rural areas. Principals said that they stood in loco parentis and so they felt satisfied that their permission would suffice. I explained the purpose and nature of the research to the learners at the time of data collection.

### *Anonymity*

In the discussions with potential participants, I explained that their identities would be protected when the research was written up. The use of videotapes poses particular problems with regard to protection of participants' identity that the use of pseudonyms does not resolve. Stigler et al (1999) suggest that the best way to deal with this problem is to restrict access to the videotaped data. Accordingly, I made it clear to participants that the videotapes would be securely stored and that the only persons who would view the videotapes besides me, would be

those persons directly engaged in the research process: possibly my supervisor/s and those engaged to transcribe the videotapes. I privately undertook to only use video clips that illustrated good practice. I explained to teachers that should I wish to use any examples of good practice from the videotapes, for teaching or research dissemination purposes, then I would seek the teacher's permission to do so and they would be free to refuse.

### *Protection from harm*

Prosser (2000) has raised an important ethical issue in relation to the use of video-tapes in classroom based research: 'Video research allows participants to see themselves and reflect on their practice *but* it also has the potential to displace previously established self-images' (p. 131) and unless this process is sensitively supported, it could result in personal discomfort and/or loss of self-esteem. I had had quite extensive experience of using videotaped lessons for the purpose of post-lesson reflection and discussion when engaged in classroom based support and mentoring of in-service teachers in ACE and BEd programmes. As a result I was well aware of the sensitivities involved and made every effort to make the teachers involved in the research feel relaxed and comfortable during the interviews; I adopted a non-judgmental attitude when watching video clips of teaching episodes with them; and sought to position them as experienced professionals when asking them to comment on particular aspects of their teaching.

I also attempted to minimize the disturbance to the teachers' teaching programmes and tried to make the interviews as congenial and comfortable as possible, with refreshments and in a venue and at a time that suited them.

### *Benefits for whom?*

A key ethical aspect of classroom-based research is that the benefits accrue to researchers with little obvious benefit for the participants. I was acutely aware of this. I made copies of the

videotaped lessons for each teacher to keep and several of the teachers said that they had found the process of viewing and reflecting on their lessons to be helpful and that they appreciated the opportunity to do so. However this imbalance in benefits is an ongoing unresolved matter that teachers themselves are well aware of.

All of the teachers who participated in the research gave of their time and shared their reflections on their teaching practices in a most generous way. They were all teachers of good reputation in their communities and demonstrated their caring and professionalism in my interactions with them. Any implicit criticism of certain practices that emerged in the data analysis have been made with great respect, in the knowledge of the extremely challenging circumstances within which they worked; and in the spirit of seeking ways of improving the opportunities to learn science for poorest and most vulnerable learners.

### **Limitations of the research**

#### ***Validity***

There were a number of potential threats to the validity of the research:

Much of the research is descriptive, where the main validity threat is that of incomplete or inaccurate data (Maxwell, 1996). However this was largely resolved by the extensive use of video recordings and transcription of lessons and audio recordings of interviews, which formed a permanent record and point of reference.

As discussed in relation to the use of videotaping of lessons, reactivity of both the teachers and learners in classroom-based research is a very real problem. Teachers preparing 'show lessons' rather than teaching in an 'everyday' mode is one aspect. More problematic is the possibility that teachers and learners might feel nervous and behave unnaturally, or teachers might change aspects of their everyday practice that they feel are 'illicit', for example codeswitching.

Thus one should regard observed lessons as teachers presenting their 'best practice'. If for example, a teacher presented a series of 'most interesting' lessons from his or her repertoire, rather than following the usual curriculum, then the inference might be drawn that the teacher did not regard issues such as consolidation and coherence as important factors in science teaching. Likewise, if a teacher refrained from using the learners' home language when being observed, one could infer that this was not regarded as a practice that was considered legitimate or appropriate.

However in the interviews following the classroom observations, teachers claimed that while they were conscious of the video camera initially, they soon forgot about it. Researchers using video data suggest that teachers' practice is fairly resistant to change and that the presence of a researcher and video camera is unlikely to change their practice markedly (Alexander, 2006; Roth et al, 2006; Stigler et al, 1999). This matter is discussed in more detail when presenting the findings on teachers' languaging practices.

### *Generalisability*

The small-scale nature of this research limits claims for generalisability. However, some claims may be made for 'face-generalisability' beyond the immediate study on the basis of the typicality of the teachers and learners involved (Maxwell, 1996; Schofield, 1993) in terms of their linguistic backgrounds and school contexts. According to Schofield such research is strengthened by multiple sites and should be combined with 'thick description' which provides enough information for readers to make informed judgments as to what extent the sites described match theirs, and the results can inform their situation. It is my contention that these criteria of generalisability were met.

### *Time frames*

The question that immediately arises in relation to the validity of the data is the long delay between data collection and final submission of this dissertation. This has obvious implications for the current validity of the data. Is the data so old that it has no relevance for the current situation in education? Sadly, the answer must be 'no'. As described in chapter one, the Eastern Cape Education Department remains mired in controversy and in TIMSS 2011 South African learners still achieved the second lowest score for science, after Ghana, despite taking the test at Grade 9 rather than Grade 8 level and the inclusion of independent schools in the 2011 testing. Would it were otherwise.

### **Data collection process**

#### **Access to research sites**

Permission to conduct the research was obtained from the Eastern Cape Provincial Education Department in 2003 and access to schools was negotiated with the three districts, starting in February 2004. The district managers and science subject advisors were interested and helpful; and I was supplied with lists of possible teachers to approach. I contacted the teachers who were recommended and they all agreed to participate. However there proved to be an imbalance with more men than women in the initial sample and so I requested names of more women teachers and approached them to participate, so that in the end there were four men and four women in the sample.

#### **Classroom observation**

Classroom observations were to have started in March 2004, but were delayed as the teacher concerned was no longer going to be teaching science; so he had to be replaced in the sample. The first week of observation started with Teacher C, on 19 April 2004, in a remote rural school about 30 kilometres from the nearest small town, along a rough gravel road.

Planned observation dates did not always work out as planned and these had to be postponed on several occasions because of school sports days, CASS moderation<sup>6</sup>, teachers writing university examinations or attending block lecture sessions, district meetings etc. and on one occasion an observation had to be repeated because of technical problems with the video camera, when the cassette jammed. In addition in the latter half of the year, teaching was disrupted by teacher union strikes. I was due to observe in the last school in the fourth term of 2004 but the teacher concerned was preparing for a family funeral; and then was occupied with CASS moderation for Grade 9, so would not be teaching the Grade 8s. Then, because of work related commitments on my part in the first term of 2005, and further delays at the school concerned, I was only able to conduct the last classroom observations in May 2005.

### Interviews

Semi-structured interviews were conducted with teachers after the fifth and last lesson observations, usually on a Friday afternoon. In the case of Teacher C however, I had to interview her on the second last afternoon as the school was participating in a choir competition on the Friday and so I arranged to give her and the choir members in her class, a lift to a small town of where the competition was being held, immediately after the Friday science lesson.

I held the interviews at the school or at the bed and breakfast accommodation where I was staying and provided refreshments for the teachers. The interviews were recorded and the

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<sup>6</sup> CASS (Continuous Assessment) Moderation refers to the process of moderation of Grade 9 continuous assessment portfolios. Teachers met in cluster subject groups at a common venue, usually a school, to compare and moderate the internal marking of Grade 9 learners' subject portfolios. However this did not prove to be practical, as many teachers do not own cars and had to travel with bulky portfolios using public transport. The travelling itself took a long time and took teachers out of their classrooms; and preparation of the portfolios and related documentation was also done during teaching hours. For example one afternoon I met a man walking along a dusty rural road when I was on my way to visit a school. He was carrying an awkward collection of wire objects and when I gave him a lift I found he was a Technology teacher on his way to a cluster meeting for CASS moderation at a school close to the one I was going to; and the wire objects were what his learners had produced for assessment. He had had to leave his school early that morning to travel by taxi and foot to get to the school that was to be the moderation venue.

teacher and I viewed video clips of particular incidents in the lesson for teachers to comment on, particularly their bilingual language use. I transcribed the interviews later.

### **Fieldnotes**

At the end of each day I wrote up fieldnotes about the research process, including organization of school visits (often thwarted); about what I had observed generally in the schools; my conversations with other staff members; my impressions of the classrooms where I was videotaping lessons; and my emerging thoughts about what I has observed and experienced. The fieldnotes provided useful contextual information and details I might have forgotten, when I was analysing the data and writing the thesis.

### **Research contexts**

Five of the eight schools were in rural areas, mostly tucked away along meandering unsignposted tracks. Finding them was a challenge and in some cases I was able to pick up a teacher in the town where I was staying, so that they could guide me to the school. The township schools were easier to find, but directions were a bit erratic; fortunately I was able to get help from a fieldworker from another Grahamstown based education project who had worked in the area and knew his way about; and he was able to show me the way to the schools.

In all of the schools there was not a reliable electricity supply - either because there was no supply at all, or because the school could not afford to pay for electricity, or because electric plugs in classrooms did not work. I had to rely on batteries for the videotaping and in most cases had to go to a venue with electricity for the interviews, so as to be able to play back the video clips on a portable television set.

## Data analysis

### Data sources

The main source of data in these case studies were the transcriptions and video recordings of a series of five consecutive science lessons in each of the eight Grade 8 classes. The lesson transcripts were analysed in detail and the video recordings provided back up visual detail for checking the physical movements of teachers and learners, chalkboard work, practical demonstrations and so on, that were not captured in the transcripts.

In addition, the teacher interviews provided background details about the school contexts, the schools, the teachers themselves, the learners, teachers' views on language and teaching science; and teachers' reflections on particular teaching episodes in lessons, particularly related to their bilingual language use. The learners' workbooks provided evidence of written tasks undertaken in the observed lessons.

### Unit of analysis

The unit of analysis for mapping the development of *science content* through *language* was the *series of five lessons* per teacher. The *public talk* in the lesson transcripts was coded and analysed for 'opportunity to learn' science as outlined below. 'Public talk' was defined as talk by teachers or students where the intended audience was the whole class.

In order to map the *lesson structure* and to provide a framework for the analysis of the *development of content through language*, each lesson was divided into lesson '*episodes*': these are defined by Gibbons (2006 p. 95, following Lemke, 1990, p. 50) as 'a unit of discourse with a unifying topic and purpose' – roughly equating to a teaching activity. A lesson episode has the following features:

- it is framed linguistically with markers such as 'okay' or 'now we are going to ...';

- a particular participant structure which might change in following episode;
- physical seating arrangements which might change in the next episode;
- fulfills a particular purpose or function;

The lesson episodes provided the structural framework for the process of data analysis which is described in the sections that follow.

### Criteria for analysis of science lessons

The TIMSS video study of teaching science (Roth et al, 2006) provided a useful set of criteria for analyzing the science content of lessons for opportunity to learn; and these criteria have been adapted for this study. However, classroom language was given limited attention in the TIMSS Video Study and was confined to quantification of teacher-learner talk by lesson time; and time spent on reading and writing activities; as well as an analysis of the different types of writing produced. In this research study, the inclusion of classroom discourse and bilingual languaging practices of teachers and learners, provided a more fine-grained analysis of the science content in the observed lessons and the classroom language practices that were utilized to construct the science content.

Theories of classroom discourse and bilingual classroom practices, drawn from the literature outlined in chapter two, informed the coding and analysis of the classroom language in the observed science lessons.

It should be noted that that the TIMSS Video Studies (Stigler et al, 2003; Roth et al, 2006) were video based – lessons were not transcribed – and so the various aspects of science lessons were coded, quantified and compared on the basis of proportions of lesson *time*; whereas in this research study, lessons were transcribed and much of the quantified analysis is based on *word counts*, which is necessary for the language analysis, and in fact makes for a more fine-grained analysis. This fine-grained analysis is time consuming and is possible with a relatively small

sample, but would not be feasible in the case of the large scale across country TIMSS Video Studies. So although the data from this research study is not directly comparable to the data from the TIMSS Video Study for science (Roth et al, 2006), the TIMSS study does provide a useful and roughly comparable international reference point.

An additional point in relation to the word counts is that isiXhosa has a conjunctive orthography whereas English has a disjunctive orthography. So in isiXhosa, words consist of several morphemes, which in English are written as separate words: for example, one isiXhosa word 'ndiyathanda' is translated into three words in English: 'I love you'. This would obviously mean that word counts that were based on the original isiXhosa and English would not be directly comparable. To overcome this, the English translations of isiXhosa passages were counted, rather than the original isiXhosa words, to maintain parity for comparison.

Although an equal number of lessons (five) was observed and recorded for each teacher, it soon became apparent that in many instances the length of lessons varied considerably from the norm of 40-50 minutes. Accordingly, for some comparisons of the data, the counts of data per lesson were scaled to a count per hour, so as to allow for direct comparisons between cases. In some cases the scaling was done in terms of a proportion rather than a raw count.

The detailed set of analysis criteria used for coding the lesson transcripts are set out in Appendix 3. These are outlined below:

The science content presented in lessons was identified and analysed in terms of:

1. Types of science knowledge
2. Source of science knowledge
3. Accuracy of science knowledge
4. Density of science knowledge
5. Coherence of science knowledge

These broad criteria are elaborated as follows:

### *1. Types of science knowledge:*

The science facts presented in lessons were classified as follows, based on categories drawn from Roth et al, (2006 pp. 48-49):

- Canonical knowledge: 'science facts, concepts, ideas, processes, or theories' (include observations made during practical work); 'an idea is canonical in the sense that it is generally shared by members of the scientific community';
- Procedural and experimental knowledge: 'how to do science-related practices such as manipulating materials, and performing experimental processes';
- Real life issues: 'how science knowledge is used, applied or related to societal issues or to learners' personal lives' (including analogies);

As can be seen, the three types of science knowledge listed above, relate directly to the three main types of science knowledge identified in the South African Curriculum: knowledge about science; knowledge about how to do science; and knowledge about how to use science knowledge (Department of Basic Education, 2011).

Three further categories of science knowledge were identified in the TIMSS Video Study, but as there was relatively little evidence of them in the TIMSS data, and likewise in this research data, they were discarded in the final analysis. These were as follows:

- Classroom safety: 'science-related safety issues';
- Nature of science knowledge: how science is conducted;
- Meta-cognitive knowledge: strategies for learning or modeling thinking processes. (Roth et al, 2006, p. 49)

## *2. Sources of science knowledge:*

As with the TIMSS Video Study, lessons were coded for the source of the science content as follows:

- teacher
- learner/s
- textbook
- chalkboard
- worksheet

In the TIMSS study the category 'learner/s' was subsumed under 'other', but in this study it was coded separately as in two classrooms learners provided high proportions of lesson content; and in this study, the category 'chalkboard' was added as in some classrooms teachers wrote up notes on the chalkboard for learners to copy down. In the TIMSS study, lessons were coded for the main source of lesson content; whereas in this study, each fact presented in a lesson was coded for its source and these were then quantified.

## *3. Accuracy of science knowledge:*

This category was not included in the TIMSS Video Study criteria as it clearly was not a consideration in the five developed countries that participated in the study: Australia, Czech Republic, Japan, Netherlands and the USA (Roth et al 2006). However, given research evidence of the poor subject knowledge of some teachers in South Africa (for example, see Taylor and Taylor, 2013); and evidence during the data collection of some incorrect science content being presented; the category of 'accuracy of science knowledge' was added to the analysis criteria.

Thus the science facts in lessons were coded and graded according to whether they were accurate or not, as follows:

- AC2: science content accurate and complete

- AC1: science content unclear/not quite accurate/incomplete concept
- AC0: science content incorrect

The categories were quantified as percentages of the total number of facts to arrive at comparable data patterns for 'correct', 'partly correct' and 'incorrect' science content.

#### *4. Density of science knowledge in lessons:*

In the TIMSS Video Study this criterion was defined as 'the number of publicly presented canonical ideas per lesson' and this gave some idea of the pacing of the science content. In this study the canonical science facts were counted and compared as a count over time to provide an indication of the density of science content and lesson pacing. In the TIMSS Video Study, only one lesson per teacher was analysed, whereas this study extended over five lessons per teacher. For this reason I differentiated between completely new ideas, ideas from previous lessons that were being reviewed, ideas that were repeated at different points in a lesson, and ideas from previous lessons that were repeated but not part of an explicit review.

- DNEW: Number of publicly presented canonical ideas – new content;
- DREV: Number of publicly presented canonical ideas – review of previously presented content; include ideas from lessons in data set or ideas marked by teacher as previously presented e.g. 'remember ...';
- DREP: Repetition of ideas – within a lesson at *different points* in the lesson e.g. a recap before moving on to a new idea or activity; not repetition at the same point in a lesson;
- DPREV: repetition of an idea/fact from a previous lesson but no explicit link made by teacher.

The number of canonical ideas in each category was quantified against the time for the lesson to arrive at a number of ideas per hour, so as to be able to compare between lessons, given the widely varying lesson times.

### *5. Coherence of science knowledge:*

The TIMSS Video Study (Roth et al, 2006) referred to the need for ‘providing students with the opportunity to develop connected, evidence-based scientific understandings that students can apply to make sense of a variety of phenomena’ as a key idea coming from international research on science teaching and learning. In addition the study claimed that ‘research on human learning suggests that unrelated ideas hold less meaning than those that are richly interrelated ...’ (p. 57). As discussed in the literature review, the issue of coherence in the science content of lessons seems central to the opportunity to learn science.

The coherence of lessons was conceptualized firstly in terms of conceptual links across and within lessons, so that facts in lessons were explicitly linked to generalised concepts; and that concepts were supported by rich factual detail (Roth et al 2006; Donovan and Bransford, 2005). Lesson content was coded for conceptual links as follows:

#### *Conceptual links across lessons*

This was an addition to the TIMSS Video Study criteria as in this study five consecutive science lessons were observed and recorded for each teacher (as opposed to one for each teacher in the TIMSS study) and so it was possible to track conceptual links across lessons and the progressive cumulation of science ideas and concepts. This was coded as follows:

- LCA-2: strong inter-lesson conceptual links: there is topic progression/continuity and teacher makes the links between lessons explicit;
- LCA-1: some inter-lesson conceptual links: there is topic progression/continuity but teacher does not make links explicit;

- LCA-0: no inter-lesson conceptual links.

#### Conceptual links within lessons

These descriptors were taken from the TIMSS study (Roth et al, 2006 p. 68) and expanded for this particular study, to also capture the need for 'rich factual detail' (Donovan & Bransford, 2005) to support the understanding of concepts; and to capture the possibility of incorrect concepts being presented in some lessons:

- LCW-2: strong conceptual links within lessons to generalising principles and theories: 'The lesson is focused on content with conceptual links that strongly connect and integrate the information and activities. The information presented consists primarily of interlocking ideas, with one idea building on another with strong conceptual links. The lesson contains a strong conceptual thread that weaves the entire lesson into a conceptual whole' (Roth et al, 2006); in addition, concepts are supported by rich factual detail.
- LCW-1: weak conceptual links within lessons: 'The lesson contains some content but there are only weak or no conceptual links that integrate the information and activities. The information and tasks presented are connected only by a shared topic or by one or two concepts that tie together some of the ideas or activities but do not connect all the information together' (Roth et al, 2005); or concepts are presented without the necessary supporting rich factual detail.
- LCW-0: no conceptual links within lessons – 'The teacher focuses students' attention primarily on carrying out an activity or procedure rather than learning a content idea. Students may encounter some science content in the process of carrying out an activity but the information is presented as isolated bits of information without being linked to a larger concept' (Roth et al, 2006); or concepts presented are

incorrect – thus there is not the opportunity to develop appropriate conceptual frameworks.

#### Goal statements and summary statements

The second indicator of conceptual links within lessons was evidence of goal statements and summary statements as this is ‘one way in which teachers can make the content organization of a lesson more explicit for students’ (Roth et al, 2006 p. 70).

Lessons were coded as follows:

- GS -1: goal statement/topic present
- GS - 0: goal statement absent
- SS - 1: summary statement present
- SS - 0: summary statement absent

The third indicator of conceptual links, not included in the TIMMS analysis, was evidence of the consolidation of ideas with a written task or assessment at the end of a lesson or a series of lessons. I included this as it seemed to me to be an important indication of conceptual coherence of lessons – that ideas were consolidated in writing at regular intervals by learners. Note taking was not included as this is essentially a passive activity that does not require thinking and application of science knowledge.

The codes and criteria are listed below:

- CI/WL -2: consolidation activity within lesson present and appropriate
- CI/WL - 1: consolidation activity within lesson present but inappropriate or confusing; or does not address key ideas; or based on partly incorrect information
- CI/WL - 0: no consolidation activity within lesson; or activity based on completely incorrect information

- CI/AL - 2: consolidation activity across lessons present and appropriate
- CI/AL - 1: consolidation activity across lessons present but inappropriate or confusing; or does not address key ideas; or partly incorrect
- CI/AL - 0: no consolidation activity across lessons; or activity based on completely incorrect information

Each lesson was coded according to the criteria above; and a value ascribed according to the codes. The values were scaled so as to arrive at a composite value for the coherence of lesson coherence, based on the three aspects: conceptual links; goal and summary statements; and consolidation activities.

#### *Ranking of teachers' practices for OTL science*

The results of the coding of the lesson transcripts for the science content of lessons, were quantified and presented in the form of charts, and illustrated with extracts from the lesson transcripts. The practices of the teachers were scored for each criterion in terms of the opportunity to learn science, along the scale of 'good - 3; partial - 2; weak - 1; very weak/absent - 0'; these scores were added so as to obtain an overall ranking of the teachers' practices, in terms of the opportunity to learn science content that their lessons provided.

#### *Criteria for analysis of classroom language*

Classroom language was not covered in any detail in the TIMSS video study (Roth et al, 2006) and the so criteria for the analysis have been based on the literature. In Chapter 2, the extensive literature on the role of language in learning science was discussed; and a rationale provided for the analysis of the lesson transcripts in terms of the classroom discourse patterns and the bilingual languaging practices of teachers and learners.

### *Classroom discourse*

In line with socio-cultural theories of language and learning (Alexander, 2006; Barnes, 1976, 1992; Gibbons, 2006; Mercer, 1995; Mortimer & Scott, 2003; Wells, 1999) as discussed in the literature review, the classroom discourse of the lessons was analysed in terms of

- the balance of teacher-learner talk
- discourse patterns for public talk
- evidence of bridging discourses

The relative amounts of *teacher-talk and learner-talk*, by a simple word count, provided some indication of the engagement of learners in constructing the science knowledge in the observed lessons. As discussed, the English translations of the isiXhosa transcriptions were counted, so as to maintain some kind of equivalence when quantifying the two languages. The word counts of teacher and learner talk were mapped onto the lesson episodes in the excel spreadsheets. The raw counts were scaled to the number of words per minute to provide a comparison between lessons and classes in the reporting.

The classroom talk was also coded for the different *discourse interaction patterns* within each episode; and a word count was done for each stretch of a particular discourse interaction pattern, to provide an indication of what forms of interaction predominated in lessons. The discourse interaction patterns are briefly described below and represent a cline along an 'authoritative-dialogic' continuum (Mortimer and Scott, 2003), as discussed in the previous chapter.

#### *1. Teacher monologue*

Teacher speaks with learners listening quietly or murmuring in response to the teacher's attention checks (for example: 'okay?'). This was further sub-divided into regulative monologue to manage the class (1.a.); and instructional monologue for exposition of science content (1.b.).

## 2. *Oral cloze*

Teacher monologue with learners providing key words in response to a pause and raised tone by the teacher; this functioned as teacher exposition, with some chorused participation by learners.

## 3. *Initiation-response-evaluation (IRE)*<sup>7</sup>

Teacher led question and answer which follows a 'triadic dialogue' pattern of teacher question (I -initiation), learners response (R), learners provide one word/short answers which the teacher evaluates (E) as correct or not; the purpose is generally to check on learners' understanding.

## 4. *Dialogic exchanges*

Teacher-led question and answer with the teacher providing feedback that prompts a further exchange. Indicators of this form of classroom interaction are as follows:

- IRFRF interactions are extended over several turns;
- Teacher's feedback responds to and builds on learners' responses (contingent responsiveness);
- Meaning cumulates over several turns and is focused on patterning facts into conceptual frameworks through logical argument – thinking aloud.

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<sup>7</sup> In line with Wells, 1999) and Mortimer & Scott (2003) (and unlike Gibbons, 2006) I have preferred to use the term 'IRE' (Mehan, 1979) rather than 'IRF' (Sinclair & Coulthard, 1975) to represent such triadic dialogue, as the 'evaluation' moves captures the closing down of dialogue in such interactions. The 'F' or feedback move in 'IRF' sequences captures the possibility of 'contingent responsiveness' (Wells, 1999) in the feedback move and the chaining of ideas into longer sequences that form the basis of 'dialogic talk'.

### 5. *Learner/s reporting back*

Exposition initiated by learners, which might be supported by the teacher: the teacher might simply accept the learners' contributions without comment; or the teacher might affirm their contributions by evaluating them (e.g. 'good') or by repeating them; or the teacher might support the learners' contributions by asking probing questions, or helping them to rephrase it more accurately. For the purposes of this analysis, these distinctions were not made – partly so as not to over complicate the analysis and partly because this aspect of classroom discourse was not the main focus of the analysis.

### 6. *Learners asking questions*

Learners ask questions to the class or group and the teacher manages the process. The structure is that of IRE with occasional extended exchanges, but with the initiation (I) move by a learner rather than the teacher.

Once the discourse patterns had been coded, the chunks of discourse were mapped onto the lesson episodes. The different types of discourse interaction were quantified and shown graphically to demonstrate the dominant interaction patterns in lessons and the similarities and differences between teachers' practices in engaging learners in constructing science knowledge. Instances of the interactions patterns were illustrated with extracts from the lesson transcripts.

#### Bridging discourses

The lesson transcripts were also coded for evidence of '*bridging discourses*', (from Gibbons, 2006); these included instances of the teacher providing support to learners in bridging the gap between

- everyday knowledge and science knowledge;
- everyday language and science language;

- practical and theoretical knowledge;
- spoken and written language.

The instances of bridging discourses and were mapped onto the lesson episodes in the excel spreadsheets; in addition they were counted and presented graphically, to identify patterns of practice; and the examples from the transcripts were provided.

### *Bilingual classroom practices*

As described in the literature review, a common practice with teachers in classrooms where learners are not full proficient in the language medium, is for teachers to switch to the learners' home language for a range of purposes. This could be described as a form of 'bridging discourse' along with those described in the previous section. However because the question of the language medium in South African education is so hotly debated; and because bilingualism in education has a long standing international research tradition and literature, the teachers' and learners' use of English and isiXhosa in the observed lessons, was afforded a separate and more detailed analysis.

Accordingly, the lesson transcripts were coded for the use of English and isiXhosa by the teachers and learners in terms of:

- word counts for each language for teachers and learners;
- the functions of the teachers' and learners' use of their common home language, isiXhosa as follows (following Ferguson, 2003):
  - for constructing and transmitting science knowledge:
  - for classroom management
  - for interpersonal relations

The bilingual languaging practices of teachers and learners, and the functions thereof, were mapped onto the lesson episodes and science content, along with the classroom discourse, onto the excel spreadsheets for each teacher.

### **Process of data analysis**

The process that I followed for coding and analysing the data was as follows:

I coded the transcripts of the lessons for each teacher, for science content (what) and the classroom language (how) according to the analysis criteria, onto Excel spreadsheets, one per teacher. I first mapped the lesson structure by dividing the lessons into 'episodes' (as defined in the analysis criteria), with a brief description of each. I then identified the science content in the lesson by underlining and numbering facts presented in each episode in the transcripts; and then mapped the episodes onto the spreadsheets, so that I had a summary of the content and structure for each lesson.

I coded the lesson content according to the criteria in the analysis framework.

Next I coded the transcripts for the discourse interaction patterns in each episode; and counted the number of words spoken by the teacher and by the learners for each stretch of coded discourse. At the same time I counted how many words by teachers and learners were spoken in English and how many were spoken in isiXhosa. In this way I arrived at patterns of language use for each lesson episode, in terms of discourse interaction patterns and bilingual language use, which were mapped onto the lesson content.

I collated the information from the master spreadsheets for each teacher onto further composite spreadsheets: one for science content; one for classroom discourse; and one for the analysis of the bilingual practices of teachers. I used content analysis to develop charts, which revealed patterns in the data for particular teachers and comparisons between teachers. These patterns were illustrated with excerpts from the lesson transcripts.

The criteria relating to science content knowledge were used to arrive at some conclusion regarding the opportunity to learn science in the sets of observed lessons for each teacher. These were linked to discourse patterns and to the bilingual practices of teachers, to see whether particular discourse patterns and/or bilingual practices appear to support or constrain opportunities to learn science.

I have provided a short summary of the sets of five lessons for each teacher (shown in Appendix 4); these are tabulated under episode number, organisation of learning, and lesson content. They are intended to provide a context and reference point for the data presentation, as only relatively short excerpts from the transcripts are practicable.

## Conclusion

This chapter has spelt out the research approach, research design, including data collection methods, analysis criteria and data analysis processes, that were employed to answer the main research question: In what ways did the lesson content and the classroom language practices combine to construct or constrain the opportunity to learn science? In addition questions relating to the validity and generalizability of the research, and the measures taken to address ethical concerns were discussed.

The following four chapters present the research findings based on the analysis of the data collected from classroom observations and interviews with teachers as follows:

- the teachers and their contexts:
  - descriptions of the schools and their settings
  - descriptions of the teachers, the learners and their classrooms
- the science content presented in lessons
- the classroom discourse used to construct that science content
- the bilingual languaging practices of teachers and learners.

## CHAPTER FOUR: TEACHERS AND THEIR CONTEXTS

The analysis of the data has disaggregated the teachers' practices and in so doing, the individuality of teachers and their contexts has been stripped out. This section, which is based on the teacher interviews and on-site observations and conversations, therefore sets out to provide a broad description of each of the teachers and their teaching contexts: the teacher's background, their school and infrastructure, the learners, teaching resources and general observations.

### Teacher A

Teacher A had 19 years teaching experience and he had been principal of his school for nine years. He had grown up in the area, had gone to school there and had studied science and mathematics for matric. He had completed a two year Primary Teacher Certificate but with no specialization in science teaching; and was completing further studies – a National Diploma in Public Management and Development. He was teaching science and mathematics to Grades 7, 8 and 9.

School A was situated in a rural area about twenty kilometres from the coast, along a dirt track, amidst rolling grassy hills and scattered homesteads. The school buildings consisted of two facing classroom blocks, opening onto raised covered verandahs, and joined at one end by a small administration block, forming three sides of a rectangle around a muddy quad. The buildings were brick, with tiled cement floors and ceilings, but they had a run down appearance with peeling paint, and some broken windows and ceilings. The principal – Teacher A - had a tiny office with space for a small desk and chair but little else; and there was no staff room.

The school had rainwater tanks but in May, at the time of the data collection, these had run dry and there would be no more water until the rains came. There was no permanent supply of

water. Teacher A apologized profusely for the fact that the classroom floors had not been mopped.

Although the school had been wired for electricity, the school could not afford to pay for it, so there was no supply. There were some pit toilets situated about 50 metres downhill from the school buildings.

School A was a senior primary school from Grade R to Grade 9, with 307 learners and 11 teachers, including the principal. There were 27 learners in the Grade 8 class – 18 girls and 9 boys – with attendance fluctuating between 27 and 24 learners over the five days of observation: for example on one day the boys came late because they had to take cattle for dipping – a common task in rural areas. Learners were seated in four groups.

According to Teacher A, the economic background of the learners was ‘not quite well’ because many were living with elderly grandparents while their parents looked for work in the big towns or cities; and some lived with relatives who were reluctant to provide the necessary support; so many learners dropped out and it was difficult to collect the school contributions of R35 per annum. Many learners could not afford school uniforms or shoes but Teacher A insisted that they should still attend school and not be made to feel embarrassed by other learners or teachers: ‘I make it a culture in our school that if a learner comes to school without shoes they must not laugh at him or her ... we don’t want them to feel small and then leave the school.’

The school received a budget for paper from the Department of Education, but they had no science equipment; and the school only received about half the textbooks that were ordered, so the supply of science textbooks was ‘scanty’. The school had received donations of books and toys from NGOs such as Rally to Read and ‘Avisa’, but ironically Teacher A claimed that the teachers were reluctant to make use of these additional resources. The school had no science equipment.

During the week of observation, there seemed to be only two other teachers at school and there appeared to be little teaching happening in other classrooms; Teacher A had to leave his classroom several times to go and restore order when the noise from unattended classrooms got too loud. Apparently four of the staff had completed NPDE courses and were graduating from Border Technikon; so they were absent and some of the other staff had gone to support them at their graduation.

There had been some conflict related to the school governing body elections the previous year which had disrupted schooling and matters were still unsettled nine months later.

### **Teacher B**

Teacher B had grown up in the same rural area in which his school was situated, and where he went to school and matriculated and then completed a Senior Primary Teacher's Diploma, specializing in mathematics and general science. He had 24 years teaching experience and had been principal at the school for 16 years. He had completed a further diploma in science teaching; and was studying for a BED Hons degree in science education. He was considering enrolling for a masters degree in science education, depending on available funding. He was teaching General Science to Grades 7, 8 and 9; and Arts and Culture to Grade 9.

School B was a Senior Primary School (Grades R-9) situated in a rural village, was also surrounded by rolling grassy hills with some thatched huts and brick homesteads nearby. There were seven classrooms in two rows which had been built by the community, so although the walls were brick, the floors were mud and dung and this meant that they had to be re-smearred each week: school closed early on Fridays so that girls could collect fresh dung from nearby homesteads and water from the river. However the scraping of chairs over the floor meant there was a fine dust over everything in the classroom and it made it difficult to keep things clean. Teacher B had repeatedly petitioned the Department of Education about these problems

but there had been no response. The SBG had recently raised funds from Transnet to build another classroom with brick walls and a cement floor, with labour being supplied by the community. This housed the Grade R learners and contained some chairs but no educational equipment.

The school did not have a supply of water – there had been three rainwater tanks but these and the gutters were rusted and the school did not have the funds to replace them - so Teacher B brought a supply of water to school for conducting science experiments. There were some dilapidated looking pit toilets about 30 metres from the classroom blocks. There was no electricity: the school had recently been wired for solar power but no sooner had the solar panels been installed than they were stolen.

The school had no principal's office or staff room, so in their free periods, teachers would occupy a corner of a classroom while another teacher was teaching. The principal used his car as an office.

There were 336 learners and ten teachers; and because of the shortage of classrooms (seven classrooms for nine classes), Grades 3 and 4 were combined, as were Grades 5 and 6. In the Grade 8 science class there were 37 learners: 24 girls and 13 boys.

According to Teacher B, the economic background of the learners was poor; many lived with grandparents and parental support was sporadic; some lived with single mothers. School fees were R5 per month for Grade R, to supplement the R1000 per month salary paid by the government; the Foundation Phase fees were R20 per annum; R30 for the Intermediate Phase; and R50 for the Senior Phase.

The school received a budget for stationery and textbooks and could order accordingly. The Grade 8 class had some science textbooks: one textbook shared by three learners; and the

school had bought six dictionaries per class out of school funds. Teacher B had limited science equipment – he improvised using glass bottles and everyday materials.

In general it appeared that teaching was proceeding in an orderly manner with learners and teachers in class and a learner went outside to ring the bell at the end of each period.

### Teacher C

Teacher C had grown up in a small village in the same area as the School C. She had completed her secondary school education, which included mathematics and science, and then a Secondary Teacher's Diploma, specialising in English and History. She had been teaching for 14 years, and had been teaching mathematics for twelve years and science for three years. She had depended on the textbooks for teaching science but she had also completed part-time studies with a BPrim Ed qualification which included some science; and was enrolled for a part-time honours degree - but in Management. She was teaching Grades 8 and 9 science, and Grades 7, 8 and 9 mathematics.

School C was a senior primary school (Grades R-9), situated in a beautiful rural area in the foothills of the Drakensberg, along a badly rutted dirt road that was bare rock in many places. The classrooms are built along three sides of a rectangle with one section built of mud bricks by the community, one brick section built by the government and another section of prefab classrooms.

Water was a problem – a very heavy snowfall four years previously has done a lot of damage to the school, including the gutters. The government has supplied the school with new gutters and water tanks but the community were expected to supply the labour; however, according to the school principal, they were unwilling to do so without payment, and only the members of the school governing body were prepared to help. Half of the gutters had been erected but the remainder and the water tanks were lying on the ground. In the meantime the school obtained

water from a single tap from a mountain spring. The government had provided solar panels to supply electricity, but these had been stolen soon after they were installed. There was a row of corrugated iron pit toilets at the bottom of the hill.

There were 340 learners in the school and 12 teachers. In the Grade 8 science class there were 23 learners: 13 girls and 10 boys who were seated in groups. Teacher C explained that few learners lived with their parents – most lived with their grandparents while their parents worked in the cities. The school fees were R10 per annum for the Foundation Phase learners; R20 for the Intermediate Phase and R40 for the Senior Phase. The fees were used for maintenance, for transport to sporting events and other extra-mural events such as choir competitions.

The Grade 8 classroom was in one of the prefab buildings, with a tiled cement floor and chalkboards across the front wall. There were three AIDS posters on the walls and some of the learners' work displayed on the pin board across the back of the classroom. There were enough science textbooks for each learner to have a copy, but no science equipment.

On one day when I was early for the Grade 8 science lesson I walked around and found the Grade 1 and 2 classes cooped up in the mud brick classrooms – dark and dusty with no equipment, only a piece of board propped up on a chair that might have served as a chalkboard; and the learners waiting patiently for a teacher to appear; very excited to see a visitor.

On the Friday, there was no formal tuition as the choir was going to be competing in a music competition in the closest small town and so the teachers were either going to help with transport or going to attend to support the choir. Teacher C agreed to specially teach the Grade 8 science class, to make up the fifth lesson so that I would not have to make a return trip the following week. In return, after the lesson, I transported her and the choir members from her class to the competition.

## Teacher D

Teacher D had grown up in a different district from that where she was teaching. She had completed a three-year teacher's diploma, specializing in mathematics and science and had been teaching at School D for nine years. She had completed a B Com degree part-time and had been teaching Economic and Management Science (EMS) and had only taught General Science for the first time to Grade 9 the previous year. She was currently teaching EMS to Grades 7, 8 and 9; and General Science to Grade 8.

School D was a senior secondary school (Grades R - 9) in a small village in a rural district – along a bad dirt road made worse by recent rains. Like all of the rural schools, there were two rows of classrooms with a small administration block at one end, making up the third side of a rectangle. It was an old fairly dilapidated brick building with cement tiled floors but no ceilings; the door of the Grade 8 classroom was broken in places and had been patched, but could not close, so it was not possible to store any resources in classrooms. The community has raised funds to paint the outside of the school buildings and the principal was arranging that at the time of the observation.

There was a rainwater tank that supplied water and the school was supplied with electricity albeit intermittently.

There were over 500 learners and 14 teachers in the school, with large numbers of learners in the Foundation and Intermediate Phases but fewer in the Senior Phase. There were 32 learners in the Grade 8 science class, with 22 girls and 10 boys. Teacher D said that most learners lived with their grandparents while their parents worked in the towns and cities but they did not always support their children financially and so that burden fell on the grandparents. The school fees were R20 per annum for the Foundation Phase, R30 for the Intermediate Phase and R40 for the Senior Phase but not all grandparents were prepared or able to pay fees. The funds

raised in this way were used for transport to extra-mural events such as the sports day during the week of observation; however there were not always sufficient funds and so teachers paid for the shortfall out of their own pockets.

The school did not have any science equipment and the Grade 8 class did not have any science textbooks. According to Teacher D these had been ordered but had not arrived. Teacher D had one textbook, but the school did not have a photocopier, so she routinely wrote notes on the chalkboard for learners to copy.

During the observation week, teaching was disrupted by a sports day on the Thursday when there was no tuition and on the next day, a Friday, there was poor attendance and there seemed to be little teaching – according to the HOD it was not a ‘normal’ day. Teacher D frankly admitted that they would probably take advantage of the fact that the principal was not there, and break early.

### Teacher E

Teacher E had grown up on a farm in the area and completed his primary education at the farm school and then moved to live with his mother’s family in a town to complete his secondary education. Thereafter he completed a three-year teaching diploma at a teacher training college, specializing in Biology and English; and had been teaching for 18 years, first in a rural school and then for 10 ten years at School E, in the peri-urban township. While teaching he had studied part-time for a BA degree, majoring in isiXhosa and Education and was about to compete a BEd Hons degree in Management.

School E was a secondary school (Grades 8 – 12) situated in a busy township street, surrounded by brick houses. It was a fairly old but solid brick building with three parallel rows of classrooms (one of which was built of vibracrete), a science laboratory, staffroom, administration block and a library, although the latter seemed to be dysfunctional – a storeroom

for textbooks and a gathering place for a group of teachers. The school buildings and grounds appeared well maintained and secure with a fence and secure gate, and a janitor on duty.

The school had flush toilets, running water, and electricity – although the supply was not necessarily reliable. The Grade 8 classroom was built of vibracrete panels, had a tiled cement floor, a ceiling, a chalkboard, and was well lit.

There were 750 learners in the school and 25 teachers but the school was going to lose five of the teachers through redeployment. In the Grade 8 General Science class there were 38 learners: 20 girls and 18 boys. According to Teacher E, the school was situated in a very poor part of the township, one of the oldest parts, and so many of the residents were pensioners; and the learners were living with their grandparents while their parents were working in cities such as Johannesburg and Port Elizabeth. The school fees had been raised from R50 to R100 per annum the previous year, but many families could not afford this and the principal had to pressurize learners and threaten to not allow them to write exams, in order to force them to pay. The learners were much more lively and noisy than the learners in the rural schools who were much more deferential to their teachers.

Although there was a science laboratory, the school did not have much science equipment and so teachers borrowed from other schools when they could. The Grade 8 class had some textbooks – about one per group of six learners; but Teacher E felt the textbook was ‘really irrelevant’ and ‘a bit complicated’ and learners ‘just get stuck there’ because they did not understand the language; so he had several different textbooks and photocopied exercises to use in class and also gave the learners notes to copy down in their notebooks.

The school seemed to be well run with a functioning timetable and lesson times observed. At the end of each lesson one of the learners presented Teacher E with a timetable to sign – seemingly a measure to ensure that teachers were in class. However, during the data collection period

there were at least two unscheduled teacher union meetings about strike action in relation to wage negotiations which disrupted teaching and learning – in one instance the observation had to be cancelled.

## Teacher F

Teacher F had grown up in a rural area near the township in which School F was situated. He completed a Secondary Teacher's Diploma, specialising in Biology and Geography but he had qualified in the year in which redeployment was introduced and posts were frozen and so he had not been able to get a teaching post immediately. After a year he had found a position teaching in the adult education sector; and then a temporary post for six months when he taught Natural Science, Biology and English (eight classes); then he was unemployed for a further seven months before obtaining his current temporary post, which he had occupied for a year.

School F was built on a steep hillside in the township. It was an older building, consisting of parallel rows of classrooms opening onto covered verandahs, neatly painted outside and the classrooms bright and clean. The school was fenced and secure. There was a principal's office which was shared with senior staff, and one of the classrooms was used as a staff room. The school had running water, flush toilets and electricity.

According to Teacher F most of the learners in the school came from poor families and were not able to pay the R100 per annum school fees – he noted that in his register class of 60 learners, less than ten had paid their fees in full. Some learners stayed with grandparents or aunts and uncles because their parents were deceased or they simply did not know where they were.

There were 47 learners present in the Grade 8 science class: 27 girls and 20 boys. The school did not have a science laboratory or much science equipment. Teachers borrowed from other

schools when they could. Most learners in the Grade 8 class had a science textbook but some had to share.

It appeared that the school stuck to the timetable on the whole, but during the observation week, on one day lesson times were shortened because a SADTU picket was planned; and on another day the school closed early for the same reason. On a third day, a gospel group visited the school during school hours and also disrupted the teaching programme.

### Teacher G

Teacher G had grown up in the area, and completed a three-year Primary Teacher's Diploma, specializing in science. She had 18 year's teaching experience and had completed a Further Diploma in Education in Management.

School G was situated on a windswept bare hillside, in a small impoverished looking village, about 30 kilometres from the nearest small town, along a poor dirt road. The school had been built by the community and consisted of seven mud brick classrooms with dung floors and small windows and in a very poor condition. The classrooms formed 3 sides of a rectangle and were built on a rocky outcrop so there was little hope of a garden of any sort. It was August and an icy wind sneaked through chinks around the window frames and door and through broken windowpanes; the cold seeped up from the floor. The school had water from rainwater tanks and some corrugated iron toilets some way off. The school had been supplied with solar panels for electricity but these had been stolen. The classrooms could not lock and so it was not possible to store anything of value in the classrooms.

School E was a Senior Primary school (Grades R – 9) with 280 learners and 8 teachers; so Grades 1 and 2 were combined. The learners came from poor families and many parents were illiterate; some learners lived with their grandparents and some were orphans or living on their

own because their parents were away working. There were 20 learners in Grade 8: 10 girls and 10 boys.

With no electricity and small windows, it was dark inside the Grade 8 classroom. There were no ceilings and the wall separating it from the classroom next door did not go up to roof height, so the noise from the Grade R next door classroom was deafening at times: there was no teacher in charge and so the learners were going through their repertoire of songs, counting in unison, and at one stage crying loudly. Three small green painted boards served as chalkboards but they had to be held up by the teacher as she wrote, to prevent them from falling off the soft mud walls. Teacher E had nailed some bright posters about Antarctica to decorate the classroom and in a corner there was a small collection of English short story books that had been donated by an American NGO.

The school did not have any science equipment but Teacher G had borrowed a science kit in a large wooden box from her husband's school and she had arranged to store it in a hut neighbouring the school for safekeeping. The Grade 8 class had five science textbooks to share amongst 20 learners.

Although the school was poor and isolated it seemed to be well ordered, and apart from in the Grade R classroom, it appeared that teaching and learning were happening.

### **Teacher H**

Teacher H had grown up in a small town not far from the township where she taught and after matriculating worked for the Department of Forestry for five years. She then completed a three-year Secondary Teacher's Diploma and after six years at another school, moved to School H where she had been teaching for five years. She had furthered her studies though a distance education college and had completed a B Tech and a Higher Diploma in Management Education. She was teaching seven classes: Grade 8 general science and Grades 10 and 11 biology.

School H was a large secondary school in a very large township. There were nearly 1800 learners and 35 teachers, so class sizes were large. The building was a relatively new and double storied, with running water, flush toilets and electricity. The school employed a cleaner, a gardener and a gateman. The school looked neat and clean, with masses of flowering chrysanthemums along the paved pathway to the entrance. The school had previously performed very badly in the Grade 12 matric examination and had been plagued by management problems and conflict between staff factions. Four years previously the Department of Education had redeployed all the teachers and principal and the school had started afresh with a completely new staff. Since then the matric pass rate had improved from 6% to over 80%.

Apparently many of the learners came from a squatter camp nearby and so could not afford to pay the school fees of R150 per annum. According to one of the teachers, there were social problems and some learners were involved in crime and sometimes the police would come to the school to arrest learners; the previous week about 30 boys had been taken to the principal's office for smoking dagga (marijuana), so their parents were called to the school and the principal and chairperson of the school governing body had spent most of the previous Saturday dealing with the problem.

There were 36 learners in the Grade 8 General Science class: 24 girls and 12 boys. Attendance fluctuated over the week from 40 to 27: on the first day four extra learners had come to sit in as they were curious as to what I was going to do; and on the third day of observation, the school gates had been locked at 8am and learners who had not arrived in time were only let in after the short break. Teacher H said that the class did not have science textbooks, only she the teacher had one copy and so she would make photocopies for the learners of the section she was teaching and she would provide the class with notes to copy from the chalkboard.

The school appeared well ordered, with teachers rushing off to their classes after morning assembly. There were some problems in actually getting the observation done, which were indicative of some of the disruptions to teaching and learning: I arranged to observe in the first week of the fourth term; but Teacher H said she was not available as she would be preparing for a family funeral in that week; in the next week she said she would also not be available as she would be involved in preparing for moderation of continuous assessment marks for Grade 9 and so would not be teaching the Grade 8 science class.

## Summary

Clearly the material conditions in schools and the resources available for teaching science would affect the opportunities for learning science. The following four chapters provide an analysis of the opportunity to learn science afforded by the science content of lessons and the language used to construct that science content; this chapter has provided a descriptive context for that analysis and has provided a brief picture of the individual schools and teachers to counter the disaggregation of their practices that the analysis has necessitated.

What this descriptive chapter also provides is a basis for comparison with other research sites and therefore a measure of face-generalisability, so that other teachers and researchers may be able to recognise whether this research has relevance for their own contexts and classrooms.

What became clear was the wide gap between the rural and township schools in terms of infrastructure, with many rural schools falling far short of meeting the most basic conditions necessary for teaching and learning; and by the same token, the great challenges faced by teachers in these schools. The differences in poverty levels in rural and township schools, was reflected in the differences between the school fees that school governing bodies were able to demand. It appeared that resources for teaching science in terms of textbooks varied between schools – but only in one school did each learner in the Grade 8 class have their own science

textbook; in two classes only the teacher had a textbook; and in the other classes, learners had to share textbooks. What was common across all schools was the lack of science equipment to teach practical activities.

## **CHAPTER FIVE: SCIENCE CONTENT OF LESSONS AND THE OPPORTUNITY TO LEARN**

As described in Chapter Three, the transcriptions of the forty Grade 8 science lessons were analysed for the opportunities to learn science that they afforded the learners in the eight classes in the study.

### **Science content in the observed lessons**

The TIMSS video study (Roth et al, 2006) that examined the opportunity to learn science in Grade 8 classrooms in five countries provided a model for analysing the science content knowledge presented in the observed lessons in this research study. The criteria for coding the science content knowledge were drawn from the TIMSS video study and adapted for this analysis. Where applicable, data from the TIMSS video study has been provided for comparison.

The lesson transcripts were coded and analysed for the science content of the lessons according to the following criteria:

1. Types of science knowledge
2. Sources of science knowledge
3. Accuracy of science knowledge
4. Density of science knowledge
5. Coherence of science knowledge

As described in Chapter Three, the results of the coding process have been presented in charts and illustrated with excerpts from the lesson transcripts. In this section, where isiXhosa was used by teachers and learners, only the English translation has been presented, so as to maintain the focus on the lesson content. The bilingual practices of teachers and learners are

presented in the fourth section of the analysis; and in that section the original bilingual language use, with translations, has been maintained in the transcript extracts.

(Note: In the transcript excerpts, three dots indicates an untimed pause; three dots in square parenthesis [...] indicates that the transcript excerpt has been edited to leave out chunks of talk.)

The teachers' practices have been graded for the opportunity to learn along each criterion as follows: good (3); partial (2); poor (1); very poor/zero (0). This provided a rough quantification and basis for comparison between teachers.

### Types of science knowledge

The facts related to the lesson topic were coded as canonical knowledge, procedural and experimental knowledge, or real-life issues. The following excerpts from the lesson transcripts illustrate these categories:

#### Examples of types of science knowledge

- Canonical knowledge:

Example 1:

Teacher B: What happens to the properties of those things, which are mixed. The properties of two things that are mixed, what do they do, do they change? Mhmm ...? They don't change i-properties remain the same, heh? They remain the same, properties remain the same.

(Lesson B1, episode 1)

Example 2:

Teacher C: So we have the three states of matter that is the gases, the liquids and? And the solids.

(Lesson C1, episode 1)

- Procedural and experimental knowledge:

Example 3:

Teacher G: We use a Liebig condenser an ... an instrument called a Liebig condenser.

(Lesson G2, episode 19)

Example 4:

Teacher H: Okay. The first step is to take the slice of bread and then you make that bread wet. And then after that what is the next step? After you have that bread wet? The next step? ... Come Xola? (pointing to learner)

Learner: You must take it and put it ... in a dark place.

Teacher H: After .. you take that ... that wet slice of bread and then you put it in a container. And close it and put it in a dark place.

(Lesson H1, episode 1)

- Real-life issues:

Example 5:

Teacher E: Now let's look at the causes of air pollution. What do you think cause air pollution? Try and mention as many as possible.

Learner: (indistinct)

Teacher E: (moving close to learner) Huh? .. Smoke from smoking heh? ... smoking cigarette.

(Lesson E2, episode 7)

Example 6:

Teacher F: Electricity ... We use it in many ways. Electricity. Is that so?

Learners: Yes sir.

Teacher F: At home. Can you give me an example? Stand up, stand up. How do we use electricity at home?

Learner: For ironing.

(Lesson F4, episode 1)

### Findings on types of science knowledge in lessons

If learners are to have an opportunity to learn science, then one would expect lessons to include exposure to the three main categories of science content: ‘canonical knowledge,’ ‘procedural and experimental knowledge,’ and ‘real life issues;’ and one would further expect that canonical, or propositional knowledge about science, to predominate, with ‘procedural and experimental knowledge’ providing the empirical basis of such propositional knowledge; and ‘real life issues’ allowing for the application of such propositional knowledge. So one would expect propositional knowledge about science to be the core science content knowledge, supported by the other two types. This was the case with the TIMSS video study; and the relative balance of knowledge types for each country is shown in Figure 5.1..

Note: The TIMSS video study data has been rescaled so as to represent a percentage of public talk time *on science content*, rather than total public talk time (which would have included classroom management talk etc.). This is to bring it more in line with the percentages of *facts about science content*, that are represented in this analysis.

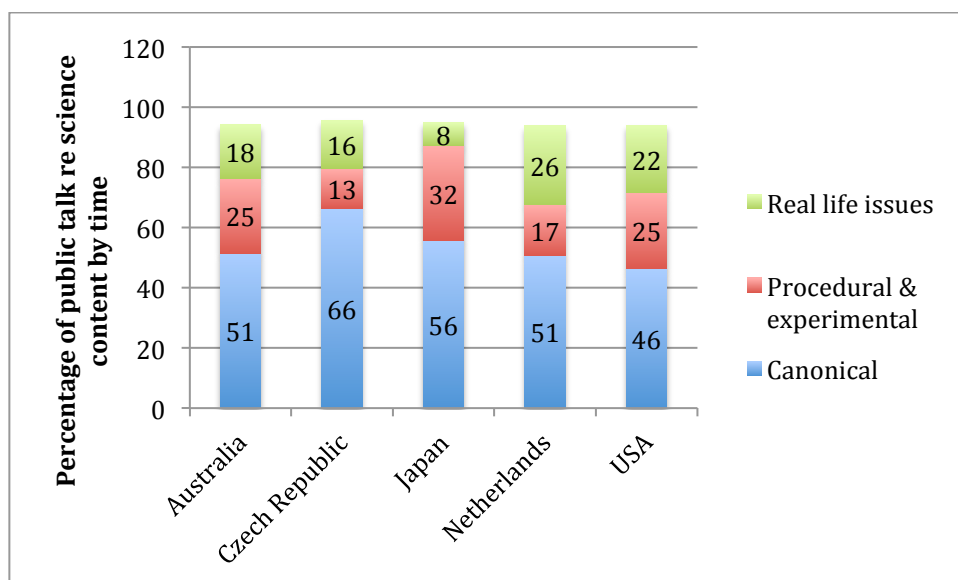
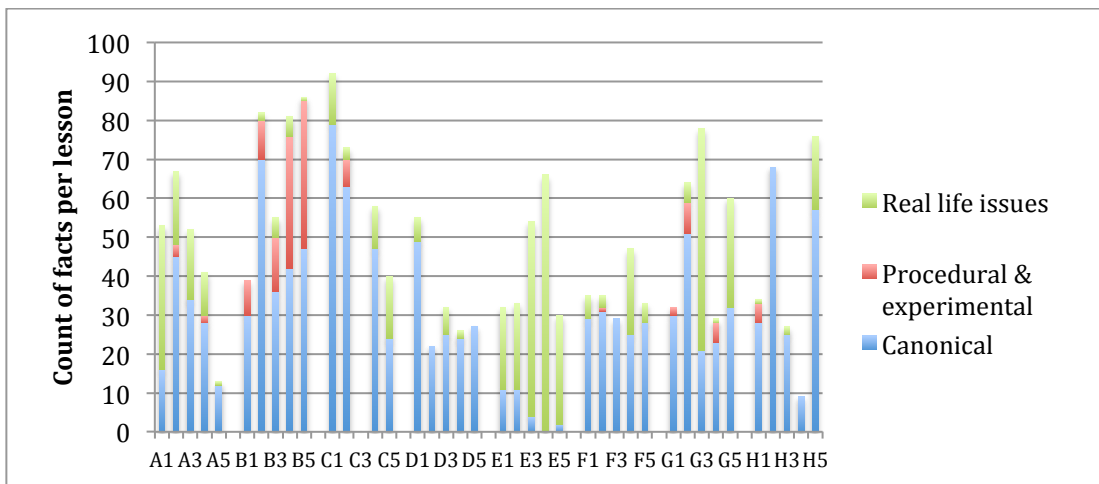
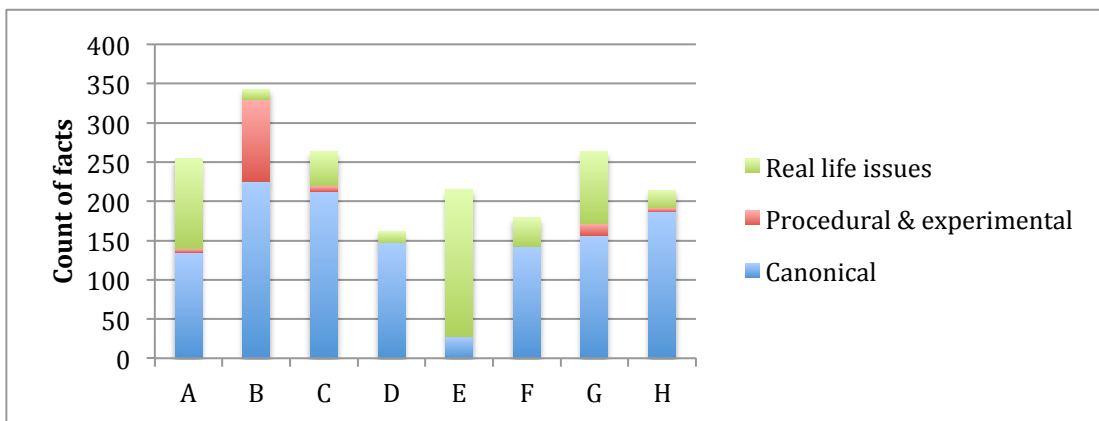


Figure 5.1: Types of science knowledge in the TIMSS video study (Roth et al., 2006)

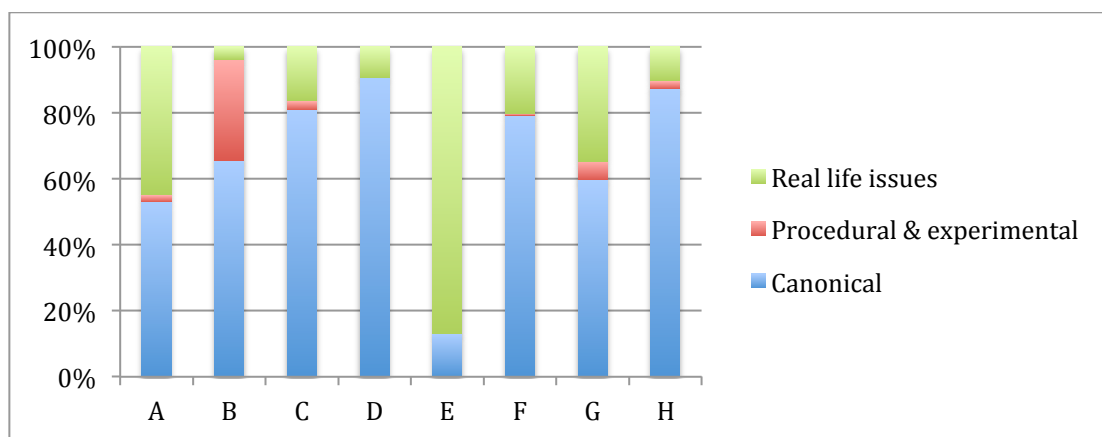
The charts in Figures 5.2-5.4. illustrate the amount and type of knowledge presented in the series of five lessons per teacher in this research study.



**Figure 5.2. Types of science knowledge for each lesson, by count of facts presented**



**Figure 5.3. Types of science knowledge for each teacher**



**Figure 5.4. Types of science knowledge as percentage of facts presented**

### *Canonical science knowledge*

As can be seen in Figures 5.2-5.4., it was canonical knowledge that predominated in the lessons of seven (all except Teacher E) out of the eight teachers (53 – 91% of facts presented). This was similar to the international data from the TIMSS Video Study, where canonical knowledge predominated in public talk about science content, but at lower levels overall: between 46% (USA) and 66% (Czech Republic).

### *Real-life issues*

However, in the case of Teacher E, it was real-life issues that predominated in all five lessons (87%), as learners reported back on saving water and various aspects of pollution. So while the literature on science teaching recognizes the value of making links between science concepts and learners' own experiences (see Roth et al., 2006, p. 121), the learners in Class E had very little opportunity to link their existing everyday knowledge and experiences to canonical science knowledge, given the low levels of canonical knowledge in their lessons; and thus they had very limited opportunity to develop canonical science knowledge.

There was also a high frequency of real-life issues in particular lessons for four other teachers (lessons A1, F4, G3 and G5,) as learners drew on their own experiences to report to the class.

Overall, the percentage of lesson content devoted to real life issues by the other seven teachers, varied between 45% (Teacher A) and 4% (Teacher B) of lesson content. This contrasted with the TIMSS video study data where the public talk about real-life issues was between 16 - 26% for four countries; and considerably less for Japan (8%). The relatively low proportion of science content knowledge categorized as real life issues in Teacher B's classes might have been in part due to the topic of mixtures and compounds which perhaps has less real life application than topics such as the food web (Lesson A1) or uses of electricity (Lesson F4).

### *Procedural and experimental knowledge*

As far as procedural and experimental knowledge is concerned, it was only Teacher B who included practical activities and knowledge about how to perform such activities (31%) in all of his lessons. In the lessons of six of the other teachers (all but Teacher E) there were several practical activities but learners were told what to do, with little explicit knowledge developed on the apparatus or processes involved, and so in these lessons, procedural and experimental knowledge only amounted to between 0% - 6% of lesson content. This is in contrast to the TIMSS video study findings where public talk time spent on developing procedural and experimental knowledge varied between 13% - 32%.

The charts also provide an indication of the absolute amount of science knowledge presented in lessons (Figure 5.3.) and it is clear from this chart that learners in Class B had the opportunity to learn more canonical, and procedural and experimental science knowledge, over their five lessons, than did learners in the other seven classes.

Overall, it appears that students in seven out of the eight classes (all except Class E) were exposed mainly to canonical science content, with some real-life issues, much like their counterparts in the TIMSS video study; but that only in Teacher B's classes were learners exposed to a substantial amount of procedural and experimental knowledge in line with

learners in the TIMSS video study; in the other seven classes there was little or no procedural and experimental knowledge (between 0 – 6%); and learners in this research sample were generally exposed to more real-life issues than those in the TIMSS video study.

### **Grading of teachers' practices for OTL science and types of science knowledge**

On the basis of this analysis the practices of the teachers have been graded in terms of the opportunity to learn science, as follows with percentage of canonical knowledge (CK), procedural and experimental knowledge (PEK) and real life issues (RLI) in brackets; and a value ascribed for OTL science as follows: good (3); partial (2); poor (1); very poor/zero (0)

Teacher A (CK 53; PEK 2; RLI 45): learners were exposed to mainly canonical knowledge, and a substantial proportion of knowledge related to real life issues; but very little explicit procedural and experimental knowledge, despite being involved in practical work in two of the five lessons (A2 and A4). (Graded OTL 2 - partial)

Teacher B (CK 66; PEK 31; RLI 4): learners were exposed to mainly canonical knowledge, with a substantial percentage of procedural and experimental knowledge; but with relatively little in the way of real life issues, although some relevant examples were included. Nevertheless it appears that the OTL science would have been relatively good in Teacher B's lessons. (Graded OTL 3 – good).

Teacher C (CK 81; PEK 3; RLI 16): learners in Class C were exposed to a high percentage of canonical knowledge, with a substantial percentage of real life issues; but very little procedural and experimental knowledge, despite the fact of practical activities in three out of five lessons (C1, C2, C4)(Graded OTL 2 – partial).

Teacher D (CK 91; PEK 0; RLI 9): learners in Class D were exposed to a very high percentage of canonical knowledge and this reflected the mainly transmission and test style of teaching. There was some real life application but no practical activities in the lessons and so no opportunity to

develop procedural and experimental knowledge or to understand science as having an empirical basis. (Graded OTL 1 – poor).

Teacher E (CK 13; PEK 0; RLI 87): learners were exposed to mainly real life issues; very little canonical knowledge; and no procedural and experimental knowledge. This seriously compromised their OTL science. (Graded OTL 0 – very poor).

Teacher F (CK 79; PEK 1; RLI 20): learners in Class F were exposed to a high percentage of canonical knowledge, but there was only one practical activity in the five lessons (F2), and so little opportunity to appreciate the empirical basis of science knowledge. There were a substantial percentage of facts relating the topic of the lessons - electricity – to real life issues. (Graded OTL 1 – poor).

Teacher G (CK 60; PEK 6; RLI 35): learners were exposed to all three types of science knowledge; although the percentage of explicit procedural and experimental knowledge was low, considering that there were practical activities in three out of the five lessons (G1, G2, G4). The relatively high levels of lesson content related to real life issues reflected the extended group reporting by learners in two of the five lessons (G3 and G5). (Graded OTL 2 - partial).

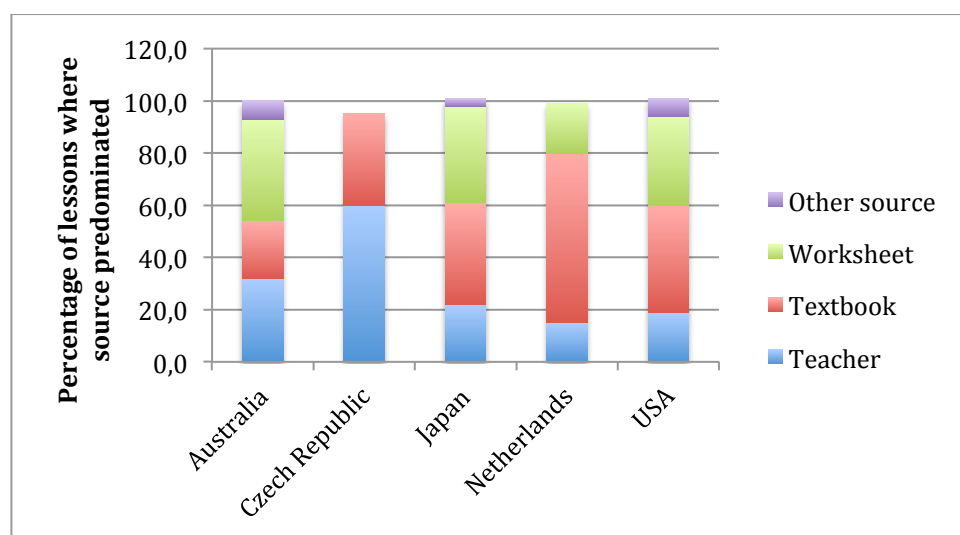
Teacher H (CK 88; PEK 2; RLI 10): learners were exposed to all three types of science knowledge but little explicit procedural and experimental knowledge, despite there being practical activities in three out of the five lessons (H1, H2, H3) (Graded OTL 2 - partial).

**Table 5.1. Grading of OTL science in terms of science content in lessons**

<b>Teacher</b>	A	B	C	D	E	F	G	H
<b>Grade</b>	2	3	2	1	0	1	2	2

## Sources of science content in lessons

The TIMSS Video Study identified three main sources of science content in lessons (Roth, 2006 pp. 59-60)– the teacher, a textbook, a worksheet - and ‘other’, which included students’ presentations. These were quantified in terms of the *main source for a lesson* and are shown in Figure 5.5. .

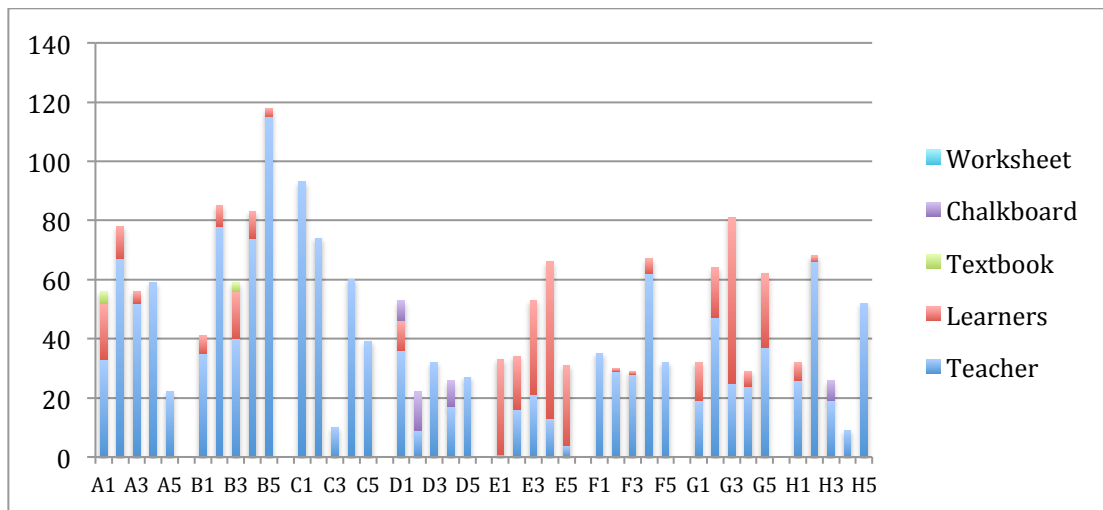


**Figure 5.5. Source of lesson content per percentage of lessons (Roth et al., 2006)**

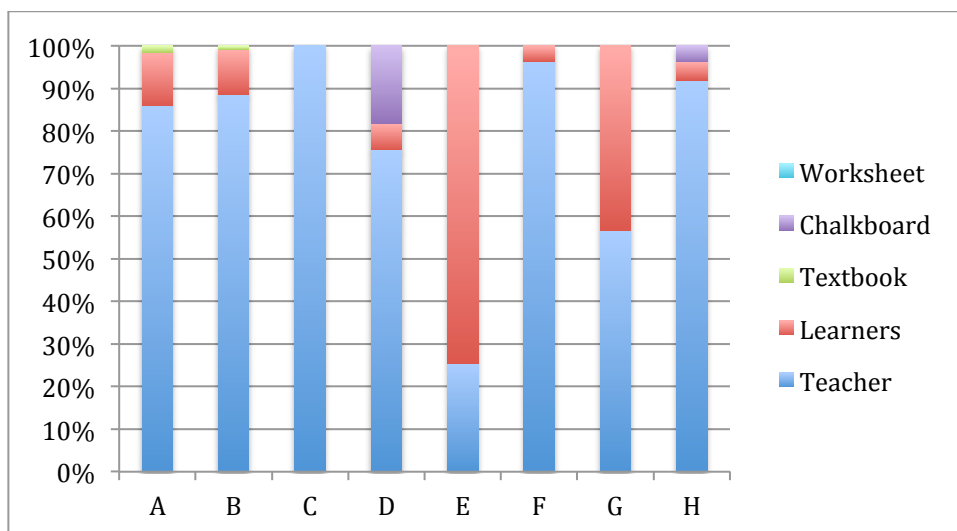
What is clear is that, apart from the Czech Republic, the main sources of science content in the other four countries were *written sources* (textbooks or worksheets) in the majority of lessons: ranging from 61% - 84% of lessons; and in the Czech Republic, where the teacher was the main source for 60% of lessons, written materials comprised the main source of science content for 35% of lessons.

In this research study, *the science facts per lesson were coded in terms of their source*, and counted, to arrive at the charts in Figures 5.6. and 5.7.. So again, the data is not directly comparable to the TIMSS video study but the relative proportions do provide some basis for comparison. The source ‘learners’ has been added: this is included in ‘other sources’ in the

TIMSS video study, but coded separately in this study as it was the main source of lesson content in one classroom (E) and a major source in another (G). The source 'chalkboard' has also been added, as this was an important source of science content when learners copied notes.



**Figure 5.6. Sources of science knowledge per lesson**



**Figure 5.7. Sources of science knowledge by percentage**

### Findings for sources of science content

The research data showed a very different picture to that of the TIMSS video study in that the sources of science knowledge in the observed lessons were *primarily oral* (an average of 98%) with lesson content coming from teachers and learners.

What was also notable was the high levels of lesson content coming from learners in Class E (75%) and Class H (43%) as a result of lengthy group presentations.

There was *little use made of textbooks* by learners in the observed lessons, although six out of the eight teachers (all except teachers D and H) said they had some textbooks to share among learners (see Table 5.2. below). Teacher D had only one textbook and wrote up notes for learners on the chalkboard and copied out worksheets based on her textbook; and Teacher H said the textbooks available were old, dating from 1990, and she had only one more up-to-date ‘OBE’<sup>8</sup> textbook from which she made photocopies for learners – although this was not evident in the observed lessons.

**Table 5.2. Availability of textbooks and reference resources**

<b>Teacher</b>	<b>Textbooks</b>
A	Some – ‘scanty’ supply (Science for All – Macmillan)
B	Some - 3 learners per textbook (Science for All – Macmillan); a set of 6 dictionaries bought with school funds
C	All students have a copy (Science Now – Heinemann)
D	1 copy for teacher (Science for All – Macmillan)
E	Some – 1 copy per group; ‘OBE’ textbook (not specified) and regarded by teacher as ‘not good’ and ‘irrelevant’ and too complicated for learners – so not used. Supplemented with photocopied exercises from different textbooks.
F	Most students have a textbook – some have to share (Science for All – Macmillan).
G	Some – 4 students share a textbook (Science for All – Macmillan).
H	‘Old’ textbooks from 1990; teacher has 1 copy of ‘OBE’ textbook (unspecified) – makes photocopies for learners.

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<sup>8</sup> ‘OBE’ refers to Outcomes Based Education – a popular term for the curriculum that was introduced in 1997 and which was superseded by a revised national curriculum in 2002.

Although Teacher A reported that there were some science textbooks for the class, in lesson A1, he handed out photocopied pages from the textbook for two activities; but as there was only one photocopy to be shared per group of approximately seven learners, it would have been more difficult for all learners in the groups to read the text than if the textbooks themselves had been used.

Similarly, Teacher C reported that all students in her class had copies of the textbooks but she also photocopied an activity from the textbook for Lessons C1 (re an activity on making jelly, in a section on phase changes) and handed out one photocopy per group of four learners – instead of learners using their textbooks. In lesson C3 Teacher C did get learners to use the textbooks to do an activity on choosing a water scheme for a fictitious village; however it appeared from the lesson that learners had difficulty in reading and understanding the different scenarios presented, despite the teacher reading them aloud and translating at times to explain; and learners seemed to mostly copy out chunks from the textbook rather than provide reasoned responses to the question, as shown in the excerpt below.

Teacher C: Let's listen to the answer for question A; how clean and good is the water? .... Raise your voice so that all the learners can hear you.

Learner: (reading from paper) Boreholes are holes which are drilled (sic) deep down into the ground until they reach water (a direct quotation from text re Scheme A) (learner looks at the teacher).

Teacher C: (to the class) Did they answer the question? The question says how clean and good is the water? ... Do you agree with that group?

Learners: (no response)

Teacher C: Let us answer the question please. Let's come to Scheme B, let's leave Scheme A and come to Scheme B.

Same Learner: (Learner reads again from her piece of paper) Ekulandeni would get an electric pump so that people collecting water in the village would simply fill their buckets from a tap (direct quotation from text re Scheme A).

(Lesson C3, episode 4)

Teacher E said that there were some textbooks – approximately one per group; but that he did not use them as they were ‘OBE’ and ‘really irrelevant’; and that learners found them complicated and ‘they just get stuck there,’ partly because the language level was too difficult. So he used to supplement the textbooks with photocopied exercises from other textbooks and claimed he gave learners a lot of notes.

In lesson B3, the teacher got learners to look up the definition of ‘properties’ and ‘reaction’ in the textbook glossary and dictionaries; and learners worked on a summative exercise from their textbooks in Lesson B5, at the conclusion of a series of lessons on separating mixtures. But this was the extent of explicit and effective textbook use by the teachers in the forty observed science lessons.

Although there was little use made of textbooks by learners in class, it was evident from the lessons that at least six of the teachers (all except E and H) were following the textbook materials in presenting their lessons. So the *textbook content was mediated orally by the teachers*, but the learners did not engage directly with the textbooks in class, except for the limited examples from Teacher B’s lessons.

Teacher D and Teacher H compensated for the lack of textbooks in their classes by *writing up notes on the chalkboard* for learners to copy down; this was done systematically by Teacher D (see example lesson summary D1, episode 4) in four out of the five observed lessons and learners were given time to copy down the notes in class (these notes were not entirely correct – see section on accuracy of lesson content). Teacher H wrote up notes for learners to copy down in Lesson H3 (information was partly incorrect and unsystematic); and told the class she would give them notes the following week, on the material on seed germination covered in Lesson H5. The other teachers all used the chalkboard to highlight key points in the lesson; and the case of Teachers B and G, to illustrate and explain experiments when they did not have the necessary equipment (e.g. Liebig’s condenser; separating funnel). In addition, in Lesson B5,

Teacher B used the chalkboard to elicit a mind map, summarising the key ideas concerning the separation of mixtures and linking them to the key generalising principle.

In the observed lessons, there was almost no use made of *teacher-designed worksheets* as a source of science knowledge. In Lesson H1 the teacher handed out a worksheet with questions based on the lesson content; but this was a very simple consolidation exercise and not the main source of science content in the lesson. Mostly such consolidation exercises, where they occurred, were written up by teachers on the chalkboard. Teacher D also handed out a worksheet in Lesson D1 – but this was a hand written copy of an activity in the textbook (rather than a photocopy).

It is notable that Teachers A, C, D and H handed out worksheets – whether copies from textbooks or in the case of Teacher H, questions which could just as well have been written up on the chalkboard, in the *first* of their observed lessons but not in subsequent lessons; perhaps there was an expectation on the part of teachers that this in itself constituted good practice and should be part of their lessons when being observed.

Classes E and G showed high levels of *learner contributions*, as a result of the group discussions and reporting back in these lessons, with 75% of the lesson knowledge contributed by learners in Class E (of which 24% was off the point), and 43% by learners in Class G. It appears that Teacher E had abdicated his role as source of knowledge, as his main focus in the observed lessons was on procedural matters such as managing the presentations by groups, asking questions by groups and the class to one another; and ‘democratic’ assessment of groups, with very limited development of science knowledge. (see Lesson summaries Appendix 4.).

This means that in seven out of the eight classes, learners depended on the *teacher as the main source of science knowledge*. This has serious negative implications when the teacher’s science

knowledge is not correct. In addition, it meant that in all classes there was little opportunity for learners to read science texts, which would limit their opportunities to develop *science literacy*.

### Grading of teachers' practices for OTL science and sources of science content

The teachers' practices were ranked for the criterion, 'sources of science content' in terms of the OTL science for learners: Teacher B was ranked the highest as there was at least some reference to textbooks and dictionaries, with the appropriate reading skills modeled (graded OTL 3 - good). The rest of the teachers (excluding Teacher E) were graded OTL 2 – partial - as in their lessons the teacher was the main source of science knowledge (57 – 100%). Teacher E was graded OTL 1 (poor) as the main source of science knowledge was the learners (87% of lesson content).

**Table 5.3. Grading of OTL science in terms of the source of science knowledge**

Teacher	A	B	C	D	E	F	G	H
Grading	2	3	2	2	1	2	2	2

### Accuracy of science knowledge

A feature of the body of science knowledge is that it strives to explain the workings of the natural world in terms of generalisable concepts and principles that are empirically verifiable; and fundamental to this is *precise and accurate meanings*. As noted in the previous chapter, accuracy of science knowledge was not a category in the TIMSS video study analysis but it has been included in this analysis as I noted during lesson observations that in some lessons, incorrect or partially correct information was being presented by some teachers, with obvious negative effects on the opportunity to learn science.

Thus the science knowledge in lessons was coded according to whether it was accurate or not, as follows:

- science content accurate and complete
- science content unclear/not quite accurate/incomplete concept (partly correct)
- science content incorrect and inaccurate (incorrect)

### Examples of coding for accuracy of science content

In Lesson A4 on force, Teacher A made the following statement early in the lesson (episode 1):

Example 1:

Teacher A: Now so we are going to see (writing on board)

**Force => action**

Teacher A: Say that a force must produce what? Action. Must produce action or must result in Action.

(Lesson A4, episode 1)

In the above extract, Teacher A confused 'work' and 'force': in scientific terms, work is done when force is applied and an object moves; but force can be applied to an object and the object may not move, in which case no work has been done. So force applied does not always result in movement or action, but it is correct to say that movement or action is a result of force applied. So the statement in Example 1 was coded incorrect. What Teacher A also did not explain in the lesson was the difference between applied force (pushing or pulling) and natural forces such as gravity, friction, air resistance; and that applied force acts against a natural force.

Later in the lesson (episode 5), Teacher A repeated the same incorrect statement as in Example 1, but went on to state correctly that if force produced movement then work had been done – see Example 2 following:

Example 2:

Teacher A: Now ... okay we said that a force produces action, okay? Or a force produces movement, okay? Now as a result of the movement of a force. Eh ... can I (indistinct) something else? As the result of the movement of the force... **(coded incorrect)** if...there is a motion that takes place because of a force people say that ... people say that work has been done. If the force produces action or movement we say that force has been...I mean work has been done. Okay? **(coded correct)**

(Lesson A4, episode 5)

Example 3 from the same lesson, illustrates the code 'partly correct', where the science content was unclear, or not quite accurate, or incomplete. In this part of the lesson, Teacher A got learners to read off a measurement from a spring balance which he had hung from the edge of the desk and so learners had to crouch down to read off the measurement correctly. Teacher A referred to the 'error of parallax' but did not explain it, so this is coded 'partly correct' as the meaning was unclear. The next statement was coded 'incorrect', as boiling water would not have a meniscus (and even if the word meniscus was used correctly, it was not explained).

Example 3:

Teacher A: And now what is important...what do you usually say in measuring, in measuring? They say you must avoid the error of parallax, okay? You must avoid the error of parallax. (writing on board)

**Error of parallex (sic)**

Error ... of ... parallax. You must avoid the error of ... parallax. ... (teacher demonstrates measuring with one eye closed) ... That is you must keep the eye, your eye level with ... with (gesturing) with the line which you are measuring, okay? **(coded partly correct)**

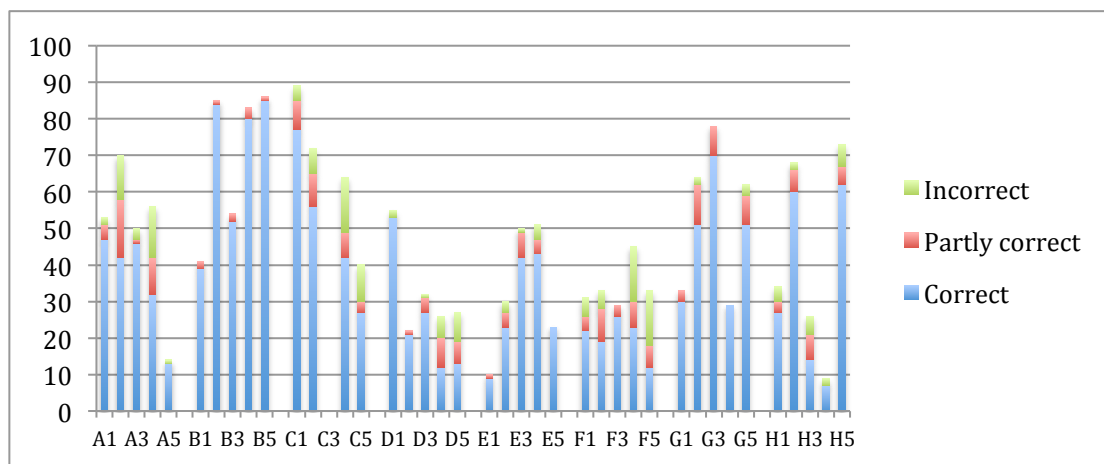
Learners: Yes.

Teacher A: Even if you are measuring the boiling hot water, you must keep your eye level with the meniscus of your water **(coded incorrect)**.

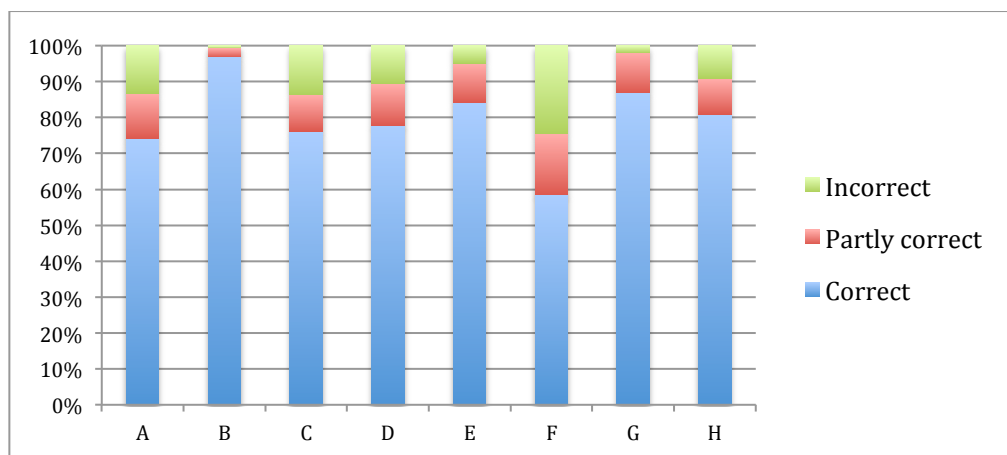
(Lesson A4, episode 9)

### Findings on accuracy of science content

All of the science facts presented in the lessons by teachers and learners were coded for accuracy as per the examples given. The results of the coding are shown in Figures 5.8. and 5.9.



**Figure 5.8. Accuracy of science content per lesson**



**Figure 5.9. Accuracy of science knowledge per teacher by percentage**

As the charts in Figures 5.8. and 5.9. show, the percentage of correct content in lessons ranged between 97% for Teacher B, to 58% for Teacher F. These findings are presented for each teacher:

### *Teacher B*

In Teacher B's lessons there was one incorrect fact in Lesson B3, namely that a mixture of sand and water could form a solution. Although Teacher B stated correctly that sand could not dissolve in water, he appeared to understand 'solution' to mean any substance mixed with water. However the definition of a solution is that one component dissolves in another component i.e. the components are completely dispersed at a molecular level. This misconception can be seen in the excerpt below:

Teacher B: Now we'll try to separate that mixture of soil and water which sometimes you can call a solution.

(Lesson B3, episode 2)

The definition in the textbook used by Teacher B was not very clear: '**solution** (n.) an even mixture of substances, such as salt in water; there is the same amount of each substance in each part of the solution' (Moodie, Keogh, Douglas & Weber, p. 281). This was the only incorrect fact in the lessons of Teacher B and amounted to less than one percent of science content.

### *Teacher F*

At the other end of the scale, in Teacher F's lessons only 58% of science content overall was correct; and in Lesson F4 (the uses of electricity and resistors) and Lesson F5 (series and parallel circuits and fuses) the percentage of correct content was even lower at 51% and 36% respectively. Some of the misconceptions are described as follows:

One of the key concepts in Lesson F4 was that of resistors in electric circuits. The correct explanation of resistors is as follows: a resistor is a poor conductor of electricity (semi-conductor). When the electric current reaches a resistor in a circuit, then the flow of the current is slowed down and the resistor heats up. In this way electrical energy is converted into heat energy; in heating appliances, the heating element contains a resistor. In a light bulb, the

resistor is made of metal called tungsten which is a poor conductor of electricity and it gives off heat and light. Resistors are used in all electric and electronic appliances.

Some of the incorrect concepts in these lessons were:

- Heating appliances have resistors which 'hold the heat' whereas radios, televisions and lights do not have resistors, they just have good conductors and they only give off light and sound.

Teacher F: Alright so why do we use now... why do these heating appliance have a resistor and then the entertainment (i.e. radios, televisions) do not have a resistor? [...]

This (indicating pictures of heating appliances) give us heat and this (indicating pictures of television, radio, lights) give us what they give us which? Sound and light. Eh ... here is in television, radio and lights there is that eh good conductor of heat, sorry, good conductor of electricity. That is the most (i.e. usual) eh ... connection for television, radio and the lights. They use copper. Instead we said actually in good conductors the electricity it just flows. It is moving okay? It doesn't stay in one place. It's always moving.

(Lesson F4, episode 2)

- 'Electric current' and 'heat' were used interchangeably.

Teacher F: That element holds on to heat. Then after some time it will become more hot, okay?

(Lesson F4, episode 2)

The consolidation exercise at the end of Lesson F4 required learners to classify household appliances that had resistors and those that did not have resistors, thus consolidating this particular misconception:

(written on chalkboard)

#### **Group work**

**Classify the household appliances that you think have resistors in them and those that do not have.**

**Appliances with resistors**

**Appliances with no resistors**

(Lesson F4, episode 3)

Teachers A, C and D had less than 80% of science content correct in their lessons: 74%, 76% and 78% respectively; some examples are presented below:

### *Teacher A*

Some misconceptions in Teacher A's lessons stemmed from the explanations and examples he gave, which were incorrect and sometimes led to lengthy digressions. For example in Lesson A2, on separating mixtures, Teacher A was trying to elicit from learners that a magnet would attract metal objects; but he likened magnetic attraction to being choked (i.e. shocked) by electricity which is incorrect.

Teacher A: Okay, let's say you hold the electricity cable. You hold the electricity cable when (indistinct). What will happen to you? Heh?

Learners: (indistinct)

Teacher A: You will become what? Choked (shocked), okay? You are going to be choked. Then it means that if you are being choked you stick to that you don't move away any more. You see?

Learners: Yes.

Teacher A: Because you have been attracted by the? Electricity cable.

(Lesson A2, episode 4)

Later in the same lesson Teacher A had got learners to mix sulphur powder and iron filings and was showing them how part of the mixture moved when he moved a magnet under the paper holding the mixture. He tried to elicit what part of the mixture was moving, but then digressed into a lengthy and incorrect explanation of the origin of iron filings:

Teacher A: But now there was something in that mixture which was moving when I bring in the? The what? The magnet. Then those iron filings they came ... they come from ...if you take .. do you know the file (pronounced 'feel').. the file .. that used to grind...say the mother is hoeing her fields. She is hoeing to her field okay? (demonstrates hoeing) And that say, "Hey, it hit hard on the stones and then the hoe (pronounced 'who') becomes....you see .....becomes hurt I would say so, becomes hurt and unable to ... becomes not sharp now. Then he will say bring me the what-you-call-it, a file so that it happens I sharpen it. To sharpen my hoe... and then while she is sharpening the hoe there are pieces of metal, that's what we call the iron...filings. Those pieces of metal are called iron filings.

(Lesson A2, episode 5)

In the next example, Teacher A was teaching scientific terms after separating a mixture of flour and water but these were incorrect: flour and water form a suspension, not a solution; the flour settles to form a sediment, not a residue; and colloids are particles that are not visible to the naked eye and do not separate out: for example butter, mayonnaise.

Teacher A: When you mix the flour ... flour and? And what? And water, okay? (writing on chalkboard)

Learners: Yes.

#### **Flour and water => solution**

Teacher A: And water. We get our solution, okay? ... Then this flour that has settled down forms a residue, okay? ... That solution has some particles of flour floating...floating in the? Water, okay?

Learners: Yes.

Teacher A: And then those floating particles they form what is known as the....(writing on board) the floating particles .. the floating ... the floating particles ... they form what? They form the colloids.

#### **Floating particles form colloids**

(Lesson A2, episode 14)

### **Teacher C**

In Teacher C's lessons on materials (lessons C4 and C5), there were several misconceptions: Teacher C confused artificial materials - described as 'man-made' in the textbook - with objects that were man-made; so when she elicited examples of materials in the classroom that were artificial, some such as wooden furniture were classified as artificial materials because the objects themselves were 'man-made.'

Teacher C: So we have these four types of artificial materials. That is we have the metals, the plastics, the bricks, and the wood and we've just give the examples in each type of material. We've said that for wood we have examples like the tables, cupboards, desks and so on. We've just made examples here in our classroom. Do you follow?

(Lesson C4, episode 1)

Teacher C listed natural materials as cotton, silk ('from worms', with no further explanation) and metals (from ores). She then stated that the metal in the classroom – chalkboard, window frames - were artificial because they were man-made but there were natural metals from ores as well.

Teacher C: We have said that there are metals that are artificial (pointing to window frames). We're going to give the examples of these metals here because they are ... ? These are man-made but these metals here (pointing to 'ores' on chalkboard) are natural, they are coming from ... or we get them from ores that is the natural materials.

(Lesson C4, episode 1)

#### *Teacher D*

Some of the incorrect information in Teacher D's lessons is referred to later in this section, in relation to teachers' misreading of textbook material about photosynthesis and respiration.

The percentage of correct content in the lessons of the remaining three teachers – H, E and G - was 81%, 85% and 87% respectively.

#### *Teacher H*

Of the three, Teacher H had the highest percentage of science content incorrect (9%) and close to the other two teachers in terms of partly correct and/or incomplete information. In Teacher H's third lesson on reproduction and different kinds of fruit, the basis for classifying fruits, which was the key to the lesson, was incorrect and confused – this is explored in more detail in the section on lesson coherence. Teacher H indicated that the primary classification for fruits was 'dehiscent' and 'indehiscent' – however this is a much lower level of classification (see example below):

Teacher H: Okay fruits are split into two groups. We have got the dehiscent fruit and the indehiscent fruit. The dehiscent fruit are the fruit that splits open when they are ripe. The dehiscent fruit split open when they are ripe. (writing on board) Different kinds of fruit. We have got dehiscent and we have got indehiscent.

### **Different kinds of fruit**

**Dehiscent => opens when ripe eg. pea**

**Indehiscent => do not open eg.**

(Lesson H3, episode 3)

Another basic misconception in Lesson H5 was in relation to the germination of monocotyledonous and dicotyledonous seeds. In monocotyledons, the hypocotyl stays underground and forms roots; whereas in dicotyledons, the hypocotyl grows above ground and forms the stem; however, Teacher H referred several times to 'the root growing above the ground.'

Teacher H: It (the hypocotyl) is that root but now it is growing above the soil.

(Lesson H5, episode 3)

### ***Teacher E***

In Teacher E's lessons, 75% of lesson content came from learners and likewise the incorrect content; but this was not corrected by Teacher E and so the misconceptions were perpetuated. For example in Lesson E2 on problems caused by air pollution, learners stated that heart disease and TB were such problems; and in Lesson E4 on land pollution, learners claimed that papers caused germs and one solution was that 'people stop old cars' – this rather strange statement was because learners identified old cars as a cause of pollution and many of their solutions, including this one, were phrased simplistically as a negation of the original problem.

In addition, in Teacher E's lessons, 24% of the science content was off the point when learners were reporting. This was coded only for Teacher E's lessons where it appeared to be a problem. Again the off the point information was not corrected by the teacher whose focus was on the procedural aspects of groups reporting rather than the content, with strict instructions about greeting the class and introducing group members, and then finishing off with 'That is about all';

how to propose and vote for marks for groups; and how to clap in unison. So for example, in Lesson E1 on saving water, learners reported some general facts about water but not saving water per se: e.g.

- Plants and animals need water.
- Our bodies are made of a third of water.
- Water is found in rivers, lakes.
- We can drink eight glasses of water a day.
- Water is colourless.

In fact the only points offered about saving water were to stop taps dripping and to stop children playing with water.

### *Teacher G*

In Teacher G's lessons, there was a relatively low level of incorrect information – only 2% overall; but 11% of science information was partly correct or incomplete, when Teacher G did not fully explain ideas or concepts. Example G1 below is an example of incorrect content – it is infrared rays (not ultraviolet rays), which are trapped and lead to global warming.

Teacher G: The sun radiates energy to ... to the soil. Not all ... not all the ... not all the radiant energy is absorbed. So the soil absorbs ... absorbs ... the soil or the earth absorbs energy from the sun. Not all ... not all the energy is radiated to? To the soil. Some is reflected ... it is reflected in the atmosphere back to the atmos ... back to the air. So it is reflected back ... it is reflected back ... Those ... those uh ... rays they are very dangerous. We call them ultraviolet rays. We call them ultra ... ultraviolet rays.

(Lesson G5, episode 5)

In the same lesson, learners were discussing how to prevent global warming. Teacher G intervened to say (correctly) that electricity production also contributes to global warming as coal is burned in the process – but did not make the crucial point that there are other greener sources of electricity. So learners were left with incomplete information.

### Impact of incorrect science content knowledge on learners' opportunity to learn science

Given the wide range of the percentages of correct science content in the observed lessons, the question is: how much incorrect information in a science lesson is too much and could be said to obstruct the learners' opportunity to learn science?

The National School Effectiveness Study (NSES) (Taylor, van der Berg & Mabogoane, 2013) found that only 'truly sound teacher knowledge is linked to better learner performance, while teachers with some gaps in their knowledge do not produce significantly better learner achievement than teachers with large gaps' (p. 227); and they note that 'it seems self-evident that insufficient teacher disciplinary knowledge creates an *a priori* barrier to learning' (p. 228).

It also seems likely that particularly with a hierarchical knowledge structure such as science, if basic misconceptions are transmitted by teachers (for example confusion about the nature of artificial materials), then all other information on the topic, is based on misconceptions, even if some of the facts that are given are correct in themselves.

It should also be noted that coding and quantifying of items of information in science lessons for accuracy, such as has been done in this study, provides a very rough indication of the opportunity to learn science along this dimension. Meaning is developed and cumulates over a lesson and over lessons; and so information left out, as well as superfluous or distracting information added in, would also interfere with the clear cumulation of ideas and the development of concepts. The issue of coherence is explored later.

Given the above, it seems fair to suppose that in terms of accuracy, the learners in Teacher B's class had a greater opportunity to learn science than those in *all* the other seven classes, as the science content in his lessons could be termed 'truly sound,' whereas the science content in the lessons of the other seven teachers was between 58% and 87% accurate, and so likely to compromise the learners' opportunity to learn science; and likewise there would not be much

difference in the opportunity science along this criterion, for all but Class B, as it appears that getting a little content wrong is as bad as getting a lot wrong.

#### Possible reasons for relatively high levels of inaccuracy in observed lessons

It is tempting to speculate as to reasons for the high levels of inaccuracy in most classes and the data offered some possible indications: teachers' qualifications and teachers' reading skills.

#### Teachers' qualifications

The teacher interviews included questions on their highest science teaching qualifications, further studies and science teaching experience. These are summarised below in Table 5.4. alongside the percentage of correct science content knowledge in their observed lessons.

**Table 5.4. Teachers' highest science teaching qualifications and further studies; science teaching experience; and percentage of correct science content**

Teacher	Highest science qualification	Further studies	Science teaching experience	Science content correct
F	Senior Teacher's Diploma - specialising in Biology and Geography	None; Department of Education workshops	1,5 years	58%
A	Matric science; Primary Teacher's Certificate – no science specialisation	Studying for National Diploma in Public Management and Development	19 years	74%
C	Matric science; Senior Teacher's Diploma - specialising in English and History	Bachelor of Primary Education; studying for Bachelor of Education Management	3 years	76%
D	3 year Teacher's Diploma – specialising in Mathematics and Science	Bachelor of Commerce in Education; Bachelor of Education Management	1 year	78%
H	Senior Teacher's Diploma – specialising in Biology and Geography	Bachelor of Technology; Higher Diploma in Educational Management	21 years	81%
E	Senior Teacher's Diploma – specialising in English and Biology	Bachelor of Arts in isiXhosa and Education; Bachelor of Education Honours in Management	18 years	85%

G	Primary Teacher's Diploma – specialising in science	Further Diploma in Education Management	18 years	87%
B	Senior Primary Teacher's Diploma, specialising maths and science	Diploma in Science Teaching; Bachelor of Education Honours in Science Education	24 years	97%

As Table 5.4. shows, Teacher F, with the lowest percentage of correct science content (58%), had been trained as a biology and geography teacher, so he had had no training in natural science and the lessons on electricity that he was observed teaching were on a topic outside of his specialisation; he had no accredited further training in science teaching; and only 18 months teaching experience.

Teachers A and C, with the second and third lowest percentages of correct science content (74% and 76% respectively), had no post school science qualifications. Teacher A had 19 years experience teaching science; Teacher C had 15 years teaching experience but only three years teaching science. Both teachers were engaged in further studies in management rather than science.

Teacher D (78% correct science content), had a teacher's diploma with a science teaching specialisation, but had done further studies for a BComm (Education) degree part-time, and so had been teaching commerce subjects but had switched to teaching science one year prior to the data collection.

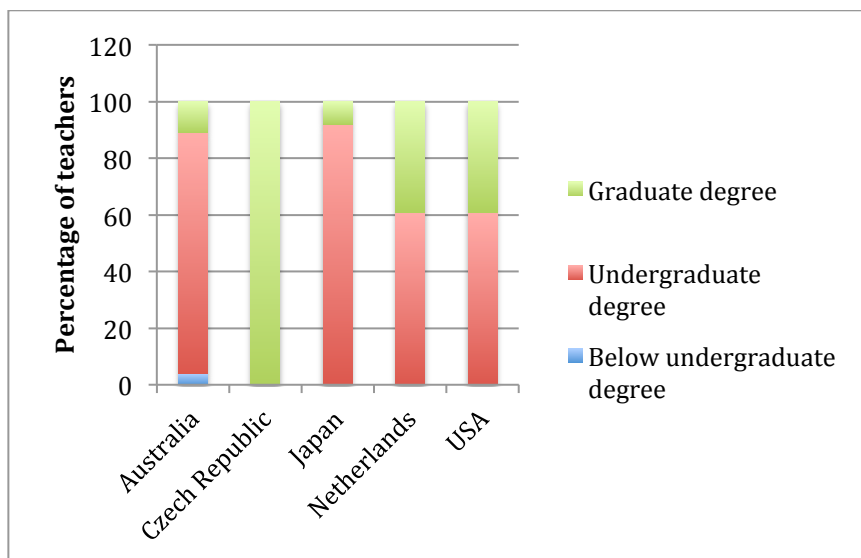
Teachers E and H also had teaching qualifications in biology but not in natural science; both had taught for a considerable number of years: 18 and 21 years respectively; their lesson content was 85% and 81% correct respectively, although there was so little science content in Teacher E's lessons that this figure is not particularly meaningful. Both Teachers E and H were also engaged in further studies in management.

Teacher G had a Primary Teachers' Diploma in science teaching; and 18 years experience teaching science - but further studies in education management, not science teaching- and her lessons contained 87% accurate information.

Teacher B had the highest levels of correct science information (97%), and 1% incorrect information. He had a teaching qualification in general science and had been teaching science for the longest of all the teachers: 24 years. In addition, he had studied further in science education, with a diploma in science education and a BEd Honours degree in science education.

If one can draw any conclusions from this data, it would appear that the teachers' educational levels in science teaching were more important than their teaching experience, as one of the teachers with relatively long teaching experience (Teacher A - 19 years experience) scored second lowest in terms of accuracy of science content; and the teacher with the highest level of accuracy (Teacher B) had the highest level of science teaching qualifications. However experience did seem to count for something as the three teachers beside Teacher A, who had less than 80% of correct science content, all had been teaching science for 3 years or less, versus the other 4 teachers who had over 80% correct science content and had between 18 and 24 years science teaching experience.

For comparison, the qualifications of teachers in the TIMSS video study are shown in Figure 5.10 and it is clear that the majority of teachers (all but 4% of Australian teachers) had undergraduate degrees equipping them to teach science, and in the Czech Republic all the teachers in the study had post graduate degrees, making the majority of teachers in the TIMSS video study far better qualified than the science teachers in this study.



**Figure 5.10: Qualifications of science teachers in TIMSS video study (Roth et al, 2006)**

If some teachers did not have adequate training in science, then this also raises the question of teacher agency in terms of seeking further training. However, as the table indicates, of the seven teachers who had studied further, six had studied Educational Management rather than science.

### *Teachers' reading skills*

There is a further point to be made in relation to the accuracy of science knowledge: teachers' precise reading comprehension skills. Although teachers and learners were not observed using textbooks in class, it was clear that most teachers had drawn their lesson content from certain textbooks and this was mediated orally to learners during lessons.

It appeared from the observed lessons that Teachers C, D, and F had misread and/or misunderstood information in the textbooks and passed on these misconceptions to learners.

#### Example 1: electricity - short circuits

For example Teacher F was following the textbook content fairly closely in his lessons on electricity, and it was possible to see where he had misread or misinterpreted the information about short circuits in the textbook: it was stated in the textbook:

A short circuit connection is a path of good conductors which lets current by-pass the resistors in the circuit (e.g. the bulbs or heating wire). Because there are only good conductors on the path, the current becomes very big.

(Moodie et al., 2000, p. 226)

There was also an illustration on the opposite page of a lamp with an electric cable plugged into a socket; and a worn spot in the insulation on the electric cable where the copper wires are about to come into contact. There was the following explanation:

This wire has been lying under a carpet and people have walked on it. The plastic insulation over the copper has broken and the conductors are going to touch. Current will by-pass the lamp. Explain what will happen then

(Moodie et al., 2000, p. 227).

It appeared from the lesson transcript that the teacher picked up the terms ‘resistors’ and ‘insulators’ and combined them to misinterpret the idea of a short circuit as follows:

Teacher F: And there is no insulator and there is no resistor there in our circuit, okay? So what does that mean? It means an ... a ... when a circuit has no insulator and no resistor we call it a short circuit.

(Lesson F5, episode 1)

Teacher F then went on to conflate heating elements and resistors and he stated that *appliances such as radios and televisions did not have resistors and so they had (were wired with) short circuits*. He also did not seem to know that the purpose of the fuse was to *burn through* so that the circuit is broken (and appliances protected) in the event of a surge of electricity caused by a short circuit which would be a *fault* in the circuit.

Teacher F: We put a fuse in a short circuit to absorb energy so that it cannot damage our electrical appliances.

(Lesson F4, episode 1)

However, part of the problem appeared to lie with the textbook itself as the information about fuses should have been induced through a practical activity that was illustrated in the textbook

(which the class did not do); this activity did refer to a short circuit as being a 'fault' – which could have clarified the misconception about short circuits. But the science information in the textbook was fragmented into small chunks throughout the chapters and interspersed with illustrated practical activities. At no point was the science knowledge available in a clearly set out exposition; and so if teachers were to depend on the textbook as their sole source of information it would not be surprising if they had bits and pieces of information that were not necessarily put together correctly.

#### Example 2: mixtures and suspensions

Likewise the textbook used by Teacher C (Science Now, Grade 8 published by Heinemann) stated in relation to mixtures of substances from different phases:

A mixture of solid particles floating in a liquid or gas consists of two phases and is called a suspension. Examples of suspensions are blood (suspension of red and white cells in plasma); milk (suspension of fat particles in water) and smoke (suspension of solid dust or ash particles in air). (Module 2, unit 5)

Teacher C seemed to have misunderstood this and stated the following in Lesson C2:

Teacher C: Blood does not dissolve easily in water. We will see that there are white, small, floating things on top, isn't it?

Learners: Yes.

Teacher C: Therefore that is the suspension, those are the (writes on chalkboard)

**white blood cells in plasma**

Teacher C: white blood cells that floats... that float in plasma, are we together?

Learners: Yes.

(Lesson C2, episode 6)

Teacher C seemed to assume that all suspensions were composed of a substance mixed with *water*; and so referred to a suspension of blood in water, missing the point that blood is itself a suspension, although she went on to write this partly correctly on the chalkboard. In addition,

while she stated correctly that white blood cells float in plasma, she left out red blood cells; the meaning of 'plasma' was not clarified; and she did not seem to appreciate that one cannot see blood cells with the naked eye.

### Example 3: photosynthesis and transpiration

Another example of imprecise reading and consequent misunderstanding by a teacher, that was passed on to learners, was apparent in Teacher D's explanation of photosynthesis and transpiration below:

Teacher D: Yes, respiration is the method used to get energy from the food we eat. So in order for us to get energy from the food we need to undergo the process of respiration (pointing to writing on board). The equation for respiration is the other way round for photosynthesis. We said photosynthesis is C-O-2 plus H-2-O plus sun energy plus chlorophyll huh? (writing on board)

**CO<sub>2</sub> + H<sub>2</sub>O + sun's energy + chlorophyll = food + oxygen**

Learners: Yes.

Teacher D: Which is equal to? Which is equal to? Which is equal to?

Learners: Food and energy.

Teacher D: Food and energy. (writing on board) Then now the equation for respiration is the other way round. It's food and energy...(corrects herself; rubs out 'energy' and writes 'oxygen') food and oxygen. Is equal to? Is equal to?

[she elicited the remaining components as she wrote out the following (incorrect) word equation on the chalkboard]

**Food + O<sub>2</sub> = H<sub>2</sub>O + CO<sub>2</sub> + sun's energy + chlorophyll**

(Lesson D4, episode 1)

The teacher was using word equations from the textbook *Science for All* (pp.22 - 23) but she did not reproduce the 'word equation' correctly: she added the words 'sun's' and 'chlorophyll' to the photosynthesis 'word equation' which in the textbook is shown as:

**ENERGY + CARBON DIOXIDE + WATER gives FOOD + OXYGEN**

So when her version of the word equation was simply reversed to represent respiration, it was not only incorrect but nonsensical: respiration produces energy but not the sun's energy; and it certainly does not produce chlorophyll. In addition the 'word equation' in the textbook uses 'gives' instead of the equal sign used in mathematical equations; 'gives' does not have the same meaning as 'equals' but it is easy to see how Teacher D's confusion arose from the textbook metaphor 'word equation'.

It seems that the need for precise and accurate meaning, which is a feature of science knowledge, is not recognized by some teachers. Research by Parry (1996) offers a possible reason: Parry compared the academic reading strategies of Nigerian ESL students with those of Chinese ESL students and found that the Nigerian students tended to adopt top-down reading strategies, including making calculated guesses at meaning, and were tolerant of ambiguity; whereas the Chinese students adopted mainly bottom-up reading strategies and were intent on pursuing precise meanings. Parry suggested that this was because the Nigerian students lived in a multilingual context and had learned to read in English rather than their home language; and so they were used to not understanding meaning precisely and as a result were tolerant of ambiguity. The Chinese students on the other hand had learned to read in their home language, so were used to being able to understand meaning precisely and as a result transferred this intolerance of ambiguity to reading tasks in English.

Perhaps in the South African context, where most teachers have become literate in an additional language, they might too be accustomed to tolerating ambiguity, possibly leading to the situation where the precise nature of science concepts and knowledge is not appreciated, or a conscious aim when teaching.

In sum: the relatively high number of factual errors in the observed lessons was cause for concern and might be related to teachers' limited training in teaching science, as well as general limited proficiency in precise reading skills. The textbook most widely used by these teachers

(Science for All, Macmillan) also appeared to assume that teachers understood the basic science concepts and at no point in the textbook were these clearly presented in a consolidated exposition. So if teachers and learners were to depend solely on the textbook as a source of science knowledge they might well find it difficult to join the dots of the relatively fragmented science knowledge, to develop a coherent and accurate conceptual framework.

### Grading of teachers' practices for OTL science in terms of accuracy of science content

Given the NSES findings referred to earlier, namely that only truly sound teacher knowledge was linked to better learner performance and that there was not much difference in achievement for learners with teachers with some gaps in their content knowledge or teachers with large gaps in their content knowledge (Taylor, van der Berg & Mabogoane, 2013), Teacher B was graded for OTL science in terms of this criterion as good (3); and the other teachers were all graded as poor (1).

**Table 5.5. Grading of OTL science in terms of the accuracy of science knowledge**

Teacher	A	B	C	D	E	F	G	H
Grading	1	3	1	1	1	1	1	1

### Density of canonical science knowledge

A count of the publicly presented canonical ideas provided an indication of the density of science knowledge in the observed lessons, which was in turn an aspect of lesson pacing. The TIMSS video study defined a publicly presented canonical idea as 'A publically presented statement that describes a scientific fact, concept, pattern in data, natural process, scientific model or law, or theoretical explanation. This knowledge is canonical in the sense that it is generally shared by members of the scientific community' (Roth et al., 2006 p. 62).

As described in the conceptual framework, there is an ongoing debate in the literature about the optimum balance between breadth and depth in terms of how much science knowledge should be presented in a lesson (see Roth et al., 2006 p. 62). Clearly, stepping up the density of science knowledge in lessons should provide learners with the opportunity to learn more science; but the opportunity to learn science would be compromised if the pacing was too fast, with too many new ideas to absorb and little opportunity for working with the ideas in consolidation activities. Likewise, working with fewer ideas in depth might be considered more profitable; but fewer ideas in a lesson could also be an indication of superficial coverage of the curriculum. So the absolute count of ideas needs to be taken into account as well as the extent to which these ideas are firmly embedded in reviews of existing ideas and the opportunity for consolidation of new ideas, as well as the coherence of these ideas. The criteria for categorizing the publicly presented canonical ideas in lessons were as follows:

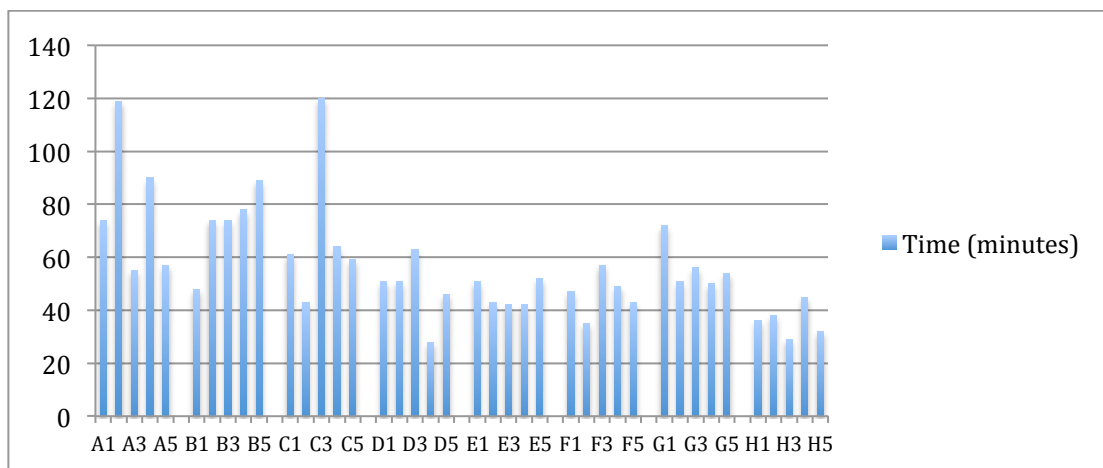
- Number of publicly presented canonical ideas – new content (new);
- Number of publicly presented canonical ideas – review of previously presented content; include ideas from lessons in data set or ideas marked by teacher as previously presented e.g. ‘remember ...’ (reviewed);
- Repetition of ideas – within a lesson at *different points* in the lesson e.g. a recap before moving on to a new idea or activity; not repetition at the same point in a lesson (repeated);
- Repetition of an idea/fact from a previous lesson but no explicit link made by teacher (previous).

Given the wide range in the length of lessons, the count of publicly presented canonical ideas per lesson was divided by the number of minutes per lesson to arrive at the number of ideas per hour. This provides a figure for the density of ideas in a lesson, that allows for comparison of the density of lesson content between teachers.

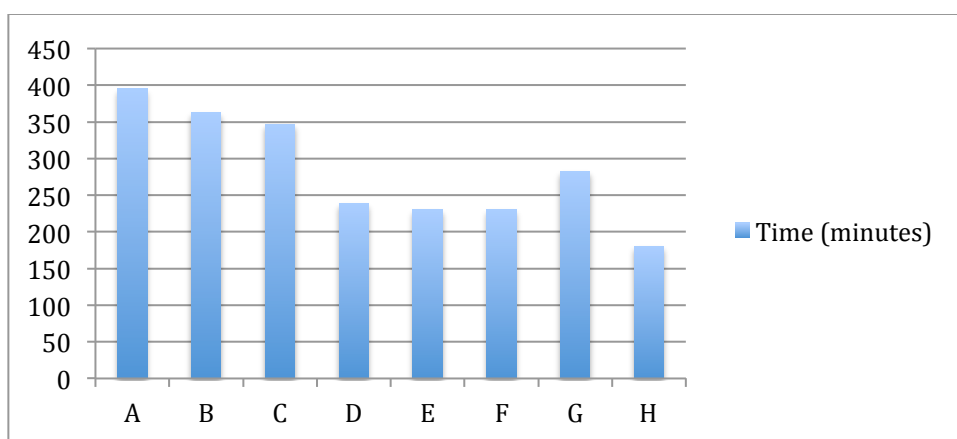
Although the TIMSS video study included an analysis based on the number of publically presented canonical ideas, (Roth et al., 2006), this was based on the percentage of lessons per country that included a 'high number' of publically presented canonical ideas i.e. 15 or more *new* ideas and specifically excluded *reviewed* ideas. So this is not directly comparable to the findings in this study.

### Findings on density of canonical science content

The length of lessons warrants some comment. The charts in Figures 5.11. and 5.12. show the length of lessons:



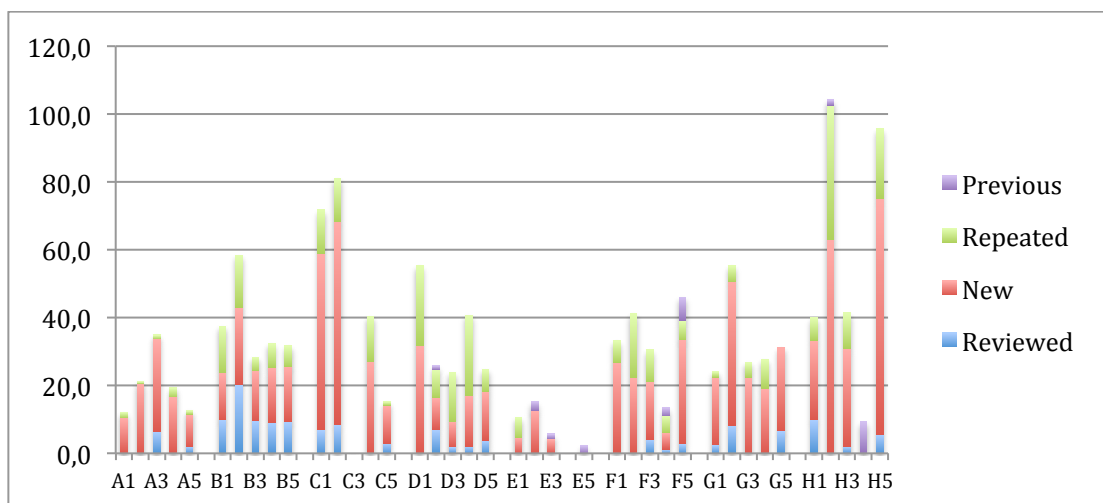
**Figure 5.11. Times for each lesson in minutes**



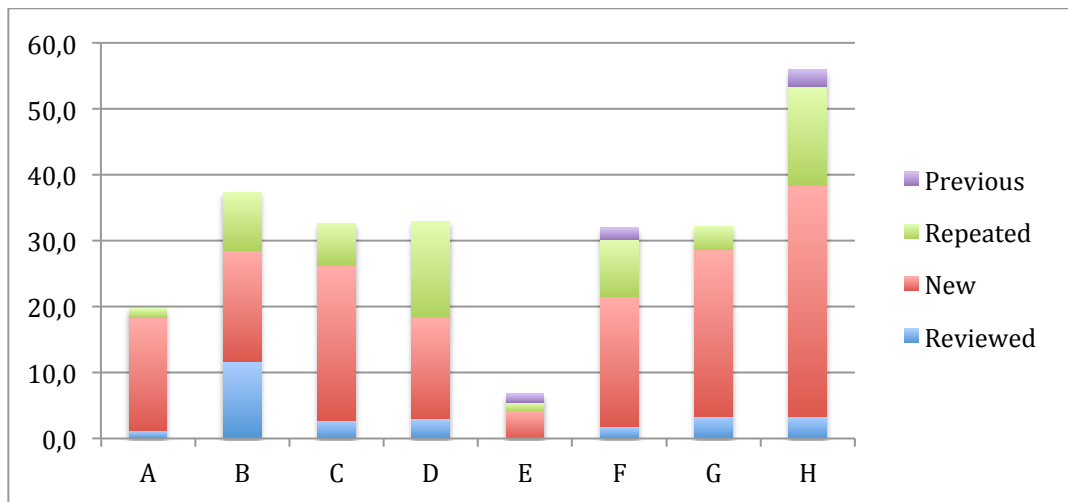
**Figure 5.12. Total lesson times per teacher**

Time allowances for the 40 observed lessons varied widely: the shortest being 28 minutes and the longest 120 minutes, with an average lesson time of 57 minutes. It appeared that in rural schools in particular (A, B, C, D, G), time was regarded as a fairly flexible resource. The presence of the researcher seemed to prompt some teachers to teach on until they ran out of steam rather than from a sense of how much learners could absorb in one go. In the township schools (E, F, H) the timetable was more closely adhered to, although in some instances teachers coming for the next lesson readily gave it up on the spot to allow the teacher being observed to carry on teaching. In addition, time allowances for particular activities within lessons were not always tightly managed – for example in lesson A2, Teacher A went from group to group in turn, to show learners how to separate sulphur powder and iron filings with a magnet; so that while he was demonstrating to one group, the other three groups were expected to sit quietly and wait their turn.

The chart in Figure 5.13. illustrates the density of canonical ideas in the observed lessons in terms of a count of ideas per hour.



**Figure 5.13. Density of science content: canonical ideas per hour for each lesson**



**Figure 5.14. Density of science content: canonical ideas per hour for each teacher**

It is interesting to note that the density of canonical science knowledge in the lessons of four teachers (C, D, F, G) was very close: 32-33 ideas per hour; and that in Teacher B's lessons slightly higher: 37 ideas per hour. The density of canonical science ideas in Teacher H's lessons was considerably higher (56 per hour) and reflected the lecturing style of Teacher H; it was much lower for Teacher A (20 per hour) who tended to digress; and lowest of all (7 per hour) in Teacher E's lessons where the focus was on learners reporting on real-life issues with very little canonical science knowledge at all. It would seem that optimal density might lie somewhere between the two extremes in the 32-37 ideas per hour range.

As can be noted in the chart in Figure 5.13., Teacher B's lessons follow a regular pattern of review of existing knowledge => development of new knowledge => repetition and consolidation. With the other teachers, six out of the seven included some form of review in just over a half (16 out of 30) of their lessons; and some repetition of facts. However it did not seem with Teachers A, C, D, E, F, G and H, that there was a regular, systematic pattern to the development of canonical knowledge in lessons, in terms of embedding new knowledge in existing knowledge and consolidating it towards the end of the lesson; this relates also to the

next section on the coherence of the science content – if there are no conceptual links between lessons, then teachers are unlikely to start with a review.

What was also apparent was that Teacher B's lessons were the *second most dense* but that they contained *fewer new ideas* per hour (16,9) than Teachers A (17,2), C (23,5), F (19,7), G (25,2) and H (35); however learners in Class B had more opportunity to build on existing ideas and consolidate new ideas. Both Teacher A and Teacher H tended to introduce new ideas without much opportunity for learners to engage with the ideas or consolidate them. Teachers C, D, F and H provided some opportunities to consolidate new ideas, but given the high number of inaccuracies in the lesson content (between 19% and 40% inaccurate or partly accurate), this did not necessarily constitute an improved opportunity to learn science.

Teacher H's lessons were the most dense of all, but as observations revealed, the lessons consisted mainly of teacher exposition of facts with little engagement of learners in working with those ideas.

At the other end of the scale, Teacher A's lessons were *second least dense in terms of science content over time*; but as the data on discourse will show, his lessons had the *most words by a teacher per minute* (89 against a mean of 54,5) and *least words by learners per minute* (1,4 against a mean of 3,9); so there was a low density of science content per words as well as per time. This is an indication of how the lesson content was buried in the discourse and learners might well have become 'lost in the discourse' - a term used by Breen (1998, in Walsh 2002). In fact Teacher A himself alluded to this, but in a positive, proselytising light:

So ladies and gentlemen I can talk and talk and talk until tomorrow so with those few words. Then I want to warn you ... because you are at school. Take this information. Take it home. Take it to our parents. Take it to our brothers who at homes. Take it to our sisters. Take it to our parents.

(Lesson A3, episode 1)

To sum up: it is difficult to arrive at an optimum density of ideas and the debates in the literature about breadth and depth (see Roth et al., 2006) are unresolved. It is also clear that the number of ideas would depend in part on the complexity of concepts and the learners' prior knowledge on the topic.

So if one is to consider the opportunity to learn science from the perspective of the density of science content, probably all one can say is that the extremes are probably too much and too little. In addition, it would seem that the extent to which new ideas are embedded in a review of existing ideas, and new ideas are repeated and consolidated, would improve the opportunities to learn those new ideas – this relates also to the coherence of the lesson content that is explored in the next section.

#### **Grading of teachers' practices in terms of OTL science and density of canonical science content**

If one were to grade the teachers' practices along the criterion of density of canonical science knowledge, the following rationale would apply:

- In the case of Teacher E, the density of canonical ideas was so low as to provide a very poor opportunity to learn science (OTL 0).
- In Teacher A's lessons, the density of canonical ideas was low in relation to time, but also in relation to words spoken which suggests that learners might well become 'lost in the discourse' (Breen, 1998, in Walsh 2002). There was very little review of ideas in Teacher A's lessons, partly because of the lack of coherence between lesson topics; and also very little repetition and consolidation. So the OTL science is coded poor (OTL 1).
- Likewise, Teacher H's lessons appeared too dense (56 ideas per hour); and there was little embedding of the new ideas in a review of existing ideas; so the OTL for Teacher H along this criterion was graded poor (OTL 1).

- The density of science content in the lessons of Teachers C, D, F, and G was very similar (32-33 ideas per hour); and although they all included some repetition and consolidation of new ideas, there was very little embedding of new ideas in a review of existing ideas. So these lessons were graded OTL 2 (partial).
- In Teacher B's lessons, the lesson density fell into the middle range; but new ideas were systematically embedded in a review of existing ideas and new ideas were also repeated and consolidated. So the OTL science in Class B was graded as 3 (good).

**Table 5.6. Grading of OTL science in terms of the density of science knowledge**

<b>Teacher</b>	A	B	C	D	E	F	G	H
<b>Grading</b>	1	3	2	2	0	2	2	1

### Coherence of science content in lessons

As described in the literature review, a key idea from the literature on teaching and learning science is that of conceptual coherence, drawing in particular on the work of Donovan and Bransford (2005).

In the analysis of the data in this research study, there were three indicators of coherence in the lesson content – the first two adapted from the TIMSS Video Study, and the third my own addition:

- conceptual links across and within lessons
- goal and summary statements
- consolidation activities

These have been presented separately and then consolidated into one chart. The criteria were ascribed a value and these were added to arrive at a total value for lesson coherence for each set of lessons per teacher.

### **Conceptual links across and within lessons**

#### ***Conceptual links across lessons***

This criterion was not included in the TIMSS video analysis (Roth et al., 2006), which only collected data for one lesson per teacher, whereas in this research, five consecutive science lessons were observed and recorded for each teacher; so it was possible to track conceptual links across lessons and the progressive cumulation of science ideas and concepts. This was coded as follows for each lesson:

- strong inter-lesson conceptual links: there is topic progression/continuity and teacher makes the links between lessons explicit (coded 2);
- some inter-lesson conceptual links: there is topic progression/continuity but teacher does not make links explicit (coded 1);
- no inter-lesson conceptual links (coded 0).

#### ***Findings for conceptual links across lesson topics***

Table 5.7. indicates to what extent there was continuity of lesson topics across lessons. The Natural Sciences curriculum (Department of Education, 2002) lists four main 'content areas or knowledge strands' (p. 5-6) which are: Life and Living, Matter and Materials, Energy and Change, and Earth and Beyond - each of these is represented by a different colour in Table 5.7.

**Table 5.7. Lesson content areas and topics**

LESSON CONTENT AREAS					
Teacher	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5
A	Food web	Mixtures separation	Food web - decomposition	Force	Force calculation
B	Mixtures & compounds	Mixtures & compounds	Separating mixtures	Separating mixtures	Separating mixtures
C	Matter - phase changes	Mixtures - types	Choosing a water system	Materials - types	Materials-synthetic
D	Food web	Producers & consumers	Photosynthesis	Respiration	Decomposers
E	Water conservation	Pollution - air	Pollution air/land	Pollution - land	Pollution - land
F	Electricity - circuits	Electricity - static	Electricity - closed & open circuits	Electricity - uses & resistors	Electricity - series and parallel circuits
G	Compounds	Mixtures	Mutual dependency plants & animals	Electrolysis	Environment - acid rain & global warming
H	Plant reproduction - asexual	Plant reproduction - sexual	Plant reproduction - fruits	Plant reproduction - test	Plant reproduction - seed germination

Life and living		Energy and change	
Matter and materials		Earth and beyond	

As Table 5.7. shows, five out of the eight teachers (B, D, E, F and H) adhered to one content area over all five lessons, while Teacher C switched between two content areas; and Teachers A and G switched between three content areas over the five lessons. It may be that Teachers A, C and G were presenting a selection of 'best' lessons for the researcher's benefit and that it might not have been their usual practice to switch between content areas in this way; but even if this were

the case, it appeared that conceptual links between lessons, and the systematic progression and development of science knowledge was not a conscious priority for these teachers.

The conceptual links between lessons were coded as per the criteria: so a maximum score of ten would indicate strong conceptual links across lessons.

### *Examples of conceptual links across lessons in the discourse*

The lesson introductions were examined for evidence of such conceptual links between lessons and examples of coding of the data are shown below:

#### Example 1 (Coded 2)

Lesson B2: Mixtures and compounds (content area: Matter and Materials)

Teacher B: Now, let's continue from where we stopped yesterday, okay? We talked about mixtures, mixtures. ... What is a mixture? Mhmm? Mixture. What is a mixture? Mixture, hands up, hands up ... What is a mixture?

(Lesson B2, episode 1)

Lesson B2 was on the same content area as Lesson B1 and Teacher B made the link explicit, so this lesson was graded 2.

#### Example 2 (Coded 1)

Lesson F2: Static electricity (content area: Energy and Change)

Teacher F: Listen ... Let's do another side of electricity. Let's look to another side of electricity. [...] So let's look to eh ... static electricity.

(Lesson F2, episode 1)

The previous lesson was on electricity and circuits and so although Teacher F was following the same content area, the new lesson content did not link directly to the content of the previous lesson, so Lesson F2 was coded 1.

### Example 3 (Coded 0)

Lesson A2: Separating mixtures (content area: Matter and Materials)

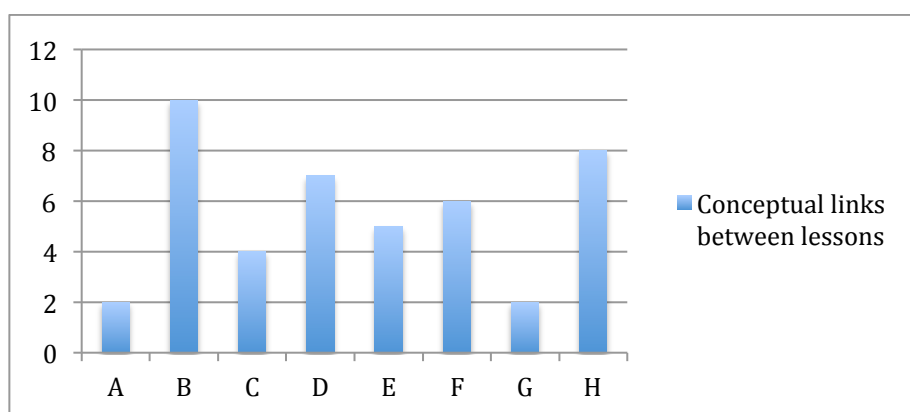
Teacher A: Now... I requested you to bring different ingredients. (elicits names of substances he has brought to class) Okay now... today, today we are going to ... work ... on ... mixtures, okay?

(Lesson A2, episode 1)

The previous lesson was on a different content area, Life and Living (see Table 5.7.) and so Lesson A2 was coded 0.

#### *Findings for conceptual links between lessons*

The results of the analysis of conceptual links between lessons are shown in Figure 5.15.



**Figure 5.15. Conceptual links between lessons**

As can be read off the chart in Figure 5.1.5., there were strong inter-lesson conceptual links across all five observed lessons in Class B, with topic continuity and explicit links made by Teacher B.

Teachers H and D scored 8 and 7 respectively, with topic coherence across all five lessons, and some explicit links made across lessons. Teachers E and F followed the same topic across lessons but the links were not made explicit, except in one Lesson (F5). Teachers A, C and G switched between topic and content areas across their lessons, which would seriously compromise the systematic cumulation of science content into coherent conceptual patterns.

### *Conceptual links within lessons*

The descriptors for conceptual links within lessons came from the TIMSS study (Roth et al., 2006 p. 68) and were expanded for this particular study, to also capture the need for 'rich factual detail' to support the understanding of concepts; and to capture the possibility of incorrect concepts being presented in some lessons:

- strong conceptual links within lessons to generalising principles and theories: 'The lesson is focused on content with conceptual links that strongly connect and integrate the information and activities. The information presented consists primarily of interlocking ideas, with one idea building on another with strong conceptual links. The lesson contains a strong conceptual thread that weaves the entire lesson into a conceptual whole' (Roth et al., 2006, p. 68); in addition, concepts are supported by rich factual detail (coded 2).
- weak conceptual links within lessons: 'The lesson contains some content but there are only weak or no conceptual links that integrate the information and activities. The information and tasks presented are connected only by a shared topic or by one or two concepts that tie together some of the ideas or activities but do not connect all the information together' (Roth et al., 2006, p. 68); or concepts are presented without the necessary supporting 'rich factual detail' (coded 1).
- no conceptual links within lessons – 'The teacher focuses students' attention primarily on carrying out an activity or procedure rather than learning a content idea. Students may encounter some science content in the process of carrying out an activity but the information is presented as isolated bits of information without being linked to a larger concept' (Roth et al., 2006, p. 68); or concepts presented are incorrect – thus there is not the opportunity to develop appropriate conceptual frameworks (coded 0).

Lessons were coded and according to the above indicators. Examples from the data illustrating the coding are shown below:

### *Examples of coding for conceptual links within lessons*

Strong conceptual links within lesson

#### Example 1 (Coded 2)

Lesson B1: Properties of mixtures. The key concept was that in a mixture, the properties of the components do not change. Teacher B reviewed this key concept (underlined) at the beginning of the lesson:

Teacher B: What happens to the properties of those things, which are mixed? The properties of two things that are mixed, what do they do, do they change? Mhmm...? They don't change. The properties remain the same, Heh? They remain the same, properties remain the same.

(Lesson B1, episode 1)

Learners then conducted an experiment where they identified the properties of iron filings and sulphur (colour and magnetism) separately; then mixed the two components and identified the properties of the mixture; and concluded that the properties of the components had remained the same.

Teacher B: Properties, what happens to the properties of the ... of the substances in a mixture? Properties of the substances in a mixture. Whom am I going to ask now? Properties of the substances in a mixture?

Teacher B: Speak, Themba.

Learner: Properties they are not change.

Teacher B: Properties do not change. Isn't that so?

Learners: Yees

Teacher B: Let's all say together: Properties of substances in a mixture remain the same. Is it clear?

(Lesson B1, episode 5)

Learners then discussed in groups a definition of a mixture, which Teacher B elicited and wrote on the chalkboard:

**Mixture – where properties of two substances remain the same**

(Lesson B1, episode 7)

This lesson was coded 2 as it conformed to the criterion: ‘The lesson contains a strong conceptual thread that weaves the entire lesson into a conceptual whole’ (Roth et al., 2006, p. 68).

Weak conceptual links within lesson

Example 1 (Coded 1)

Lesson A1: Food web. The key concepts according to the textbook were that a food chain shows where food energy moves as living things eat other living things; and a food web is made up of many food chains; it shows all the different feeding relationships which connect the plants and animals in an area.

In Lesson A1, episode 2, Teacher A gave learners a photocopied page from the textbook (see Appendix 5) which required learners to draw arrows to link plants and animals in food chains. However, he did not use the term ‘food chain’ until after the activity.

Teacher A: I want you to join and show by means of arrows which animal that eats plants and which animal that eat the other animal. ... (gives example of cat, mouse and mealies)

(Lesson A1, episode 2)

After learners had worked in groups, Teacher A wrote ‘finding food chain’ on the chalkboard, but without saying or explaining the term ‘food chain’ before eliciting learners’ contributions:

Learner: Lion eats impala.

Teacher A: The lion eats ... eats impala, okay?

Learners: Yes.

Teacher A: Oh lion ... (writing on board) Go on ... lion ... you say lion eat impala?

Same learner: Impala eats grass.

Teacher A: Okay, impala ... (writing on board) impala eats grass? Okay.

Same learner: Cow eat grass.

Teacher A: Cow?

Same learner: Eat grass.

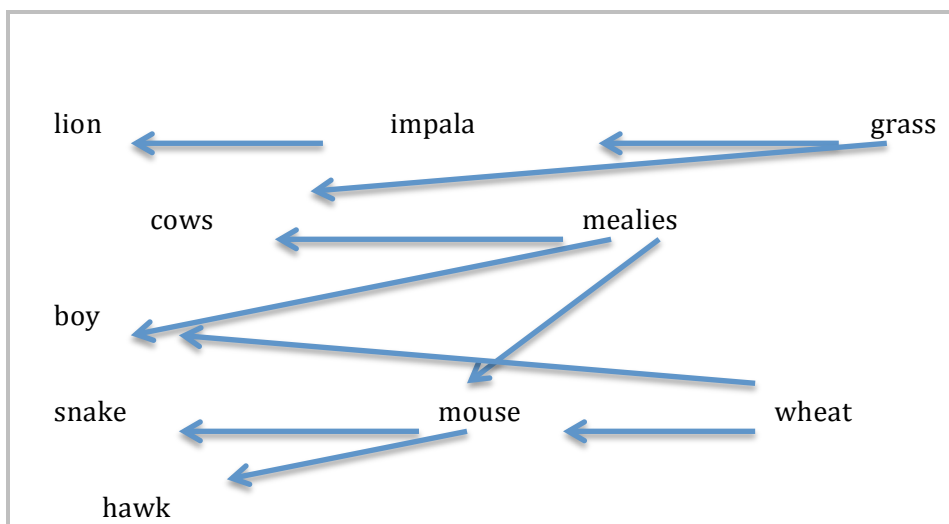
Teacher A: Okay. Cow. (writing on board)

Same learner: Cow eat mealies.

Teacher A: Okay cow... mealies okay? (writing on board) Go on ... go on.

(Lesson A1, episode 3)

During the reporting activity Teacher A wrote up the learners' examples with arrows indicating what ate what. However the examples were not written up systematically, with plants at the bottom of the diagram, then herbivores and then carnivores (see Figure 5.16. below), so the hierarchical structure of the system was lost – despite this being illustrated in the textbook (see Appendix 5.).



**Figure 5.16. Copy of chalkboard diagram of food chains elicited from learners**

In episode 4 of the same lesson, Teacher A explained the term 'food chain' using a learner's chain necklace as an analogy:

Teacher A: Okay ...ladies and gentlemen. We have finished our food chain, okay? ... Please, do you have a chain? Yes, he has one (referring to learner) Then if you can look at this chain (indicating chain around learner's neck) Can you see this chain? .... One ring is connected to one another one ring ... one ring is connected to one another, one is connected to one another, one is connected to one another. ... That is the food chain. So. one animal lives because it eat one another, then another one it eat another animal and the other will eat what? The grass, okay?

(Lesson A1, episode 4)

Again the hierarchical nature of food chains was not made clear; nor was the notion of energy transfer.

After a lengthy digression where Teacher A acted out a lion hunting its prey (represented by a learner's bag placed on the floor), and which included folk lore about lions hunting horses, he explained the concept of a food web by reference to the webbed feet of a goose and an umbrella:

Teacher A: This is what we call a food web. The whole exercise is called a food web, okay? Now do you know a web? A web? Do you know a web?

Are the feet of the fowl the same as the feet of the? Geese? Of the geese? Huh?

Learner: The chicken's feet are not connected, they are apart, the geese's are (connected).

Teacher A: The chicken's are apart. So which means that those of ... the feet, the what ... the fingers ... you mean the fingers?

Same Learner: Yes.

Teacher A: Then the fingers of a fowl are scattered, okay? In fact are not joined in between by any (demonstrating with fingers) membrane like web, okay?

Learners: Yes.

Teacher A: But those of a goose they have been ... joined together, okay?

Learners: Yes.

Teacher A: Like something ... they look like what? Like an umbrella ... they look like an umbrella, okay? And then it is raining you open up our umbrella, okay? And then you find that between those wires, okay, there is a cloth, a silk cloth of a material that covers the whole of the? ... those

metals, okay? Then the feet of a goose look like that, okay? They have been joined together by what is known as a web, okay? That is a web. That is the web. ... Therefore now here ... in this whole collection ... whole network of the food ... between the animals, among the animals and the grass and the other animals ... they make a complete food web, okay?

(Lesson A1, episode 6)

This explanation was unclear and the webbed geese feet and umbrella analogies were incorrect and confusing. In addition, the link between food chains and a food web was not explained. Immediately after this Teacher A went on to expound at length on the 'Law of the jungle' (unscientific) and photosynthesis (another topic altogether).

So although the concepts of food chains and a food web were referred to, they were not clearly and correctly explained. This lesson was therefore coded 1.

Example 2 (Coded 1)

Lesson D2: Producers and consumers. In this lesson, learners were instructed to write down the following note from the chalkboard. Once they had done this one member of each group copied down the table while the rest of the group read the notes; and then the group had to fill in the correct answers ('herbivores' or 'carnivores') in the table.

#### **INFORMATION ABOUT PRODUCERS AND CONSUMERS**

- **Plants are producers**
- **Plants can use water, carbon dioxide and the sun's energy to produce food.**
- **Plants store energy in food.**
- **Plants are called producers.**
- **Animals are consumers.**
- **Animals use energy from food.**
- **Animals cannot make their own food and therefore they need to eat plants or other animals.**
- **The word consume means to use or to eat.**
- **Animals which eat only plants are called herbivores.**

- **Herbivores are also called primary consumers. They eat producers.**
- **Animals which eat only meat are called carnivores.**
- **Carnivores are called secondary consumers because they eat primary consumers.**
- **Animals which eat plants and animals are called omnivores.**
- **Humans are omnivores.**

<b>PRODUCERS</b> <b>(plants)</b>	<b>CONSUMERS</b>		
	<b>Animals</b>		
	<b>Primary consumers</b>	<b>Secondary consumers</b>	<b>Consumers that are primary and secondary consumers (omnivores)</b>

This lesson was coded 1 as Teacher D provided learners with key concepts but no factual detail, such as examples of animals, to support the conceptual framework.

No conceptual links or concepts presented are incorrect

#### Example 1 (coded 0)

Lesson E1: Saving water

Teacher E: Okay...okay...okay first group to report please. (Group of learners get up and go to front of the class) Thank you for coming forward. We are going to give each group about two minutes to present. (looking at stop watch) Ummm ... a minute to the audience to ask questions from the group. A minute or two ... and also a minute to the presenters to pose questions to the prese ... to the audience. And after that we go to award them some marks ... we going to call upon three hands and will decide which mark we going to give that group. Okay, you can start.

(Teacher goes to back of the classroom, holding stopwatch, notebook and pen. Learner from group standing in front of class steps forward)

Learner: (holding up poster) Stop wasting water. (Turns poster around to read from it) Stop wasting water.

Teacher E: Okay sorry, what is the procedure when we do that. What do we do? What do we do first? You first greet the class, huh? You introduce yourselves huh? Who are you? First greet the class, who are you, then start presenting.

(Learners greet the class, one by one)

Learner: (reading from poster) Stop wasting water. Because ... we can't live without water because water is an important thing. It is also stop ... stop...control our lives. Stop wasting ... leaving water with running drops to the taps...thank you.

(Learner steps back and holds up card for class to see)

Teacher E: Is that all? Time ... carry on. Explain now what is on your poster. Please help her ... the two of you help her put the poster against the chalkboard. Put the poster against the black board. The other two hold it and the other one tell them what happening about the poster.

(learners read out the same information from the poster)

Teacher E: Okay ... er ... time now to give chance to audience to ask questions from the presenters. Hands up, audience. Ask questions to the presenters about their presentation. ... It seems there are no questions from the audience, huh? Questions from the presenters to the audience. Are the any questions to the audience?

Learners: No.

Teacher E: No questions huh? Okay. Ummm ... what mark? What mark do you think we can give the presenters? We are going to call upon three people, okay? Three learners.

(Hands go up; the teacher notes down three suggested marks and then the class votes)

Teacher E: Umm...now it's time for comments. It's time for comments.

(Learners offer procedural comments: 'They didn't raise their voices'; 'They are also shy'; 'They are not sure about what they are presenting'; Teacher E confirms these comments by repeating them)

Teacher E: They are not sure of what they are presenting, huh? Not sure. Not quite sure. Anyway, lets clap hands for that group class.

(clapping hands)

Teacher E: No, no, no ... Not clap like that. (directs learners to clap three times in rhythm)

Teacher E: Next group.

(Lesson E1, episode 2)

As can be seen from the above episode, and from the lesson summaries, Teacher E's focus was on managing the process of groups reporting, rather than on developing science content knowledge. The few facts that emerged from the presentations were hardly acknowledged and

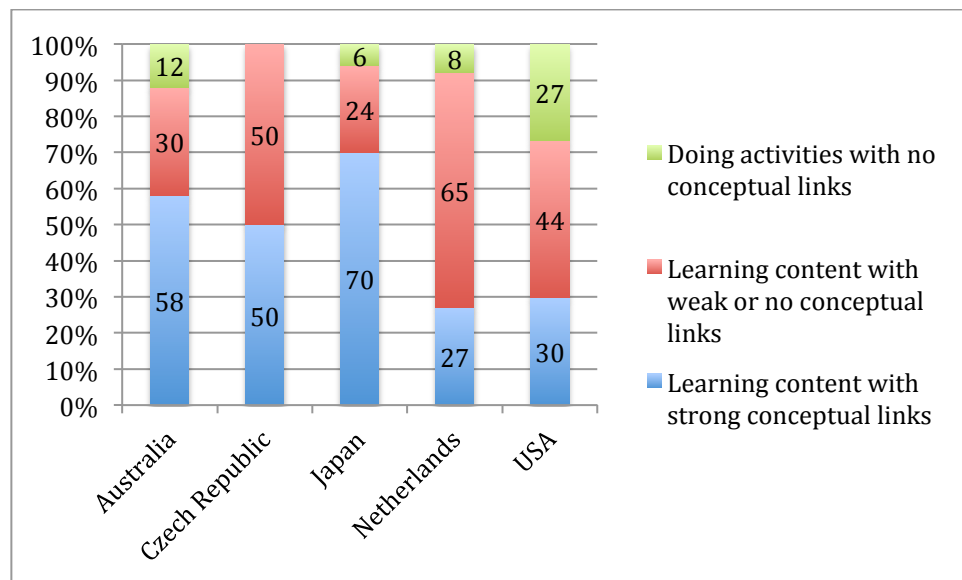
not probed for relevance or elaboration. In this lesson ‘the teacher focuses students’ attention primarily on carrying out an activity or procedure rather than learning a content idea’ (Roth et al., 2006, p. 68); and so the lesson was coded 0.

Example 2 (Coded 0)

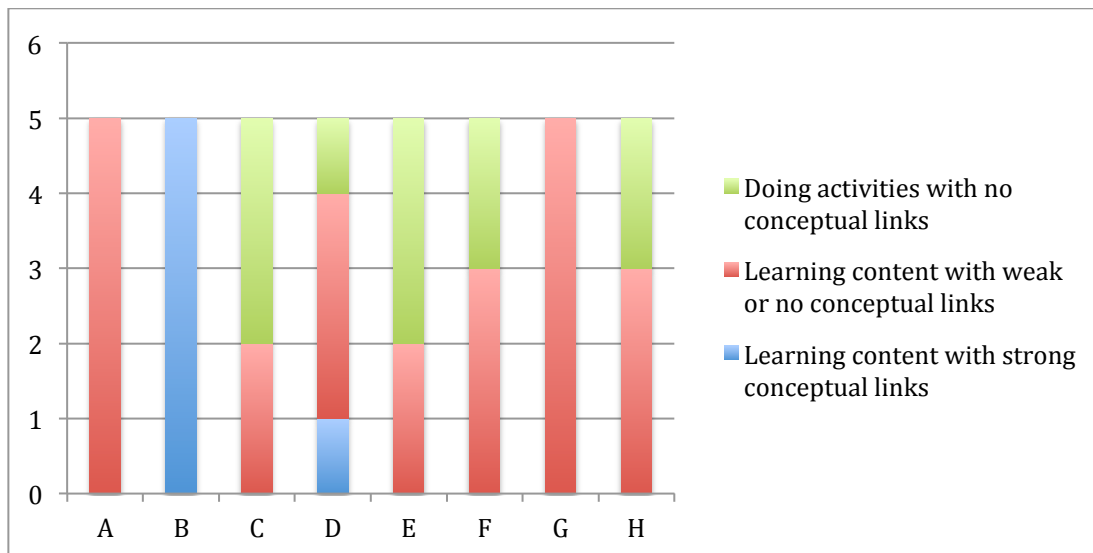
As described in the section on the accuracy of lesson content, In Lesson C4, Teacher C’s classification of natural and artificial materials was incorrect and so what followed in the rest of the lesson was based on this misinformation. The lesson was accordingly coded 0.

*Findings for conceptual links within lessons*

The TIMSS Video Study analysed lessons for conceptual links within lessons and Figure 5.17. illustrate the results. This provides some basis for comparison with the findings about conceptual links within lessons in this study, as illustrated in figure 5.18.



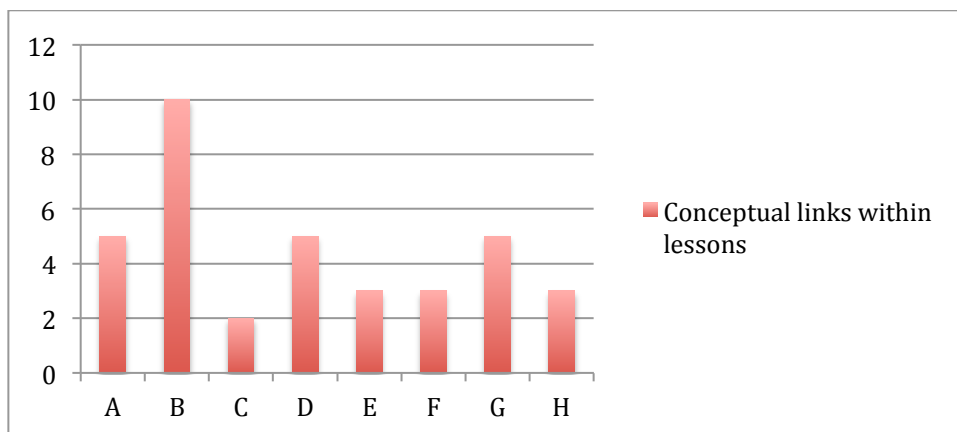
**Figure 5.17. Conceptual links within lessons in TIMMS video study (percentages of lessons) per country**



**Figure 5.18. Conceptual links within lessons over 5 lessons per teacher**

As the chart in Figure 5.18. shows, overall only 15% of lessons in this study included learning content with strong conceptual links – considerably less than the international findings that ranged between 27% and 70%; and 28% of lessons in this study included doing activities with no conceptual links – either because the focus was on the procedural aspects of the lesson rather than lesson content; or because key ideas in the lesson were incorrect - which is considerably more than four out of the five countries in the TIMSS video study but equivalent to the USA (the country with the poorest performance in the TIMSS tests of the five countries represented in the TIMSS video study).

In order to compare the practices of teachers within this study, values were ascribed to each category as shown in the analysis criteria (Learning content with strong conceptual links -2; learning content with weak conceptual links or learning content with concepts but no supporting detail - 1; doing activities with no conceptual links or incorrect concepts – 0). A score of ten would indicate strong intra-lesson conceptual links within all five lessons for a particular teacher.



**Figure 5.19. Conceptual links within lessons**

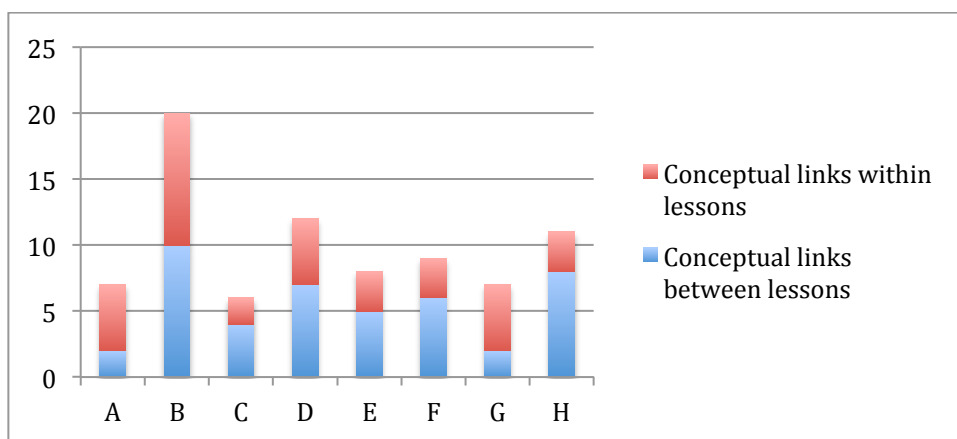
As the chart in Figure 5.19. indicates, Teacher B's lessons contained strong links to key concepts. For example, the principle that the difference in the properties of materials in a mixture, should be the basis for separating mixtures, was reiterated at several points in the three lessons on the separation of mixtures (B3, B4, B5); and the practical activities using different methods to separate mixtures were clearly linked to the key generalizing principle (see the example given above to illustrate coding). By contrast, in the lessons of Teachers A, C, E, F G and H, there was at best weak intra-lesson coherence (scores of 5/10 or less) and so learners were mostly left with collections of facts, where organizing principles and conceptual frameworks were left implicit. For example, Teacher A and Teacher G each taught one lesson (rather than a series of lessons) on separating mixtures (Lessons A2 and G2). Although they got learners to separate some mixtures and demonstrated other forms of separation, at no point did they refer to the key principle that formed the basis of Teacher B's lessons. So learners in classes A and G were left with a collection of examples of how to separate particular mixtures, but no principled basis on which to do so (see lesson summaries A2 and G2 in Appendix 4.).

Teacher D's lessons on the other hand, appeared to fall short in respect of the second aspect of 'learning with understanding' as proposed by Donovan and Bransford (2005, p. 6): 'concepts are given meaning by multiple representations that are rich in factual detail', as Teacher D tended

to present principles or abstract concepts with little substantiating detail – see coding example given for Lesson D2; and in Lessons D3 and D4, photosynthesis and respiration were presented as formulae with little contextualization in real life examples (see summaries in Appendix 4.).

In addition, there were eleven lessons graded 0: four lessons where the focus was on procedural aspects rather than learning content (see summary for Lessons C3, E1, E4, E5); and seven lessons where the key ideas presented were incorrect (C4, C5, D4, F4, F5, H3, H4).

The conceptual links within and across lessons have been combined in the chart in Figure 5.20.. This provides a basis for comparison between teachers' practices.



**Figure 5.20. Conceptual links within and across lessons**

*The low levels of clear conceptual links within lessons for seven out of the eight teachers (scores of 5 and below); and the fairly low levels of clear conceptual links across lessons (scores of below 5/10 for four out of the eight teachers), seemed to be a key failing in the majority of science lessons observed as it meant that learners' opportunities to learn science with understanding, as described by Donovan and Bransford (2005) were restricted; as were the opportunities for them to develop an understanding of the nature of science knowledge, namely that it seeks to explain the world in terms of generalizable principles and hierarchically organised conceptual frameworks.*

### Goal statements and summary statements

The TIMSS video study identified goal statements and summary statements as ‘one way in which teachers can make the content organization of a lesson more explicit for students ...’ (Roth et al., 2006 p. 70).

Lessons were coded as follows:

- goal statement/topic present: coded 1
- goal statement absent: coded 0
- summary statement present: coded 1
- summary statement absent: coded 0

### Examples of coding for goal statements

#### Example 1: (Coded 1)

Lesson A1: Food web

Teacher A: Today our lesson is going to be on natural science. But in natural science we are going to take one of the ... basic items that we use everyday in our lives. Therefore that is about some relationships in the natural world.

(Lesson A1, episode 1)

#### Example 2 (Coded 1)

Lesson C1: Phases of matter and phase changes

Teacher C: Today I want to see about the phases of matter and the phase of changes.

(Lesson C1, episode 1)

#### Example 3 (Coded 0)

Lesson D1: Food web

Teacher D: What did you eat last night for supper? What did you have for supper last night?

(Lesson D1, episode 1)

#### Example 4 (Coded 0)

Lesson E1: Saving water

Teacher E: Uh, which group is going to present first? Which group? Which group will present first? Which group? Quickly class. Time. Which group?

(Lesson E1, episode 1)

#### *Examples of coding for summary statements*

#### Example 1: (Coded 1)

Lesson A2: Separating mixtures

Teacher A: Then now. It means that from all what we have done here, it means that mixtures can be separated. See? All the mixtures that we do can be separated.

(Lesson A2, episode 15)

#### Example 2: (Coded 1)

Lesson B2: Compounds

Teacher B: So, now we have seen a compound, okay? The properties of a compound, we have seen the properties of a compound. We have seen the properties of a mixture. Can you see? Mixture ... compound. It was an example. That was an example to show you the difference between a what? A mixture and a what? A compound.

(Lesson B2, episode 6)

#### Example 3: (Coded 0)

In Lesson G2 on separating mixtures, Teacher G described the last example of separating mixtures - paraffin and water - illustrating the process on the chalkboard. But she did not sum up the key ideas or principle, only ending with, 'Okay, that is all' and then went on to tell the learners that she was going to give them an assignment.

Lesson G2: Separating mixtures

Teacher G: We are going to use a separating funnel. Okay, that is all. I am going to give you an investigation.

(Lesson G2, episodes 21 & 22)

Example 4: (Coded 0)

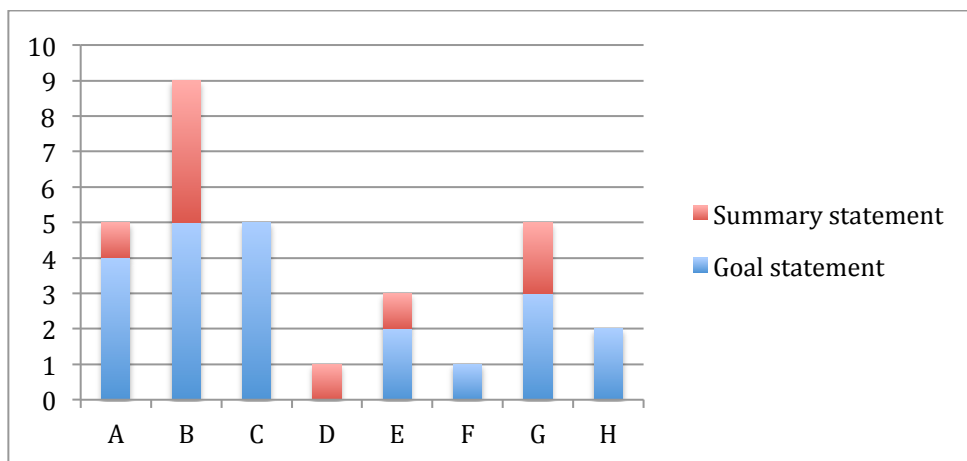
In Lesson H3 on types of fruit, Teacher H concluded her exposition on different types of fruit, by telling learners to copy down notes off the chalkboard and told them that they would be writing a short classwork (test) the following day. There was no summing up of key ideas:

Lesson H3: Types of fruit

Teacher H: Keep quiet. Keep quiet. Simply take these short notes and then tomorrow we will take a short classwork. We are going to take a short classwork.

(Lesson H3, episode 4)

The lessons were all coded as illustrated in the examples above. The chart in Figure 5.21. illustrates the findings in terms of the presence or absence of goal statements and summary statements.



**Figure 5.21. Goal statements and summary statements**

As the chart in Figure 5.21. shows, goal statements were more prevalent than summary statements. Again, it was Teacher B, who stood out from the other teachers in terms of this

aspect of lesson coherence, with goal statements in all five lessons and summary statements in four lessons. Teachers A, C and G all scored 5/10, four points behind Teacher B. At the other end of the scale, in Teacher D's and Teacher F's lessons, there was only one summary statement and one goal statement respectively; and two and three points respectively for Teachers H and E.

### **Consolidation of ideas/concepts by learners in and/or across lessons**

Although consolidation of ideas by means of a written task or assessment was not a criterion considered in the TIMSS video study, it seemed from the lesson observations that this was an aspect of lessons that was often absent and yet one which is important in establishing coherence of science knowledge and learning.

Lessons were coded for consolidation activities as shown below:

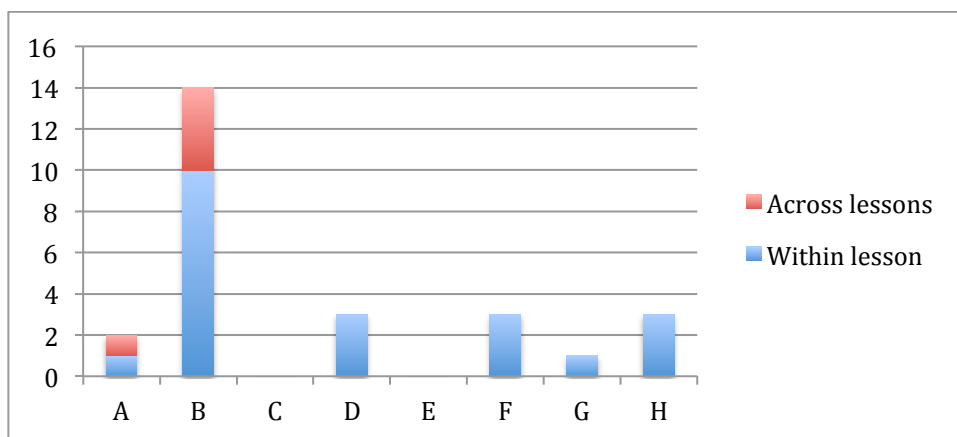
- consolidation activity within lesson present and appropriate (coded 2)
- consolidation activity within lesson present but inappropriate or confusing; or does not address key ideas; or based on partly incorrect information) (coded 1)
- no consolidation activity within lesson; or activity based on completely incorrect information (coded 0)

A lesson was coded as 2 if a consolidation activity was present and appropriate: for example, writing up an experiment (e.g. Lesson B4); or tabulating the differences between mixtures and compounds (e.g. Lesson B2). A lesson was graded 1 if a consolidation activity was present but the activity omitted key ideas in a lesson (e.g. Lessons D2 and G1); or was based on some incorrect information (e.g. Lessons D3 and F3). Lessons were graded as 0 when there was no consolidation activity or there was a consolidation activity, but it reinforced mainly incorrect information or concepts (e.g. Lesson F4) as this would clearly not improve the learners' opportunity to learn science.

Lessons were also coded to show if consolidation activities referred to science knowledge that had been presented within that particular lesson, or included knowledge that had been developed across lessons: for example Teacher B got learners to construct a mind map, that summarized the key points about separating mixtures, at the end of three lessons on the topic (Lesson B5) and so this was coded CI/AL (consolidation of ideas/across lessons).

- consolidation activity across lessons present and appropriate (coded 2)
- consolidation activity across lessons present but inappropriate or confusing; or does not address key ideas; or partly incorrect (coded 1)
- no consolidation activity across lessons; or activity based on completely incorrect information (coded 0)

The patterns that emerged from the coding are shown in the chart in Figure 5.22..



**Figure 5.22. Consolidation activities within and across lessons**

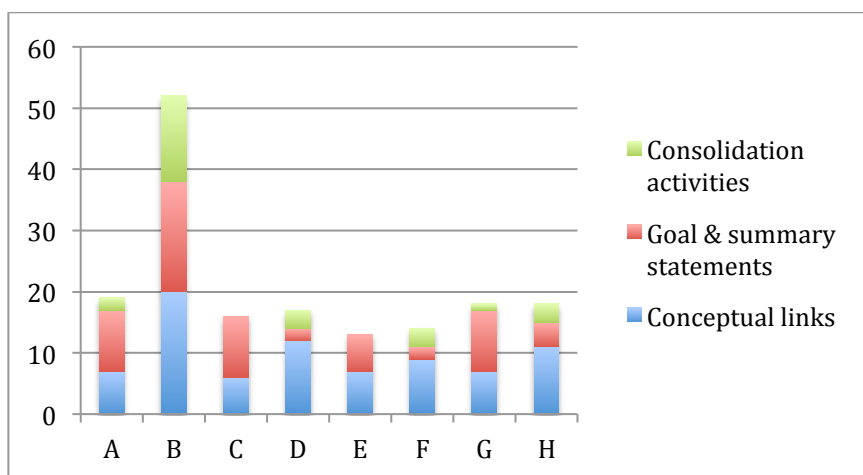
As can be seen from the chart in Figure 5.22., appropriate consolidation activities were relatively sparse, apart from Teacher B's lessons, which included appropriate consolidation activities in all five of the observed lessons, and in two lessons these activities covered content across more than one lesson. Teachers D and F each included consolidation activities in three of their observed lessons: but in three of these (D3, D5, F3), the activities included some content

that was incorrect (coded 1); in lesson D2 the consolidation activity required learners to fill in a simple table and identify that primary consumers were herbivores and secondary consumers were carnivores, which formed a relatively small part of the lesson content, so it was also coded 1; and in lesson (F4) the whole activity was based on an incorrect premise - that some household appliances have resistors and some do not (all household appliances have resistors) - and so it was coded 0.

Teacher H's lessons included two consolidation activities, one of which was a test (Lesson H4) on the work of the previous lesson which included many factual errors; and the test itself did not focus on key ideas, so it was coded 1. Teachers A and G each included one consolidation activity over the 5 lessons; and Teachers C and G did not include any such activities in the observed lessons.

#### **Findings on coherence of science content in lessons**

The three aspects of lesson coherence - conceptual links, goal and summary statements, and consolidation activities - have been combined to a total out of 60 to arrive at an overall value for lesson coherence for each teacher. (Note that the totals for the criteria of conceptual links and consolidation activities were each out of a maximum total of value of twenty; whereas goal and summary statements were out of a maximum of only ten. So the values for goal and summary statements were scaled up a maximum of twenty so as to be comparable with the other two criteria.) The findings on lesson coherence are shown in the chart in Figure 5.23.



**Figure 5.23. Coherence of science content in lessons**

The chart shows a wide gap between Teacher B and the rest of the teachers in terms of overall lesson coherence in the observed lessons, with Teacher B scoring 52 out of a possible 60, almost three times that of the next highest score of 19 for Teachers A; and with a range of 13 to 18 points for the rest of the teachers.

#### Grading of teachers' practices for OTL science and coherence of science content in lessons

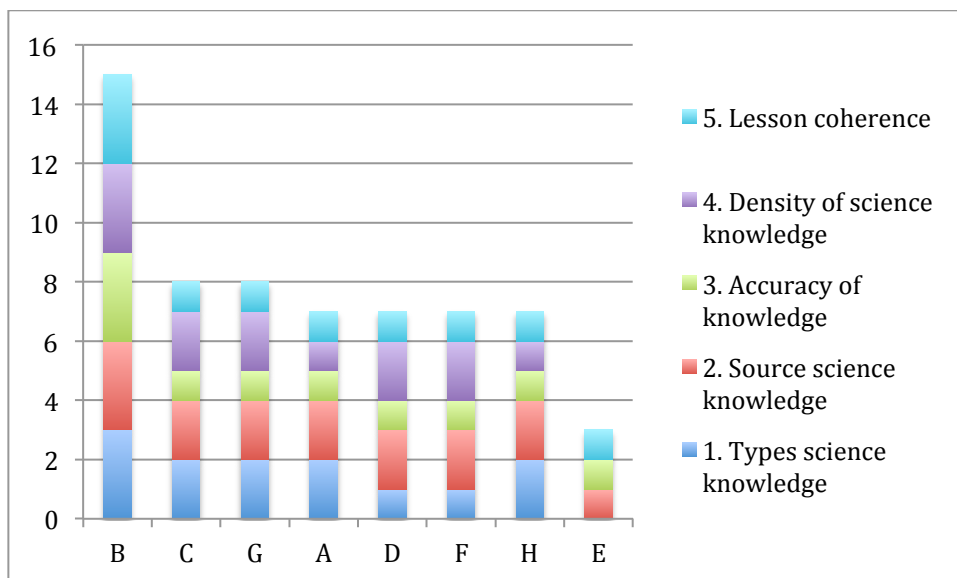
On the basis of this analysis, Teacher B was graded as 3 (good) and the remaining teachers as 1 (poor) for lesson coherence.

**Table 5.8. Grading of OTL science in terms of the coherence of science knowledge**

Teacher	A	B	C	D	E	F	G	H
Grade	1	3	1	1	1	1	1	1

#### Consolidated grading and ranking of teachers for OTL science content

The scores of teachers were consolidated and provided a basis for ranking of their practices across all five criteria. These were consolidated into one chart in Figure 5.24.



**Figure 5.24. Consolidated grading and ranking of teachers for OTL in terms of science content of lessons**

The grading and ranking of the eight teachers across the five criteria for the science content of lessons shows that six of the eight teachers were clustered in the seven to eight point range; while the opportunity to learn science content was greatest in the lessons of Teacher B, who scored 15, which almost twice as much as the next highest scores for Teachers C and G (scored 8), and five times as great as for Teacher E (scored 3), ranked eighth.

## Summary

The key findings in relation to the science content in the observed lessons were as follows:

For seven of the teachers, as was found in the TIMSS video study, *canonical knowledge predominated* in their lessons; however, for the eighth teacher (E), real life issues predominated (87% of lesson content) with a correspondingly low percentage of canonical knowledge; and so for learners in Class E this constituted a barrier to their opportunity to learn science. The other notable pattern was that in all but Teacher B's classes there was a *relative absence of procedural and experimental knowledge*, despite there being a large number of practical activities in some classes (A and G). This was because in Classes A and G, learners were directed what to do or the teacher demonstrated practical activities, but knowledge about 'how to do science-related

practices' (Roth et al., 2006) was left implicit and Teacher B was the only one who made this kind of knowledge explicit.

What was striking from the analysis of the data was how *little use was made of written sources* in the observed lessons, even when textbooks were available. In seven out of the eight classes, the teacher was the main source of science content, while in the eighth class (E), the learners were the main source of science content. This lack of written sources would have negative consequences for the development of the learners' science literacy; but also meant that it was crucial that the teachers' content knowledge was sound. And in Class E, learners were engaged in circulating their existing everyday knowledge rather than learning new science content.

Reference has been made to the finding in the NSES report (Taylor, van der Berg & Mabogoane, 2013) that only 'truly sound teacher knowledge is linked to better learner performance, while teachers with some gaps in their knowledge do not produce significantly better learner achievement than teachers with large gaps' (p. 227). An analysis of the *accuracy of the science content* revealed that only one teacher (B) could be considered to present 'truly sound' science content knowledge (only one incorrect fact constituting 0,6% of lesson content), but accuracy levels of the other seven teachers varied between 87% (Teacher G) and 58% (Teacher F). It would seem then that the levels of inaccuracy in the observed lessons of seven of the eight teachers would constitute a barrier to the opportunity to learn science.

It appeared that some of the factual inaccuracies stated by teachers might have arisen from *inaccurate reading* of the textbooks used by teachers; and it is noted that Teacher B, whose lessons were factually accurate, had both the longest *teaching experience* and the highest level of science *teaching qualification*. By contrast, six of the other teachers who had studied further or were engaged in doing so, were studying Management rather than Science Teaching. The teachers in the TIMSS video study (all but 4% of Australian teachers) had undergraduate or

postgraduate degrees equipping them to teach science; by comparison, the teachers in this study were far less qualified to teach science.

As noted, it is difficult to claim a 'just right' *density* for science lessons that is measurable; much depends on the complexity and cognitive challenge of the topic. Nevertheless it was interesting that there were very similar levels of science content density for five out of the eight teachers. One could probably assume that the density levels that lay outside of this middle grouping were problematic: the very low levels of canonical science knowledge in Class E constituted an obstacle to the opportunity to learn science; and likewise the high number of facts per hour presented by Teacher H, without much review, reflected the chalk and talk style of her teaching; and while Teacher A presented relatively few science facts per hour, his lessons were the longest and the facts buried in high levels of teacher talk – raising the possibility of learners becoming 'lost in the discourse' (Breen, 1998 in Walsh 2002).

All of the above factors constitute necessary conditions for providing learners with an opportunity to learn science. However even when there is science content in lessons – not too much and not too little; and the science content is correct; and learners have access to written sources, these do not appear to be sufficient conditions for the opportunity to learn science. The lesson content needs to also be coherent for learners to have the opportunity to learn with understanding.

Again, in respect of *lesson coherence*, it appeared that the practice of Teacher B stood in contrast to that of the other seven teachers: In all of Teacher B's lessons, there was strong lesson coherence within and across lessons, with the central generalisations and principles emphasized at key points in the lesson; and lessons proceeded systematically from a review of key ideas => practical activity => observation and description => explanation and generalization => application to real life situations and/or problem solving. In the lessons of six of the other seven teachers (all but D), there was little linking of the facts presented in the lesson to develop

a clear conceptual framework. Teacher D on the other hand tended to present the bare bones of a conceptual framework without the necessary supporting factual detail.

*The presence of clear conceptual frameworks and the necessary supporting factual detail, appeared to be a key strength in the practice of Teacher B and conversely, a key shortcoming in providing opportunities to learn science in the lessons of the other seven teachers.*

What follows in the next chapters, is an analysis of the classroom language in the observed lessons to ascertain whether the patterns of language use supported or constrained opportunities to learn science.

## CHAPTER SIX: CLASSROOM LANGUAGE: CONSTRUCTING SCIENCE KNOWLEDGE

In line with socio-cultural approaches, the analysis of the data in terms of the opportunity to learn science, was approached from two complementary perspectives: the science content of the lessons, and the language used to construct that science knowledge. In turn, the classroom language was analysed from two different perspectives, which are in fact functionally different: the classroom discourse and the bilingual language alternation patterns.

The analysis of the *classroom discourse* explored how the teachers used language to engage learners in constructing science content knowledge, and to cumulatively structure or *chain* science facts into coherent conceptual frameworks, and a hierarchical knowledge structure (Bernstein, 2000). This process as described in the literature, appears to be one that operates *vertically*, over *time* (Mercer & Littleton, 2007).

The analysis of the *bilingual practices* explored the use of the teachers' and learners' common home language, isiXhosa, to access and provide a *horizontal bridge* to science knowledge expressed in the language of reading, writing and assessment: English.

It should be noted that in the analysis of the classroom discourse patterns, the bilingual alternation by teachers and learners, where this did occur, has been removed from the lesson transcript extracts; only the English translations of the isiXhosa have been provided, so as to focus attention on the discourse interaction patterns themselves, and to reduce the length of the transcript excerpts. In the next chapter on the bilingual language use by teachers and learners, the complete transcripts, including language alternations have been included, so as to focus on the bilingual practices of teachers and learners.

This analysis of the classroom language practices of the eight teachers in this study commences with an analysis of the classroom discourse patterns.

## **Classroom discourse: how did the teachers engage learners in constructing science knowledge through the classroom discourse?**

As described in the methodology chapter, the classroom discourse was analysed from the following perspectives:

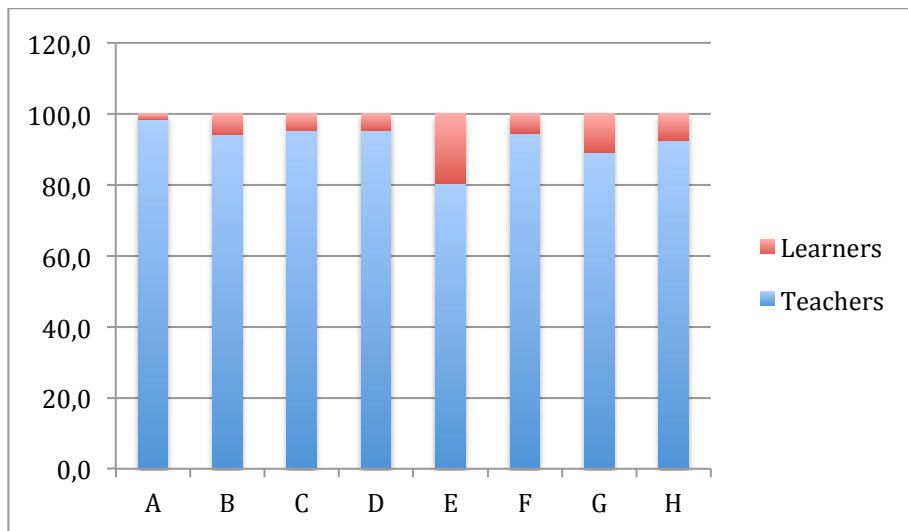
- the balance of teacher-learner talk
- discourse interaction patterns for public talk
- evidence of bridging discourses

The rationale for this focus has been discussed in full in the literature review. A brief recap of the key ideas from the literature is presented along with the findings in the sections that follow.

### **Balance of classroom talk by teachers and learners**

As outlined in the literature review, Barnes' (1976, 1992) work on the cognitive function of classroom talk stemmed from socio-cultural perspectives on language and learning; and concerns about the domination of teacher talk in classrooms and the resultant poor opportunities for learners to engage in talk for learning.

So, to start with, it is perhaps instructive to look at the total word counts for teacher and learner talk as illustrated in the figures below. Figure 6.1. illustrates the relative percentages of teacher talk and learner talk in the observed lessons. The literature on classroom talk has indicated that most classrooms are dominated by teacher talk (for example, Barnes, 1976/1992; Edwards & Westgate, 1994; Mercer, 1995) and the classrooms in this study are no different as Figure 6.1. shows.

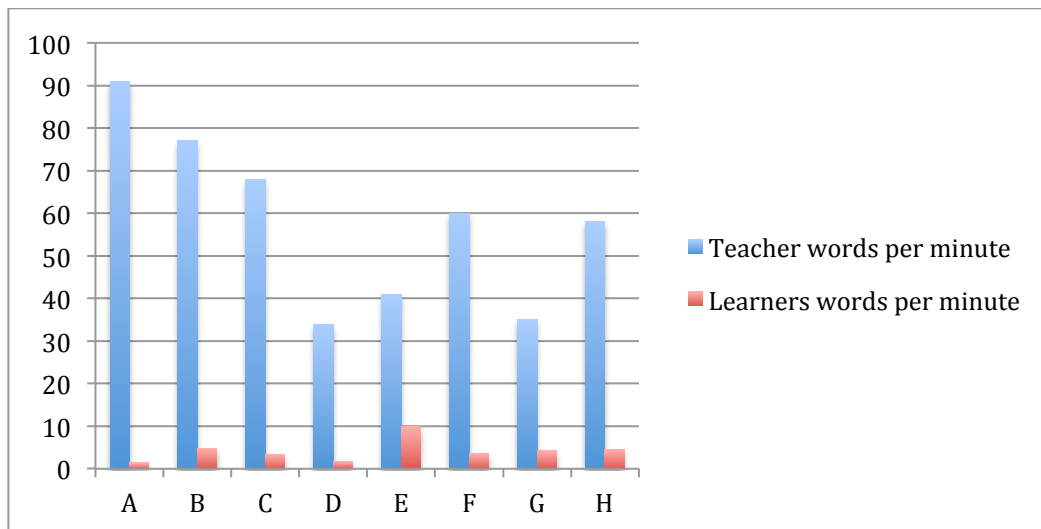


**Figure 6.1. Teacher and learner talk: percentages**

The first thing to note is *how very little learners spoke in relation to the teachers*: even in the case of Class E, when the lesson activities consisted almost entirely of groups reporting, asking questions, commenting on one another's presentations and voting for marks, learner talk only amounted to 19,5% of words spoken. In Teacher G's lessons, there were two lessons (G3, G5) that also included extended reporting by groups, and the word count for learners in Class G was second highest at 11% of the classroom talk.

In the remaining classes, teacher talk was 92,6% (Teacher H); 94,1% (Teacher B); 94,5% (Teacher F); 95,2% (Teacher C); 95,5% (Teacher D); and 98,5% (Teacher A). Thus the range of teacher talk for the eight classes was 80,5% - 98,5% of classroom talk. This is consistent with international literature on the subject: for example a word count of teacher/learner language in the TIMSS video study showed similarly high percentages of teacher talk in the five participating countries: 86% - 92% (Roth, 2006 pp. 115-116).

In the chart in Figure 6.2. teacher talk and learner talk has been scaled to a *count of words per minute of teaching time*, to allow for comparison between classes.



**Figure 6.2. Teacher and learner talk: words per minute of teaching time**

It is clear from the above chart that while Teacher A spoke the most words per minute in lessons, the learners in his class spoke least words per minute of all the classes; this is indicative of the lack of interactive classroom discourse in these lessons. One might expect then that this pattern would apply more generally: that the more the teacher spoke, the less the learners would speak. However this did not seem to be the case, as Teacher B was second in terms of the number of words spoken per minute, and yet the learners in Class B were also second only to learners in Class E (where lessons consisted almost entirely of groups reporting) in the number of words spoken per minute - this is indicative of the more interactive nature of the classroom talk in Class B. There was a similar finding in Probyn (2006) where it seemed that increased teacher talk did not necessarily reduce learner talk; rather that the reverse might apply when there was a more interactive style of classroom discourse; and that high levels of teacher talk were necessary to elicit and sustain learner talk in whole class interactions.

A raw word count of the balance of teacher-learner talk tells one little about the nature of that talk; it merely provides a broad context for a closer examination of the classroom discourse patterns and how they serve to construct opportunities to learn science. What follows next is an

examination of the classroom discourse interaction patterns as found in the analysis of the observed science lessons.

### Classroom discourse interaction patterns

As discussed, the nature of science knowledge is that it is hierarchically structured and seeks to explain the natural world through generalisable principles. In addition, science knowledge is empirically based and so a key idea coming from international research on science teaching and learning is the need to provide students with 'the opportunity to develop connected, evidence-based scientific understandings that students can apply to make sense of a variety of phenomena' (Roth et al., 2006, p. 57).

However as Mortimer and Scott (2003 p. 1) have pointed out, practical work does not speak for itself and scientific principles are not self-evident. Rather that it is in the *teacher orchestrated discussion* around the practical activities that science learning takes place (p. 1). This discussion will usually follow a pattern of description => explanation => generalization (pp. 26-27) as the teacher models the linking of facts and observations, through reasoning, into conceptual frameworks and generalizable principles.

A range of possible discourse interaction patterns has been identified from the literature as follows (described in full in Chapters Two and Three):

1. *Teacher monologue*: the analysis has distinguished between regulative (coded 1.a.) and instructional purposes (coded 1.b.);
2. *Oral cloze*: teacher monologue with learners providing key words or 'yes'/'no' in response to a pause and raised tone by the teacher;

3. *IRE*: teacher led question and answer which follows a 'triadic dialogue' (Lemke, 1990, p. 8) pattern of teacher question (I -initiation), learners response (R) which the teacher evaluates (E) as correct or not; the purpose is generally to check on learners' understanding.

4. *Dialogic exchanges*: teacher-led question and answer with the teacher providing feedback that prompts a further exchange. Indicators of this form of classroom interaction are as follows:

- I-R-F/R-F/R-F (Initiation – response –feedback) interactions are extended over several turns (Gibbons, 2006);
- Teacher's feedback responds to and builds on learners' responses - contingent responsiveness (Wells, 1999);
- Meaning cumulates over several turns and is focused on patterning facts into conceptual frameworks through logical argument and models thinking aloud.

5. *Learners reporting back*: the content of the discourse is determined by the learners; and the teacher may or may not respond to and scaffold the learner's contribution.

6. *Learners ask question/s*: learners ask questions to the class or a group and the teacher manages the process.

Mortimer and Scott (2003) made the point that discourse interaction patterns shift over the course of a lesson, with more interactive, dialogic exchanges at the point in the lesson when new knowledge is being constructed; and more authoritative exchanges when reviewing or consolidating established concepts - the point being that skilled teachers would draw on the appropriate interaction patterns at different points in the lesson.

The key point here in relation to the analysis of classroom discourse interaction patterns seems to be that in order for learners to develop the necessary conceptual frameworks, the teacher needs to *engage* learners in extended dialogic exchanges in order to *connect* facts and

observations through reasoning to generalizable principles and conceptual frameworks. The more typical IRE interaction patterns do not build on learners' contributions and so do not operate in the same way as dialogic exchanges to guide reasoning and build concepts.

So the next question is: *to what extent was this kind of dialogic discourse evident in the observed classrooms; and how did the classroom discourse in the observed classrooms contribute to or constrain the opportunity to learn science?*

The analysis took into account both the discourse patterns as well as the science content of the lessons, as recommended by Christie (2002: 5), Gibbons (2006) and Mortimer and Scott, (2003), in order to show how the science content was constructed through the classroom discourse. Examples of coding for classroom discourse interactions are shown below:

#### *1.a. Teacher monologue – regulative*

Teacher E: That guy (pointing to learner). You are chewing, stop chewing in class. Which group? Will present first? Which group? Okay (pointing to learners in front row) let's start from this side.

(Lesson E1, episode 1)

#### *1.b. Teacher monologue – instructional*

Teacher D: Yes. All the animals that live on green plants only are known as herbivores. They are not producers but they are consumers. (writing on chalkboard) They are consumers. They are primary consumers. They are the first ... they are the first link in the ... they are the second link in the? food chain. The first link are the producers. Green plants are those that produce food.

(Lesson D1, episode 1)

#### *2. Oral cloze*

Teacher G: Very good! Iron filings are ...? (writing on chalkboard)

Teacher G & Learners: magnetic.

Teacher G: Sulphur ... is ... ?

Teacher G & Learners: not magnetic.

Teacher G: Those are the properties of iron filings and ... ?

Teacher G & Learners: sulphur powder.

(Lesson G1, episode 3)

### 3. IRE

Teacher H: Who can tell me...what is asexual reproduction? Yes? (pointing to learner)

Learner: Asexual reproduction is the reproduction by means of spores.

Teacher H: Very good.

(Lesson H1, episode 1)

### 4. Dialogic exchanges

In Lesson B3, learners had separated a mixture of soil and water by means of filtration. In the whole class question and answer that followed, Teacher B elicited the description of what learners had observed; and then in the extract below, he elicited the explanation that water could pass through the filter paper but soil could not, because the soil particles were bigger than the holes in the filter paper. (The turns are numbered for reference).

1.	Teacher B: Why does that soil remain in that filter paper? Water passes through, why? Or let's say why does the water pass through the filter paper? What could be on the filter paper?
2.	Learners: A hole.
3.	Teacher B: So it shows us that there are some holes... there are some holes in the filter paper there are some holes in the filter paper. Now if there are holes why does soil not pass through the holes together with water? Mhmm? Raise your hands. Why does soil not pass through, why does soil not pass through the filter paper? (writes on chalkboard)  <b>Filter paper has holes. Why does soil not pass through the filter paper together with water?</b>
4.	Teacher B: Why does soil not pass through the filter paper together with water? Why? Hands up. (nominates learner by name)?
5.	Learner: It has small hole.
6.	Teacher B: Filter paper has small holes, right? So we say the soil does not pass through. So we say the soil does not pass through the filter paper because remember the holes in

	the filter paper are what? They're small, okay?
7.	Learners: Yees
8.	Teacher B: And particles of soil ... which means the particles of soil are bigger than the holes of the what? Of the filter paper, is it clear?
9.	Learners: Yees
10.	Teacher B: Particles of soil are bigger than what? (writes on the board)...Soil particles are bigger than the holes that are in the what? In the filter paper, are we clear?  <b>Soil particles are bigger than the holes.</b>

(Lesson B3, episode 5 - edited)

The above extract was coded as 'dialogic' as it included the three indicators: extended I-R-F/R-F/R-F exchanges; 'contingent responsiveness' to learners' contributions; and cumulation of meaning and modeling of logical argument. In turn 1. Teacher B initiated a question and the exchange extended over several turns (extended I-R-F/R-F/R-F exchanges). In turn 3. Teacher B provided positive feedback by confirming the learners' response and used it as the basis for the next question in turns 3. and 4.; the learner's response in turn 5. was confirmed (turns 6. and 8.) and then repeated and written up on the chalkboard in turn 10 (contingent responsiveness.) In addition, Teacher B led the learners through the argument: 'so' ... 'now' ... 'if' .... 'why'... (turn 3); 'because' (turn 6.); and 'which means' (turn 8.) – demonstrating reasoning and cumulation of meaning.

##### *5. Learners reporting to class*

In the original coding of the data, a distinction was made between the kinds of responses by teachers to learners' reporting to the class:

- Learners report back without comment or evaluation of the science content by the teacher;
- Learner/s report back with evaluation by the teacher;
- Learner/s report back with feedback and scaffolding by the teacher

Examples of each are provided below, but in the findings these categories have been merged as 'learners report back' to simplify the analysis and because these distinctions were not central to the final analysis. The examples follow:

- Learners report back without comment or evaluation of the science content by the teacher

In Lesson E 1, a group of learners went to the front of the class and Teacher E reminded them about the procedures for reporting. A learner started to report:

Learner: (holding up poster) Stop wasting water. (Turns poster around to read from it) Stop wasting water.

Teacher E: Okay sorry, what is the procedure when we do that? What do we do? What do we do first? You first greet the class, huh? You introduce yourselves huh? First greet the class, who are you, then start presenting.

(Learners introduced themselves and then resumed reporting)

Learner: (reading from poster) Stop wasting water. Because...we can't live without water because water is an important thing. It is also stop ... stop ... control our lives. Stop wasting ... leaving water with running drops to the taps ... Thank you.

Teacher E: Is that all? Time! ... Carry on.

(Lesson E1, episode 2 – edited)

As can be seen in the above excerpt, the teacher's responses to the learners' reporting was entirely procedural, with no evaluation or feedback on the content they had presented.

- Learner/s report back with evaluation by the teacher

In Lesson G3 learners discussed in groups and reported on the uses of plants in their community. Teacher G accepted the learners' contributions uncritically:

Teacher G: Okay face the class and read, ahuh?

Learner: (group A) They beautify our community.

Same Learner: They give us wood.

Teacher G: Plants give us wood. Huh?

Same Learner: They also make our furniture.

Teacher G: Make ... furniture

Same Learner: They give us oxygen.

Teacher G: They are the givers of oxygen.

(Lesson G3, episode 3)

- Learner reports back with feedback and scaffolding by teacher

In Lesson B3, learners had to work out in groups how to fold a filter paper to fit in a funnel. One learner from each group came to the front to show their folded filter paper and funnel. Teacher B called on one of the learners to explain to the class how to fold the filter paper.

Teacher B: Imagine we closed our eyes and then describe to us how to ... fold the paper. Who can do that for us quickly? (nominates a learner)

Learner: (demonstrating) I just folded it in half.

Teacher B: You fold it in what? When you fold it in half, what is the name of the part where you fold it? Heh? In what?

Same learner: Centre

Teacher B: The centre?

Same learner: Half

Teacher B: Half? So you fold it in what?

Learners and Teacher B: In half.

Teacher B (to class): Okay?

Learners: Yees

Teacher B: Good, go on then.

Same learner: I folded it again teacher.

Teacher B: In what?

Same learner: In half

Teacher B: Good. You made quarters, right? So you fold it in half. So when you make a half you make a half of this half, okay? (demonstrating with his own filter paper)

Learners: Yees

Teacher B: Good. Like that. Then what happened?

Same learner: After that I opened the inside, teacher.

Teacher B: Good. Then you ... you ... you what?

Learners: You open

Teacher B: Good. Like that there is your funnel and you fit it in, you fit it in. There it is. Sit down.

(Lesson B3, episode 2 – edited)

The learner reported to the class and demonstrated how to fold the filter paper. Although it took the form of an I-R-F/R-F/R-F interaction, the demonstration was initiated by the learner and supported by the teacher, who intervened to prompt, confirm and extend her explanation.

#### *6. Learners asking questions*

There were some instances of learners asking teachers questions; and learners asking one another questions. In Class E, after group presentations, the teacher routinely gave the rest of the class the opportunity to ask the group questions; and for the group to ask the class questions on what they had presented, as shown in the next excerpt from Lesson E5, on the causes of land pollution.

Teacher E: (to learner with raised hand) What's your question?

Learner A (to the group that had presented): Does fire cause land pollution? (the group had stated this in their presentation)

Learner X (from group): Yes. Yes.

Learner A and some of his group: How?

Teacher E: Okay, one person please ...

Learner X: Yes, the pollution ... (pointing to poster and then gestures upwards)

Learner A: Air pollution ... not land pollution.

Learners around Learner A: (mumbling)

Teacher E: Okay, one person to talk at a time. One person speaks at a time please. Yes? Say the question again.

Learner A: How does ... how does fire cause land pollution?

Teacher E: (to Learner A) Okay, sit down.

(Group clustered round poster)

Learner from group: (indistinct) (lots of chatting, laughing in class)

Teacher E: People stop laughing please. Give them chance to answer please, stop laughing. One person at a time please.

Learner A: (indistinct)

(whole class laughs)

Teacher: Okay class (indistinct)

Learners from group: Ash.

Teacher E: Ash huh?... or ashes huh?

Learner X: There's lots of ashes.

Teacher E: Yes after fire ... veld fires. What's happening?... lot of ashes and some other materials are burnt up heh? Which go to make the environment dirty, huh?... land dirty.

(Lesson E5, episode 6)

The above was an example of learners asking one another questions. Another example was when a learner asked a teacher a question: in a lesson on decomposers, Teacher D had given the class the singular and plural forms of fungus/fungi:

Teacher D: (to learner who has raised his hand) What is your question?

Learner: Sorry miss I want to ask why the word bacteria does not have a plural?

Teacher D: Bacteria? What about it?

Same Learner: Why it does not have?

Teacher D: Does not have?

Same Learner: Plural?

Teacher D: Plural? Oh just like we mentioned the plural for fungus. It's plural my child ... you have helped me ... it is in plural form already. (writing on chalkboard)

### **Bacterium**

Teacher D: It is bacteria in plural. Then for singular form, it's bacterium. Okay? Bacterium singular. Then bacteria is plural. Okay?

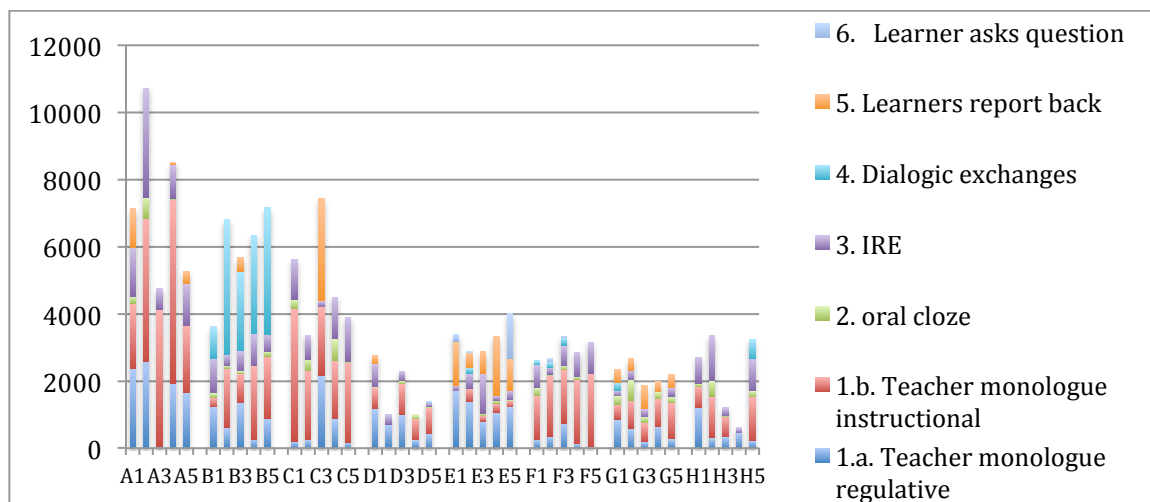
(Lesson D5, episode 2)

The above categories of classroom interaction in the discourse covered all the forms of public talk in the observed lessons. As described, public talk has been defined as talk that could be heard by any attentive learner in the class and so it excluded any group talk by learners or talk by the teacher that could not reasonably be heard by an attentive learner.

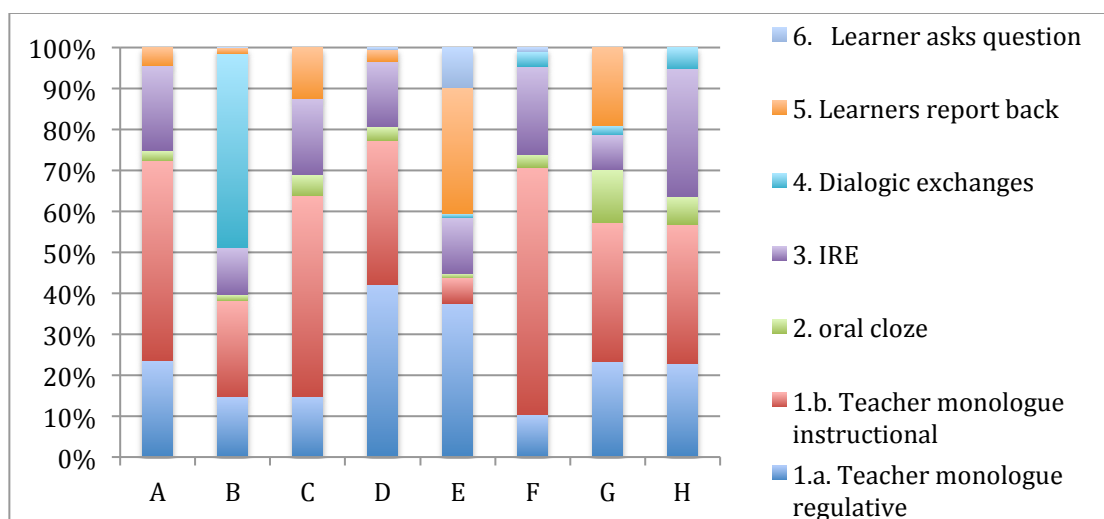
As described in the methodology chapter, the classroom discourse patterns were marked off and coded in the lesson transcripts for each teaching episode. A word count for teacher and learners for each stretch of coded discourse was done, so as to be able to quantify the discourse interaction patterns, and these were illustrated with excerpts from the lesson transcripts. In this way the discourse interaction patterns were tracked across the set of five lessons per teacher and linked to the lesson content and also to the bilingual classroom practices, so as to explore how the science content was constructed through language in ways that supported or constrained the learners' opportunities to learn science.

### Findings in relation to classroom discourse interaction patterns

Figures 6.3. and 6.4. provide a summary of classroom discourse interaction patterns over the five lessons for each of the eight teachers. These provide a picture of the dominant discourse patterns and as can be seen there are rather different patterns for the eight teachers. These are discussed below.



**Figure 6.3. Classroom discourse patterns for each lesson**



**Figure 6.4. Classroom discourse patterns for each teacher by percentage**

### *Regulative discourse*

The relatively high levels of regulative discourse for Teachers D and E are noticeable (42% and 38% of classroom talk), as compared to the other teachers (between 10% and 26%). However the purpose of this regulative talk by Teacher D and Teacher E was rather different: in the case of Teacher D, much of this was addressed to a group of older boys in the class to keep them under firm control, and to monitor note-taking and classwork activities; whereas in the case of Class E, the lessons consisted mainly of groups reporting on various aspects of conservation and pollution and so the regulative talk by Teacher E was in relation to managing this process (see coding example).

### *Instructional discourse patterns*

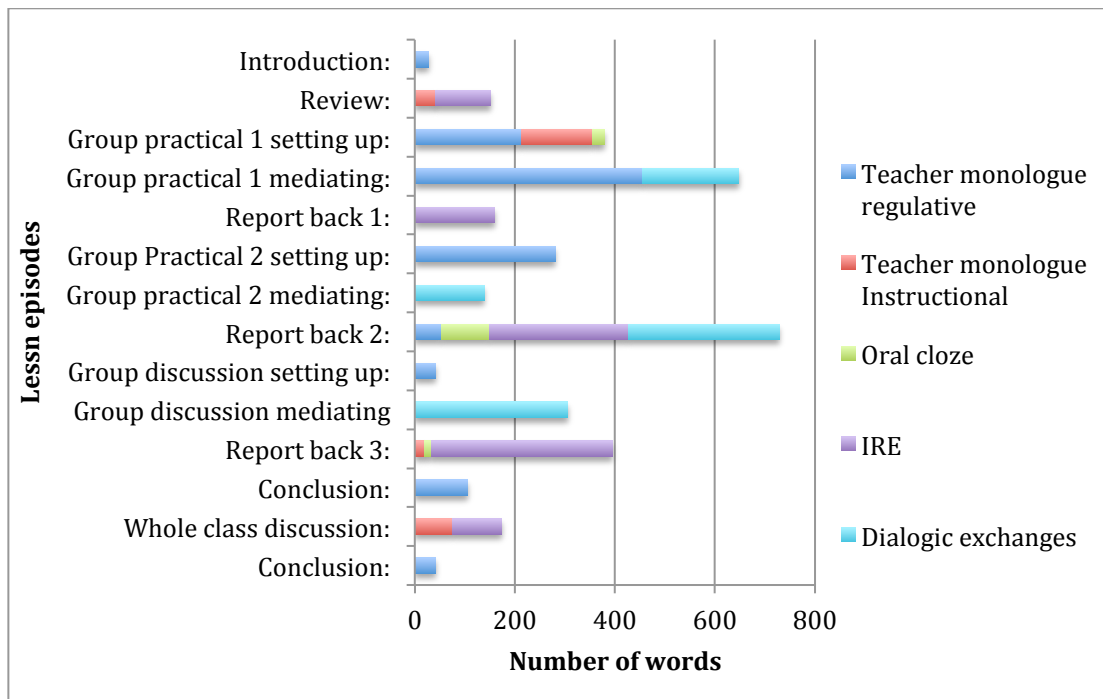
The instructional discourse patterns for communicating science content followed fairly similar patterns for six out of the eight teachers (A, C, D, F, G, H) in that they were dominated by teacher instructional monologue (1.b.), interspersed with some oral cloze (2.) to get learners to repeat key terms or points after the teacher; and then short stretches of IRE (3.) to check on understanding or to elicit contributions from learners or observations from practical work where this was done. As the charts in Figures 6.3. and 6.4. show, this combination of discourse patterns accounted for over 50% of classroom discourse in these six classes: from 55% for Teachers D and G; 70%, 72% and 73% for Teachers A, H and C respectively; and 85% for Teacher F. There was very little evidence of I-R-F/R-F/R-F sequences which form the basis of dialogic exchanges: 0 – 5% of classroom talk (Teachers A, C and D – 0%; Teacher G – 2%; Teacher F – 3%; Teacher H – 5%).

The discourse patterns for Teachers E and B were different to the rest of the teachers: as described, Teacher E's lessons consisted mainly of learners reporting to the class; learners asking questions of the groups and a voting for marks for each group; and the teacher managing

this process. The IRE sequences were mainly related to the teacher eliciting marks from the class for the groups once they had presented; and there was very little science knowledge evident in the lessons, as the analysis of the types of science knowledge in lessons has shown. In Teacher E's lessons there was also little evidence of dialogic exchanges – only 1%.

Teacher B on the other hand showed very different discourse patterns for communicating science in that 47% of classroom discourse took the form of dialogic exchanges, with extended I-R-F/R-F/R-F sequences, as Teacher B elicited responses from the learners and modeled the linking of facts and observations to generalisable principles through reasoning – in this way building conceptual frameworks. Teacher B's feedback move was closely tied to the previous response move from the learner – in what Wells (1999) has described as 'contingent responsiveness'.

There was far less instructional monologue in Teacher B's lessons than in the lessons of the other teachers (with the exception of Teacher E). The discourse patterns in Teacher B's class shifted over lesson episodes, much as described by Mortimer and Scott (2003) with reviews and summaries being conducted through fairly brisk IRE sequences; and the stages of the lesson when teacher and learners were engaged in exploratory talk in groups and whole class feedback and discussion – working on meaning – were conducted mainly through dialogic exchanges. The chart in Figure 6.5 shows the shift in discourse patterns across one such lesson - B1.



**Figure 6.5. Shifts in discourse patterns over Lesson B1**

*Learner talk*

The public talk of *learners* in the classes of four of the teachers (A, D, F, H) was largely though elicitation by the teacher in IRE sequences; and in Teacher B’s classes, through dialogic exchanges. In the remaining three classes (C, E, G) learner talk was also though groups reporting (C – 12%; E – 30%; H – 19%); and in Teacher E’s class, learner questions comprised 10% of classroom talk as the class was given the opportunity to question groups after they had reported and members of the presenting groups could ask questions from the class. However much of this questioning by learners in Class E was on procedural matters such as the behaviour of groups; and there was little guidance or support from the teacher in modeling more probing questions about lesson content. The content of group presentations was mostly accepted uncritically by Teacher E who focused on managing the class, which became more and more unruly as they appeared to get bored with the repetitive nature of presentations; and learners appeared to relish the opportunity to ask questions to poke fun at the presenting

learners. However there were a few instances of learners in one particular group in Class E attempting to engage with the science content, as has been shown in the coding example. It appeared that this and other similar learning opportunities were lost in Class E.

A key point to make about the classroom discourse interaction patterns in the observed lessons is that it was only in Teacher B's class that there was evidence of the kind of dialogic 'learning discourse' that Alexander (2001, 2006), Gibbons (2006), Mercer (1995), Wells (1999) and others have referred to.

*It seems fair then to argue that it was this kind of dialogic classroom interaction that was the basis for the high levels of coherence of science content in the lessons of Teacher B (see Chapter Five); and it also seems fair to argue that conversely, it was the lack of this kind of patterning of meaning (Roth et al., 2006) that contributed to the relatively fragmented nature of the science content in the lessons of the other seven teachers. This point is illustrated in the next section: comparative excerpts of the transcripts for episodes for three of the teachers, each covering the same science content.*

#### ***Content coherence through the discourse: comparisons between three episodes covering same science content***

In the following three edited excerpts of episodes from the lesson transcripts, Teachers A, B and G were teaching the same topic: the separation of a mixture of iron filings and sulphur powder. The excerpts have been edited to remove the bilingual interactions, as well as repetitions; and digressions have been summarized in brackets. (The full transcripts for these excerpts are provided in Appendices 7-9.) This is to reduce the length of the transcripts and to focus on the interaction patterns and the linking of ideas in the discourse; and the engagement of learners by the teacher in 'pattern based reasoning' during and after the practical activity, as they moved from description of observations, to explanation, to generalization. Despite this editing, the

transcripts are of necessity fairly long in order to track the development of ideas from inception to conclusion over time, as suggested by Alexander (2000, 2006), Christie (2002), Gibbons (2006), Mercer and Littleton (2007), Mortimer and Scott (2003). So patience is requested of the reader!

In the edited transcripts, three dots enclosed in square brackets [...] indicate that repetitions and bilingual language have been removed. The interactions have been numbered in the first column for reference purposes and each interaction has produced an idea in the overall cumulation of ideas related to the topic and/or a switch in the discourse interaction pattern. So two of the same type of discourse interaction pattern may follow on one another (as in interactions 1, 2 and 3 in the first excerpt) but the breaks between them indicate a new idea. Bold font is used to show information written on the chalkboard.

The key ideas that should be taught in relation to this topic - the separation of a mixture of iron filings and sulphur powder - are listed briefly:

1. Identify properties of sulphur powder and iron filings (*description*):
  - a. the colour of sulphur powder is yellow (observe appearance);
  - b. the colour of iron filings is silver grey (observe appearance);
  - c. sulphur powder is not magnetic (test with magnet);
  - d. iron filings are magnetic (test with magnet).
2. Make a mixture of sulphur powder and iron filings.
3. Separate the mixture using a magnet (*description*).
4. The mixture of iron filings and sulphur powder can be separated using a magnet because of the difference in the properties of iron filings and sulphur powder: iron filings are magnetic and sulphur powder is not magnetic (*explanation*)
5. *Key principle: the method for separating any mixture is based on the differences in the properties of the substances in the mixture (generalisation).*

As can be seen above, the scientific reasoning process proceeds from description, to explanation to generalization.

Separating a mixture of iron filings and sulphur powder: Lesson A1

In Teacher A's lesson, the following excerpt formed part of a two hour lesson on the separation of five different mixtures. Three of the mixtures were separated in practical activities and the separation of the other two mixtures was explained by Teacher A and supported by chalkboard drawings (see lesson summary, Appendix 4; full transcript for this excerpt in Appendix 7). This edited excerpt covers the whole class talk that accompanied the practical activity as well as the post activity talk.

**Lesson A2 excerpt: separating a mixture of iron filings and sulphur powder**

	<b>Development of ideas in discourse</b>	<b>Discourse interaction patterns</b>
1.	<p>Teacher A: (holding up bottle) Now can you see this words? [...] How do you pronounce it? Sulphur okay?</p> <p>Learners: Yes.</p> <p>Teacher A: (he passes round the bottle of sulphur to groups) [...] How is its colour? (warns learners not to smell the chemical; suggests that men are colour blind) [...] Yellow, okay?</p> <p>Ls: Yes.</p> <p>Teacher A: [...] I want you to make a mixture of the sulphur and the iron. [...] Mix them on that piece of paper [...]</p> <p>(Learners in groups mix sulphur and iron filings while teacher repeats instructions)</p> <p>Teacher A: [...] Okay, so we have mixed the iron filings ... and sulphur. [...] (writes on chalkboard)</p> <p style="text-align: center;"><b>Iron filings and sulphur</b></p> <p>Teacher A:[...] So how is the colour now of your mixture is it still that much yellow or that much brown? A little bit darker, okay?</p>	1.b. Teacher monologue instructional
2.	<p>Teacher A: Okay, now I want you to tell me, what can you use to separate that mixture? [...]</p>	1.b. Teacher monologue

	(teacher suggests various means of separating the mixture: tea strainer, strainer used in making traditional sorghum beer, hand sorting, filter paper and then a magnet)	instructional
3.	(teacher explains that the magnet is not a bar magnet but a horse shoe magnet and then explains the difference between the foot of a cow and that of a horse; not clear how this relates to the magnet itself)	1.b. Teacher monologue instructional
4.	Teacher A: [...] What happens when you bring the magnet to a straight pin? [...] Or what happens to when you bring the magnet to something that is a metal like this nail clipper? [...]  Learner: It can be broken.  Teacher A: She says it can be broken.[...]	3. IRE
5.	Teacher A: Okay, let's say you hold the electricity cable. [...] You will become choked (sic) [...] you stick to that (electric cable) you don't move away any more [...] Because you have been attracted by the electricity cable.	1.b. Teacher monologue instructional
6.	Teacher A: Now let us see what will happen to this. [...]  (Teacher demonstrates: moves the magnet under a sheet of paper with the mixture of iron filings and sulphur powder on top of it)	1.b. Teacher monologue instructional
7.	Teacher A: [...] Look carefully. [...] What is happening? [...] They are moving? What are they? [...] There are things that look like hairs ... baby hairs. ... [...] What was moving there? What was it? [...]  Learner: Hairs  Teacher A: Did you mix hairs there?  Same Learner: No.  Teacher A: But what did you mix? [...]  Learner: You mixed this with salt teacher.  Teacher A: No, no, no. Let me take you back. [...] We mixed the iron filings and the sulphur. Those are the only two things that we have mixed together, okay?  Learners: Yes.	3. IRE
8.	Teacher A: But now there was something in that mixture which was moving when I bring in the magnet. [...]	1b. Teacher monologue instructional
9.	(describes, along with actions, how when a woman is hoeing her field and the hoe hits the stones and gets damaged 'hurt' then the woman would get a file to sharpen the hoe and then while she is sharpening her hoe there are little pieces of metal which we call iron filings)	1.b. Teacher monologue instructional
10.	Teacher A: What was moving? [...]  Teacher A: Was it sulphur? [...] (offers learners 50 cents if they get answer correct)	3. IRE

	Learner: Yes.	
11.	Teacher A: [...] Let us see if it can pull the sulphur. [...] (demonstrates with sulphur) Is the sulphur moving? [...]  Learners: No.  Teacher A: [...] What is it that was moving in our mixture?  Learners: Iron.	3. IRE
12.	Teacher A: [...] Let us see now there in the mixture ... let us see what will happen now.  (demonstrates separating iron filings from sulphur and iron filings mixture with magnet; tells each group to write down what was 'moved away')	1.b. Teacher monologue instructional
13.	Teacher A: [...] There is something blackish which has been taken away. What do we call that? [...]  Learners: Iron filings.  (Teacher asks each group in turn and they give the same answer)	3. IRE
14.	Teacher A: [...] Now what did you use to separate the iron filings from the mixture of the sulphur? [...] When we are separating the beans from the mixture we used our hands. But now I want to know what did you use now to take the iron filings away from the mixture?  Learners: Magnet.  (teacher gets class to repeat 'magnet' three times)	3. IRE
15.	Teacher A: [...] So a magnet was used to separate the mixture of the iron filings and the sulphur.	1.b. Teacher monologue instructional
16.	Teacher A: Now let us go on to the third one.	1.a. Teacher monologue regulative

As the above extract from Lesson A1 shows, the main discourse patterns in this teaching episode were *teacher instructional monologue* (1.b.) interspersed with some brief *IRE interactions* (3.) in interactions 4, 7, 10, 11, 13 & 14. However learner contributions overall in the discourse were very limited, amounting to only 19 words (0,8% of total words spoken).

In some instances Teacher A answered his own questions (e.g. interactions 1. & 2.) – so although the exposition appeared to be in the form of a question and answer IRE interaction, in fact the

teacher filled both the I and R moves. The exposition of science content was disrupted by several digressions (interactions 3, 5 and 9) which did not appear to contribute to improved understanding of the science content, either because the links to the science content were not made: for example in interaction 3. re the shape of cows' and horses' hooves and the link to the shape of a horseshoe magnet; or because they were factually incorrect: re attraction and electric shocks in interaction 5; and iron filings coming from sharpening a hoe in interaction 9. So these digressions served to disrupt rather than support lesson coherence.

In interaction 7. there was the start of an I-R-F-R-F sequence but it collapsed when learners twice provided incorrect responses that clearly indicated that they had not understood the preceding exposition – partly because Teacher A had likened the iron filings to ‘baby hairs,’ which the learner took literally. Teacher A then appropriately demonstrated that sulphur was not magnetic (interaction 11.) - an example of contingent responsiveness; but this fact should have been established *before* mixing the two substances, and this demonstrates the general lack of ‘systematic organisation of learning’ (Morrow, 2007, p. 29) that characterised Teacher A’s lessons. At the end of the episode, the learners were left with the correct idea that the mixture of sulphur and iron filings was separated by using a magnet (interaction 14 & 15); but this fact was not linked to any explanation, or generalization i.e. that the difference in the property of magnetism of the two substances formed the basis for their separation. The teaching episode stopped short at description without proceeding to the explanation and generalization stages; and the teacher immediately moved on to the next experiment.

#### Separating a mixture of iron filings and sulphur powder: Lesson G2

The following extract from Lesson G2 was part of a 51 minute lesson when seven different methods of separating mixtures were covered – three with practical activities and four by means of explanation and chalkboard drawings (see lesson summary, Appendix 4; full transcript of excerpt in Appendix 9).

## Lesson G2 excerpt: separating a mixture of iron filings and sulphur powder

	Development of ideas in discourse	Discourse interaction patterns
1.	Teacher G: There is another ... there is another way of sorting. Yesterday you mixed a sulphur and ...?  Teacher G & Learners: iron filings.	2. Oral cloze
2.	Teacher G: Get it out. (points to back of class where science equipment is kept; learners fetch materials)  Teacher G: Can you separate sulphur from iron filings?  Learners: Yes.  Teacher G: [...] Do it. Separate that mixture.  (learners working in groups make a mixture of sulphur and iron filings; teacher monitors)	1.a. Teacher monologue regulative
3.	Teacher G: Separate that mixture [...] I am going to give you a magnet. [...] You use this... to separate the mixture. [...]	1.b. Teacher monologue instructional
4.	Teacher G: (calls on a group to report) So what ...what do you see? [...]  Learner: The iron filings they are too fast the way they come up to the magnet.  Teacher G: They come very fast to the ... to the magnet.	5.2. Learners report back
5.	Teacher G: So it means iron filings are ...?  Teacher G & Learners: Are magnetic.  Teacher G: They are magnetic.	2. Oral cloze
6.	Teacher G: Is sulphur magnetic?  Learners: No.  Teacher G: So sulphur is not magnetic.	3. IRE
7.	Teacher G: So that method is called magnetism. (writes on chalkboard)  <b>3. Magnetism</b>  [...]	1.b. Teacher monologue instructional
8.	Teacher G: Okay. We can also separate mixtures by another method called distillation. ...	1.b. Teacher monologue instructional

The discourse patterns in this extract are mainly *teacher instructional monologue* (1.b. – in interactions 3, 7 and 8); a short *reporting* of observations by one of the *groups* after the practical activity (interaction 4); and key facts consolidated with *oral cloze* (interaction 2) and short *IRE* exchanges (interactions 5 & 6). In contrast to Teacher A, the discourse style of Teacher G was fairly minimalist (227 words in total versus 2413 in class A) and there were no distracting digressions. But like Teacher A, ideas were not consolidated or reinforced and not linked to generalised principles or conceptual frameworks through the discourse. Learners were left with the key idea that a mixture of sulphur powder and iron filings could be separated with a magnet but this was not linked to the key generalizing principle: that the difference in properties is the basis for separating substances in a mixture.

As with the teaching episode in Lesson A2, there was no evidence of dialogic exchanges and the discourse that followed the practical activity stopped short at the description stage without further development of explanation and generalization; and the teacher moved straight on to the next experiment.

### Separating a mixture of iron filings and sulphur powder: Lesson B3

In the next extract from Lesson B3 (1 hour 14 minutes) Teacher B reviewed a practical activity done two days previously when learners identified the properties of sulphur and iron filings and found that in a mixture the properties of the component substances did not change - the first of two lessons that investigated the difference between mixtures and compounds. The episode in the extract below introduced a series of three lessons on separating mixtures. The class did not repeat the practical activity itself (separating iron filings and sulphur powder), but Teacher B drew on it to establish a different but related concept in relation to separating mixtures: that in order to separate a mixture, one needs to base the separation method on the differences between the properties of the substances making up the mixture. The lesson continued with a practical activity on separating a mixture of sand and water (see Appendix 4

for lesson summary; full transcript of excerpt in Appendix 8). (In this excerpt strong emphasis is shown by upper case font.)

**Lesson B3 excerpt: separating a mixture of iron filings and sulphur powder**

	<b>Development of ideas in discourse</b>	<b>Discourse interaction patterns</b>
1.	<p>Teacher B: How can we separate or how did we separate iron from sulphur in the mixture of iron and sulphur? [...] What did we use to separate the mixture of iron and sulphur? [...] (nominates learner)</p> <p>Learner: We used a magnet.</p> <p>[...]</p> <p>Teacher B: Good! We used a magnet, very good. [...]</p>	4. Dialogic exchanges
2.	<p>Teacher B: Now, in using that magnet, what did you consider? [...] What did we consider in these two substances, in order for us to use that magnet, to separate the mixture? [...] (nominates learner) [...]</p> <p>Learner: Iron filings.</p> <p>[...]</p> <p>Teacher B: We considered iron filings?</p>	4. Dialogic exchanges
3.	<p>Teacher B: What happens to the iron filings and the magnet? [...] What happens when we bring the magnet closer to the iron filings? [...](nominates learner)</p> <p>[...]</p> <p>Learner: Iron filing is magnetic.</p> <p>Teacher B: Is magnetic. Iron filings ARE, remember, magnetic, okay? Filings ARE magnetic.</p>	4. Dialogic exchanges
4.	<p>Teacher B: [...] What does it mean when we say iron filings are magnetic? [...] What does the magnet do to the iron filings? [...] (nominates learner)</p> <p>Learner: It combines them.</p> <p>[...]</p> <p>Teacher B: I would not exactly say it combines them.</p>	4. Dialogic exchanges
5.	<p>Teacher B: What other term can we use? [...] When you say it combines them, you mean it brings them closer, okay? What does it do to them? [...] What happens?</p>	4. Dialogic exchanges

	<p>Learner: [...] It pulls them.</p> <p>Teacher B: [...] Pull, pull. It pulls them, heh?</p>	
6.	<p>Teacher B: Another word which we can use? A scientific word that we can use, we used it yesterday? ... (nominates learner)</p> <p>Learner: We put up.</p> <p>Teacher B: You put up ... no, we did not use that name.... It starts with A. (gesticulates pulling action with hand) [...] Are what? [...]</p> <p>Learner: Identify.</p> <p>Teacher B: [...] Not at all! Not identify. [...]</p> <p>Learner: Attract</p> <p>Teacher B: [...] Good! Attract, attract. [...] Magnet attracts iron filings [...] (writes on chalkboard)</p> <p style="text-align: center;"><b>Attract</b></p> <p>Teacher B: [...] It is that pulling we were referring to. [...]</p>	4. Dialogic exchanges
7.	<p>Teacher B: But does the magnet attract sulphur?</p> <p>Learners: No. [...]</p> <p>Teacher B: It does not attract it. So, we use that magnetism or that attraction to identify iron filings. Iron is attracted by a magnet. [...] (writes on chalkboard)</p> <p style="text-align: center;"><b>Iron is attracted (magnetized) by a magnet</b></p>	4. Dialogic exchanges
8.	<p>Teacher B: Sulphur is attracted, isn't it?</p> <p>Learners: No</p> <p>Teacher B: Is what ... is not ...Sulphur is not attracted by a magnet. (writes on chalkboard)</p> <p style="text-align: center;"><b>Sulphur is not attracted</b></p>	4. Dialogic exchanges
9.	<p>Teacher B: So what did we say those are? [...] Which we use to differentiate between an iron and a sulphur? [...] (nominates learner)</p> <p>Learner: It is a reactor.</p> <p>Teacher B: It is a reactor? No, no it is not a reaction.</p>	4. Dialogic exchanges
10.	<p>Teacher B: Let me remind you we had a table like this, okay? (draws on chalkboard) [...] What does this table show us about these two things? Iron, sulphur. [...] What were we looking at? To differentiate between those two things. We will look at the colour [...] So the colour we said it is what of the iron?</p> <p>Learners: Silver grey.</p>	4. Dialogic exchanges

11.	Teacher B: So that ... that grey colour we use to differentiate between sulphur and what?  Teacher & Learners: And iron	4. Dialogic exchanges
12.	Teacher B: Or to identify [...] between iron and sulphur. In one word we called those things the what of iron?  Learner: It is properties.  [...]  Teacher B: Very good. (gets learners to repeat 'properties' twice) [...].	4. Dialogic exchanges
13.	Teacher B: So which means, to separate those two, the mixture of iron and sulphur we use the properties. [...] So because we know iron is attracted by a magnet and sulphur is not attracted by a magnet, [...] then to separate them we use what?  Learners: A magnet  Teacher B: We use a magnet. Is that clear?  Learners: Yes.  Teacher B: So which means to separate mixtures, [...] we should look at the PROPERTIES of those substances we have mixed. Is it clear to everyone?  Learners: Yes.	4. Dialogic exchanges
14.	Teacher B: [...] We'll try to do another experiment which is going to show us how to separate another mixture. So we should keep in mind [...] that now when you separate mixtures, you have to look at the properties of the two substances that are mixed.  (in the next experiment, learners separated soil and water by filtration)	1.b. Teacher monologue instructional

In the above episode, the classroom discourse displayed the key indicators of 'dialogic discourse' in that Teacher B engaged learners in I-R-F/I-R-F/R-F exchanges that *extended over several turns* (thirteen). Teacher B provided clear feedback, which responded to and built on learners' responses, demonstrating '*contingent responsiveness*'. In this way, the discourse and development of ideas was built on the learners' contributions, while being carefully orchestrated by the teacher. As Wells (1999) has put it: 'it is in this third step (the 'feedback' move) in the co-construction of meaning that the next cycle of the learning-and-teaching spiral has its point of departure' (p. 207).

In interaction 9. the learner made an incorrect response ('reaction' instead of 'property') so Teacher B looped back to reteach; and elicited from learners the colour and magnetism of iron filings and sulphur powder; and then was able to elicit the correct response: 'properties' in interaction 12 – which formed the basis of the key concept in interaction 13: Teacher B: '*So which means, to separate those two, the mixture of iron and sulphur we use the properties*'.

In addition, meaning *cumulated* over several turns and was focused on *patterning facts into conceptual frameworks through logical argument* – thinking aloud or what Scott, Mortimer & Ametler (2011) have described as 'pedagogical link-making'. Logical connectives such as 'how (1) ... what did you consider (2) ... what happens (3) ... what does it mean (4) ... but (7) ... so (9) ... so that (11) ... or (12) so which means (13) linked ideas and structured the argument. As the excerpt shows, this teaching episode followed a process of description => explanation => generalization, with the generalised principle forming the basis for the next experiment: '*So we should keep in mind that now when you separate mixtures, you have to look at the properties of the two substances that are mixed*' (Teacher B).

#### ***Opportunities for learning science content through the discourse***

The charts in the Figures 6.6. - 6.8. provide a visual representation of the *different discourse patterns* across each of the three teaching episodes. The chart in Figure 6.9. shows the *different amounts of classroom talk* employed to teach the same lesson content:

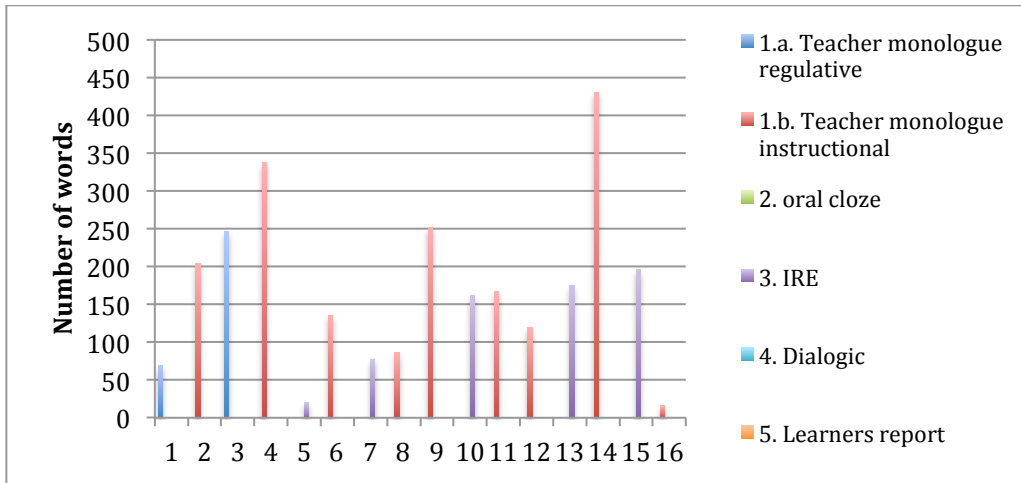


Figure 6.6. Discourse patterns in teaching episode from Lesson A2

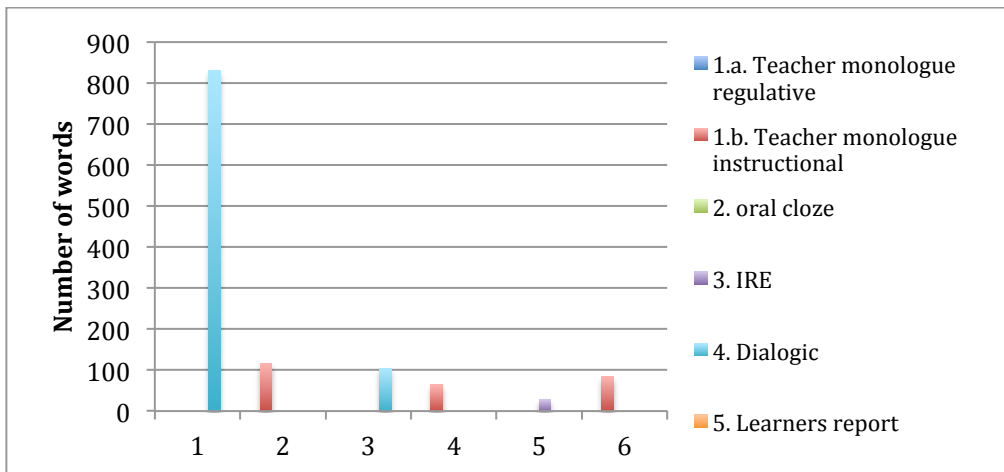


Figure 6.8. Discourse patterns in teaching episode in Lesson B3

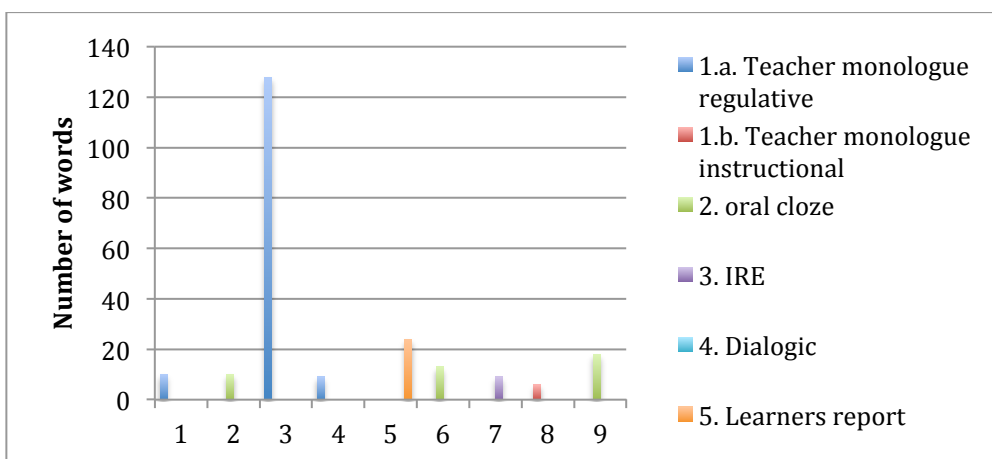
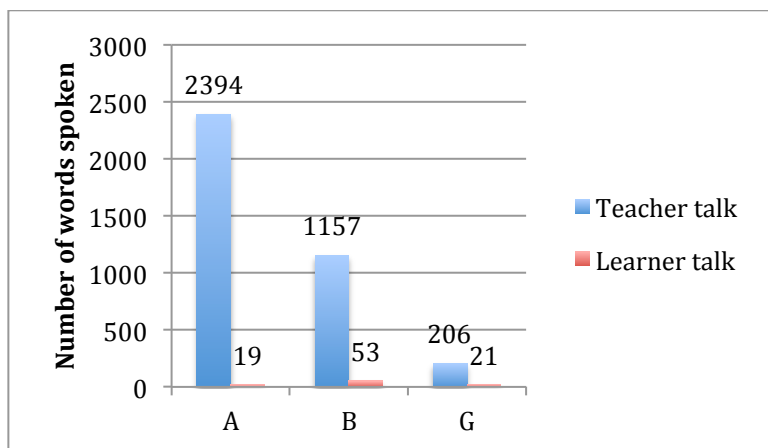


Figure 6.7. Discourse patterns in teaching episode in Lesson G2



**Figure 6.9. Amounts of classroom talk in three classes to teach same content**

What the analysis of the three excerpts and the charts in Figures 6.6. - 6.9. show is that Teachers A, B and G, constructed the same science content in very different ways:

In Teacher A's lesson, the predominant discourse patterns for this teaching episode, were that of *teacher instructional monologue* (1.b.) for presenting ideas (64%); and IRE (3.) for eliciting some ideas (24%) (see Figure 6.6.). The balance of teacher/learner talk was: Teacher A - 99% / learners - less than 1%. So although learners in Class A were engaged in a practical activity, the meaning making talk during and after the practical activity did not engage them in the kinds of dialogic discourse patterns likely to promote coherent meaning making. The talk during and after the practical activity stopped short at description and did not proceed to explanation and generalization. In addition, the relatively high volume of teacher talk in Class A (see Figure 6.9.), which was roughly ten times that of Teacher G and twice that of Teacher B, included three digressions; and with the limited participation of learners in this episode it meant that learners might well have been 'buried in the discourse' (Breen, 1998, in Walsh, 2006, p. 16) with key ideas omitted or obscured and left fragmented, rather than linked to key organising principles.

In Teacher G's lesson 65% of classroom discourse consisted of *teacher regulative monologue*; the key ideas were elicited through the reporting back by learners (24% of classroom discourse) and one limited IRE sequence (4% of classroom discourse); these ideas were

reinforced through oral cloze (18% of classroom discourse). In Class G, learners contributed the greatest percentage of classroom talk at 9%; but this was in the context of a low word count overall, with minimal elaboration or examples – the ‘factual detail’ considered important for learning by Donovan & Bransford (2005). As with Class A, the key ideas were not linked to generalizable principles and conceptual frameworks, but left as stand alone items – leaving learners with a fragmented collection of facts.

By contrast, in Teacher B’s lesson, the dominant discourse pattern in the episode was *dialogic exchanges* (76%) with extended I-R-F/I-R-F/I sequences and some instructional teacher monologue (22%). The key ideas were carefully linked into a conceptual framework, through engaging learners so that their contributions were built into the developing argument in ways that were ‘contingently responsive’ – the kind of discourse patterns that could be described as ‘learning discourse’ (Alexander 2001) (see also Gibbons, 2006; Mercer & Littleton, 2007; Mortimer & Scott, 2003). The development of ideas after the practical work did not stop short at *description*, but the full explanatory arc of *description => explanation => generalization* was completed.

It appeared that this dialogic discourse in Teacher B’s lesson, was an important aspect of constructing the science knowledge cumulatively and linking ideas into a coherent *vertical knowledge structure*. This was a significant aspect of Teacher B’s practice that supported learners’ opportunities to learn the science content. Conversely the absence of this kind of discourse from the practice of seven of the eight teachers, indicated the relatively fragmented nature of the science content made accessible to the learners in their classes, and constituted a limitation on learners’ opportunities to learn science.

According to Vygotsky (1962), language and thought are closely intertwined; and so the disentangling of discourse patterns and the science content of the lessons for the purposes of analysis, has provided a somewhat fragmented picture. It could be argued that the classroom

discourse patterns are merely a manifestation of a particular teacher's understanding of the science content: that if a teacher understood the broader conceptual frameworks within which a particular example was situated, then the discourse they employed would reflect the pattern-based reasoning that forms the basis for dialogic exchanges. However the linking of facts into conceptual frameworks could be accomplished linguistically in terms of teacher instructional monologues. So dialogic exchanges not only link and pattern ideas, but also reflect an *engaged pedagogy* that ties the construction of conceptual frameworks closely to learners' contributions – paying careful attention to their responses; and providing the kind of contingent responsiveness that carefully leads and guides learners in the cumulative construction of science knowledge.

As noted, the classroom discourse does not stand on its own, only in relation to the lesson content: so if some of the facts that are the building blocks of a generalised conceptual framework are left out, the framework will collapse; and if the teacher introduces lengthy digressions, they can disrupt the thread of an argument linking the facts into a conceptual framework. Likewise, if the teacher stops short of linking the description and explanation of a phenomenon to the generalisation that the practical observation is intended to exemplify, then the facts remain fragmented and the vertical knowledge structure is not built. So it is in the interplay of the science content and the discourse patterns that engage learners in pattern based reasoning that the learning discourse is enacted; but unless the teacher has a clear idea of the logical structure of the science content, the discourse patterns are irrelevant.

So perhaps one can claim that dialogic exchanges or learning discourses depend on the necessary condition of teachers' truly sound subject knowledge; but equally one can claim that subject knowledge is best learned through the kind of classroom discourse that include interaction patterns that have been described as dialogic.

What follows next is an analysis of the horizontal bridging discourses that have the potential to provide access to the vertical discourses of science.

### **Bridging discourses: from the known to the new**

As discussed in the literature review, there is a gap in terms of the kinds of language skills and knowledge that learners bring to school, and the kinds of language skills and knowledge required by schooling; between the horizontal discourse of everyday knowledge and the vertical discourse of the specialized knowledge of schooling. Gibbons' (2006) research (drawing on the works of Barnes, 1976, 1992; Bernstein, 1971; Cummins, 2000; Vygotsky, 1962; Wells, 1999, in the sociocultural tradition) identified a 'bridging discourse' employed by skilled teachers to scaffold learners' induction into the specialized knowledge and language of science, while simultaneously supporting learners in moving from context-embedded face-to-face, exploratory talk while engaging in practical activities - to context-reduced, presentational talk, abstracted from the practical experience; and then moving along the mode continuum to recontextualise these ideas in writing. In this way, the bridging discourses managed by the teacher span the known and the new and support learners in accessing the vertical discourses of science.

The observed lessons were coded for aspects of bridging discourses as follows:

1. Everyday knowledge to science knowledge (including analogies);
2. Everyday language to science language;
3. Practical experience to theoretical knowledge
4. Oral to written language – across the mode continuum

These metaphorical 'bridges' may be crossed and re-crossed in both directions in the process of inducting learners into the specialized practices, knowledge and language of schooling. Successful instances of the four types of bridging discourses were identified in the lesson

transcripts and were counted in order to establish their prevalence in the observed lessons. Attempts at bridging that were not successful, such as confusing analogies or written tasks that did not address key ideas in the content, were not coded and counted.

Examples of the coding follow:

1. Everyday knowledge to science knowledge and vice-versa (including analogies)

In Lesson F2 on static electricity, Teacher F drew on learners' everyday experience to illustrate a science concept:

Teacher F: Have you ever seen or heard the little... lightning spark that happens when you take off your clothes? That spark... that spark when you're taking off your clothes, okay?

Learners: Yes.

Teacher F: That is the static electricity, see?

(Lesson F2, episode 1)

2. Everyday language to science language

Words represent concepts and so it was sometimes not clear whether to code an instance as 'knowledge' or 'language'. When a teacher drew special attention to the language as in the example below: 'what special term ...' or specifically taught science terms, then the example was coded as language rather than knowledge although the instance would generally serve both purposes: bridging knowledge and language.

In Lesson E2 on land pollution, after eliciting various forms of land pollution, Teacher E specifically taught the term 'pollutants':

Teacher E: Now, ...all these things pollute our environment. What collective term can you give them? What special term can we give them? Things that pollute the environment. Does anyone know? Try, can you try? (pointing to learner) Try please.

Learner: (indistinct)

Teacher E: No, no, no...we said all these things we have mentioned ... starting from here (pointing to a list on the chalkboard) up to here, we said these are all things which pollute the environment ... some ... because there are still more. Then we say if we take them all together, what one word to make you do those things.

Learner: Pollutants.

Teacher E: Very good! They are the pollu...?

Teacher E & Learners: ..tants. (writing on board)

## **POLLUTANTS**

(Lesson E3, episode 3)

### 3. Practical experience to theoretical knowledge

In lesson B1, learners had mixed sulphur powder and iron filings and observed and reported that the properties of colour and magnetism for both had not changed – they were the same before the substances were mixed and after they were mixed. Teacher B then told the groups to discuss a definition of a mixture:

Teacher B: So, so, what can we say a mixture is? It is something where things are what? Mhmm? Mhmm? Mixture... talk. Discuss it in your groups, briefly; discuss it briefly.

While groups were discussing this question, Teacher B moved from group to group, asking probing questions to guide learners to a generalisable definition for all mixtures (see 'the outcome should be the same' below):

Teacher B: (moves to another group) What did you say here?

Learners in group: Something that has been added to another.

Teacher B: Something that has been added to another? Like when you add salt to water? Discuss it. Remember, if you say it's something added to another. Then when anything is added to another the outcome should be the same.

A definition was elicited; and then learners were made to repeat the definition twice with the teacher, who wrote it on the chalkboard and then repeated it again:

Teacher B: Mixture. You should look at the properties of those things, okay? When you have those two substances... let's all listen ... when we have those things. When you have those two substances, iron filings and sulphur, okay?

Learners: Yees

Teacher B: Then we put them together... what happens to i-properties, mmmm? Do the properties change or remain the same?

Learners: Remain the same.

Teacher B: They what?

Learners: Remain the same

Teacher B: Good! They remain the same, heh? So, that's how we should ehh... define our mixture. A mixture is a substance where you have mixed or you have combined two substances, okay?

Learners: Yees

Teacher B: And the properties of those two substances remained what?

Teacher B & Learners: The same.

Teacher B: Is it clear?

Learners: Yees

Teacher B: The properties of those substances remained the what?

Teacher B & Learners: The same

Teacher B: Remained the same. (writes on the chalkboard) So, a mixture is ehhh... where properties... where properties of two substances ... remain the same, they do not change at all.

### **Mixture – where properties of two substances remain the same**

Thus learners were guided from observation of a particular mixture to a generalized definition that would apply to all mixtures; the teacher supported them in bridging the practical-theoretical gap.

#### 4. Oral to written – mode continuum

In Lesson B4, Teacher B had demonstrated separating salt from water in a salt solution by heating the solution in an evaporation dish so that the water evaporated and the salt remained behind. He then wrote up a writing frame on the chalkboard while eliciting the key ideas:

**Aim: to separate salt from water**

**Method:**

- 1.
- 2.
- 3.
- 4.

**Observation:**

**1. After a few minutes ...**

**Conclusion: Salt is separated from water by (process)**

Teacher B: So you do that on your workbooks okay? You complete experiment...complete that experiment there ... complete the experiment. So you have the aim, you have the apparatus, you write the method ... what we did, okay?

Learners: Yees.

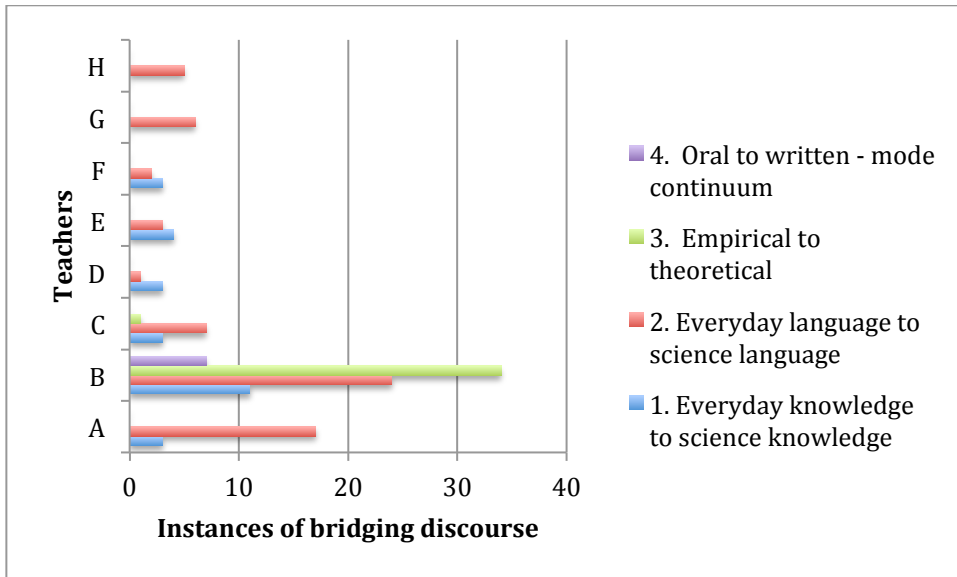
Teacher B: You write the observation - what you saw. And you write the conclusion ... the conclusion ... the conclusion. I have started it for you there... salt is separated from water by?... Write the process, heh?

Learners: Yees.

(Lesson B4, episode 6)

#### Findings for bridging discourses

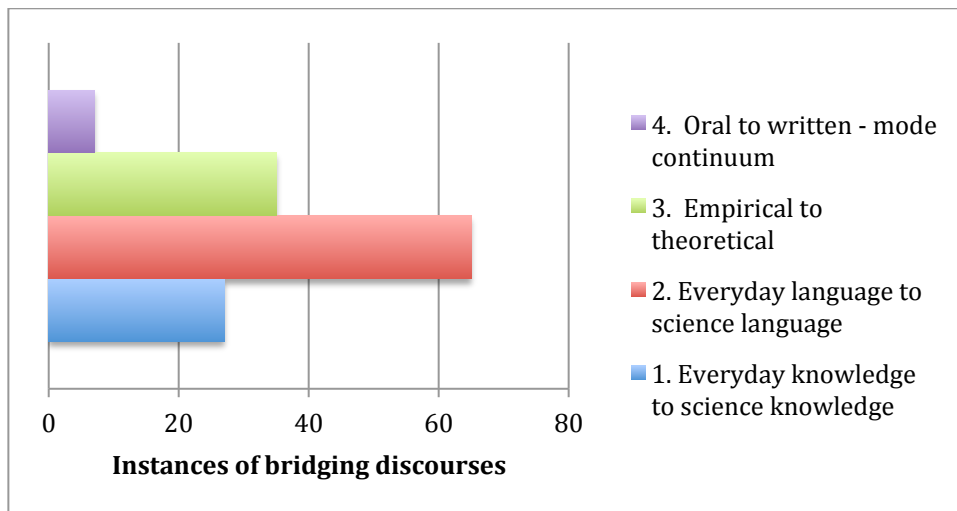
Instances of the four types of bridging discourses were counted for each teacher. These findings are illustrated in the chart in Figure 6.10.



**Figure 6.10. Bridging discourses: number of instances for each teacher**

What is immediately apparent is how sparse the instances of bridging discourses were for six out of the eight teachers: Teacher D - 4 instances; Teachers F and H - 5 instances each; Teacher G - 6 instances; Teacher E - 7 instances; Teacher C - 11 instances. The number of instances of bridging discourses in Teacher A's lessons – 20 instances - was nearly twice as many as that of teacher C; but this was still far less than in Teacher B's lessons which included 76 instances of bridging discourses – almost four times that of Teacher A, and at least seven times or more than that of the remaining six teachers. The four aspects of bridging discourse are discussed in more detail below.

The overall distribution of instances of bridging discourses is shown in the chart in Figure 6.11.



**Figure 6.11. Distribution of bridging discourses**

*Everyday knowledge to science knowledge, including analogies*

There were 27 examples of bridging by teachers from everyday knowledge to science knowledge or vice versa, with 11 (40%) coming from Teacher B. Three examples follow:

*Lesson A1: Food web*

Near the end of a lesson on the interdependence of plants and animals, Teacher A described the process of photosynthesis and then gave an example of the everyday application of photosynthesis:

Teacher A: So far now you know the importance of the plants also. Some they use the plants to refreshing their sitting rooms and their offices... therefore when they are making that food, that organic food, when they are making their food they give off oxygen because they make their own food. During the day when there is sun, and then they... they give off a lot of oxygen ... and then we need that oxygen to breathe, okay?

Learners: Yes.

Teacher A: We need that oxygen to breathe and then...during the night...during the night, they give off what? Carbon dioxide...You must never, never, never take plants into your sleeping bedroom, okay?

(Lesson A1, episode 7)

*Lesson B3: Separating a mixture of soil and water*

After learners had separated a mixture of soil and water by means of filtration, Teacher B asked how filtration was used in their homes:

Teacher B: Where do we use that... that filtration at home?

Learner: We use a tea.

Teacher B: We use tea - when you did what?

Same Learner: When you pour.

Teacher B : Mhmm? When you pour we use it with tea. What else? What other thing do we use it for?

Learner: When you make African beer.

Teacher B: Good! When making a Xhosa beer, okay?

(Lesson B3, episode 8)

*Lesson B2: Compounds – an analogy*

There were also examples of teachers using analogies from learners' everyday lives to explain a science term. For example in Lesson B2, Teacher B got the learners to look up the definition the word 'properties' in the glossary at the back of their textbook and one learner read it aloud to the class. Teacher B explained the meaning of the word 'feature' in the definition by using an analogy of physical features that might be used identify members of a family:

Learner: (reading aloud) Properties: feature of something which can be used to identify.

Teacher B: Did we hear it? Feature of something which we can use to what? To identify ... to identify. Is it clear?

Learners: Yees

Teacher B: Good! Like ehh... like ... children of the same family, okay? Like if we have a pointed nose, for example. If you notice that the nose is pointed then you will know that this one is related to Thabo (a learner in the class). Now, at home we have a chin ... do you see how my chin is shaped?

Learners: Yees

Teacher B: How is it shaped?

Learners: It is pointed.

Teacher B: It is pointed. Now all my brothers are like this. So, you can say that is a feature... feature that we have. Is it clear?

Ls: Yees

Teacher B: Feature that we use to identify that thing.

(Lesson B4, episode 3)

However, not all references to everyday knowledge necessarily bridged the gap to science knowledge. Although Teacher A provided many lively and entertaining everyday examples or analogies for science concepts, few were clearly linked to science knowledge and some were misleading or factually incorrect: for example Teacher A's reference to iron filings and sharpening a hoe; and his attempt to explain the concept of a food web with reference to a goose's webbed foot and the fabric between the spokes of an umbrella (transcript excerpts provided in Chapter Five). These were examples of attempts to bridge everyday and science knowledge; but they were not counted as instances of bridging discourse as the analogies were misleading and so the bridging attempts failed.

### *Everyday language to science language*

This was the most widely represented category with 65 instances - with 24 from Teacher B and 17 from Teacher A. Three examples follow:

#### *Lesson B4: Separating a mixture of salt and water*

Teacher B was preparing to demonstrate how to separate a mixture of salt and water through evaporation. He showed learners the scientific word 'sodium chloride' and then linked it back to the everyday word 'table salt'; then taught and reinforced the scientific term 'sodium chloride':

Teacher B: (showing the class a bottle of table salt labeled 'sodium chloride' and tells them to read the label) What is it?

Learners: (reading from the bottle) Sodium chloride

Teacher B: Good! It's table salt. This is the one we use at home ... we put it in our food. When we name it we say its chemical name, okay? (writes on chalkboard)

### **Sodium chloride**

Learners: Yees

Teacher B: Sodium chloride, so which means here we have...ehh, a what?

Learners: Sodium chloride

Teacher B: This is table salt, that sodium chloride. So this is the common name that is used by everyone. Everybody knows that when you speak about table salt, but sodium chloride we find that some of the people don't know this word okay?

Learners: Yees

Teacher B: Parents do not know that word so don't get home and ask ... for sodium chloride, they won't know sodium chloride. Your little sibling at home does not know what sodium chloride is.

(Lesson B4, episode 2)

### *Lesson C2: Different types of mixtures*

Teacher C had instructed groups of learners to mix vinegar and water in test tubes and then shake them to show that the two liquids dissolved in one another. She then introduced the scientific term: 'miscible liquids' – a 'special name'.

Teacher C: Therefore the liquid that dissolves easily in water, those liquids are known as the miscible liquids (writes on chalkboard).

### **Miscible liquids**

Teacher C : We have a special name for liquids, one dissolves in another. We call those liquids the?... the?...

Teacher C & Learners: miscible liquids.

Teacher C: It means they... they dissolve easily, are we going together?

Learners: Yes.

Teacher C: If they are miscible it means they dissolve easily. [...]

Teacher C: Okay just give me other examples besides vinegar and water. Other examples of miscible liquids, that is the ... the liquids that dissolve easily. We've done this example that is vinegar and water and we've seen that vinegar dissolves easily in water. Then what ... give me other examples of miscible liquids.

Learner: Orocush (a brand of concentrated orange drink).

Teacher C: That is a drink. Cool drink. (writes on chalkboard)

### **Cool drink + water**

Teacher C: Cool drink, cool drink and? and water are also examples of miscible liquids, okay?

(Lesson C2, episode 6)

### *Lesson G2: separating mixtures*

In Lesson G2 one learner had demonstrated separating a mixture of soil and water by means of filtration. Teacher G drew learners' attention to the 'clean water in the bottom of the test tube' and then taught the scientific word: 'filtrate'

Teacher G: Okay. We call this clean water that you see at the bottom of this ... of ... of this glass. A ... a filtrate! We call it not a filtration ... we call it a? ... a? ...

Teacher G & Learners: Filtrate.

Teacher G: We call it a fil...(writing on board) filtrate.

### **filtrate**

(Lesson G2, episode 10)

Where scientific terms were introduced without a clear link being made to everyday language then these instances were not counted as examples of bridging discourse.

### *Practical experience to theoretical knowledge*

As Mortimer and Scott (2003) have stated: 'practical activities can be interesting, motivating and helpful in getting ideas across, but they cannot speak for themselves. It is only through the

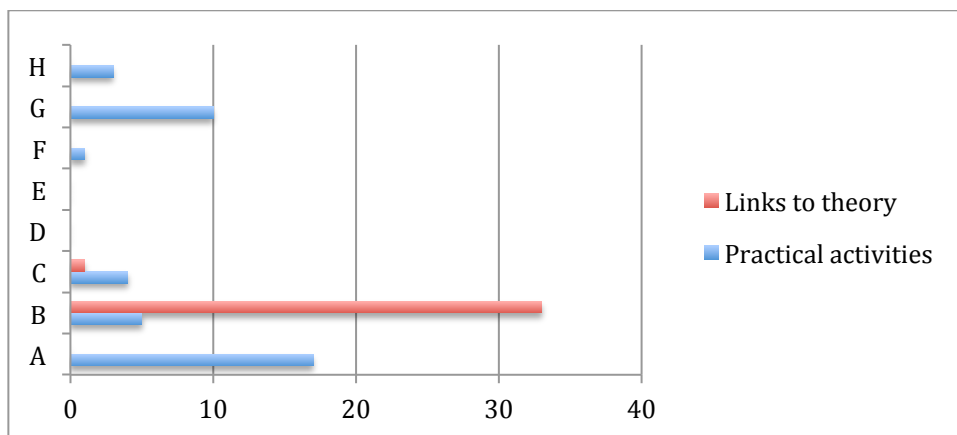
teacher's and students' talk around the activities (Leach and Scott, 2002) that teaching and learning can occur.' (p. 1).

In this analysis, instances were counted of teachers provided an explicit bridge from empirical evidence to generalization, by following a process of description of observations, then explanation and generalization.

There were a total of 40 practical activities and demonstrations in the 40 observed lessons, although these were not evenly distributed between teachers or over lessons: (see Appendix 6. for summary of practical activities): there were no practical activities in the lessons in Classes D and E; and only 1 observed in Class F. At the other end of the scale there were 10 practical activities in Class G and 17 in Class A. However, in five of the six classes where there were practical activities (A, C, F, G, H), there was only one instance (in Lesson C1) of bridging discourse that supported learners' understanding of the practical work as evidence of a broader generalized principle, following the stages of description => explanation => generalization.

By contrast, in Teacher B's lessons, where there were five practical activities, there were 34 instances of bridges made from practical observations to generalisations. These generalizing principles were repeated at several points in the lessons and served to link the series of five lessons on mixtures, compounds and separating mixtures, into a coherent conceptual framework.

The counts of practical activities and instances of bridging from practical activities to theoretical knowledge are illustrated in the chart in Figure 6.12. and thereafter some examples are given – both of successful bridges and some instances when the talk around the activities stopped short at the description or explanation stages of the explanatory arc.



**Figure 6.12. Practical - theory bridging discourses: number of practical activities with number of links to theoretical knowledge**

As noted in the lessons of Teachers A, C, F, G and H, in the talk that followed the practical activities, there was generally some description and perhaps explanation. However there was only one instance (in Lesson C1) where there was a link to an explicit generalization. This is shown in the extract below:

*Lesson C1: Phases of matter and phase changes*

Teacher C had introduced the different phases of matter and the idea that these should be classified according to their properties.

Teacher C: So we classify these phases according to their properties. Why do we classify them? Because we want to know what the phases are made of and what the phases, in fact how the phases differ.

After describing the properties of solids and gases (shape and volume), she demonstrated that one of the properties of liquids was that they take the shape of their container:

Teacher C: Now let's come to the liquids. (Places the three containers and a bottle of water on the front desk) We are going to use these three containers for the properties of liquids. You are going to tell me what are the properties of liquids, after we have done this activity.

One of the learners poured the water into the three different shaped containers. Teacher C elicited that the liquid took the shape of the container:

Teacher C: Okay. What can we say about the shape of the liquids? Hands up. We have observed the water. We have poured the water in that one litre bottle, into the dish.

Learner: The shape of the liquid was the same.

Teacher C: The shape was?

Same Learner: Of the second one.

Teacher C: The shape of the liquid, that is the shape of the water in the dish was?

Same Learner: Circle.

Teacher C: Was round, isn't that so?

Learners: Yes

Teacher C: Yes. So what do you want to say?

Same Learner: I want to say that the ... the dish is round.

Teacher C: The dish is round and the, the liquid, the water that was in the dish was also round, not so?

Same Learner: Yes

Teacher C: So it means the liquids takes the ... the shape of the container, are we together?

Learners: Yes

(Lesson C1, episodes 2 & 3)

Teacher C then elicited that the volume of the liquid remained the same and concluded by describing the properties of volume and shape for all three phases of matter. In this way the demonstration relating to the properties of liquids was linked to the broader concept of the properties for all three phases of matter.

In Teacher B's lessons, there were practical activities in each of the five lessons (see Appendix 4 for Lesson summaries and Appendix 6 for Summary of practical activities) and the practical activities were tightly linked to conceptual frameworks.

The two examples below illustrate the same practical activity – making a compound, iron sulphide - and the difference in the talk that followed in two different classes: Class B and Class G. In Lesson B2, the bridging from practical observation and description, to explanation, to generalization was clearly evident; whereas in Lesson G1, the talk that followed the same practical activity stopped short at description and then at the end of the lesson, Teacher G provided a partial explanation, but no generalisation.

*Lesson B2: The differences between mixtures and compounds*

Teacher B elicited a review of the definition of a mixture and then he demonstrated heating a mixture of iron filings and sulphur powder in a test tube so that they reacted and formed a compound, iron sulphide. After the demonstration, Teacher B systematically guided learners through the stages of description and explanation to arrive at a generalization

(learners pass round the test tube and look at the colour of the substance in the test tube)

Teacher B: Colour, colour... that one that was going around the class? Is it yellow, brown, black? What is it?

Learners: Brown

Teacher B: Brown, heh?

Learners: Yees

Teacher B: So, a brown substance was formed as you say. A brown substance was ...what? Was formed.

Teacher B then elicited that the colours of the substances that were initially combined were yellow and silver grey.

Teacher B: Now, initially what was the colour of the things we combined? Heh?

Learners: Yellow and silver grey

He elicited that the product of the reaction was a completely different colour to the colours of the reactants; that the name of the product was iron sulphide; and that it was called a compound. He then asked:

Teacher B: What can we say about the properties of a compound when we look at them in relation to the things we mixed? Mhmm? Are they the same or different? Are they the same or are they different?

Learners: Different.

Teacher B: The properties of products, the thing that resulted? They are what?

Learners: They are different.

Teacher B: Good! They are different, they are not the same, heh?

Teacher B then elicited the generalization and repeated it:

Teacher B: So, your compound here ... it's totally different from the what? From the reactants, is it clear?

Learners: Yees

Teacher B: Totally different from the what? From the reactants.

Teacher B took learners through the argument again and then elicited the same generalization in relation to a different compound: water. He then reiterated the generalization (see below: 'its not always going to be iron and sulphur'; and 'every time') and wrote up the generalization on the chalkboard:

Teacher B: It won't always ... it's not always going to be iron and what? And sulphur. Once elements react together, once elements react, okay? They form a what? A compound, is it clear? Once elements react they form a what?

Teacher B & Learners: A compound

Teacher B: Every time, once they react they are going to form a compound. The compound will have different properties from that, ehh ... (writes on the chalkboard) Let's put there 'with' ... with different ... with different properties from what? From the reactants, okay? Is it clear?

**Compound – substance formed when two elements have reacted with different properties from reactants**

In the last episode in the lesson, learners had to individually draw up a table showing three differences between mixtures and compounds.

In the above example, learners were led through a process of reasoning that provided a bridge from practical experience to theoretical understanding of a phenomenon and demonstrated to learners the empirical basis of science knowledge. This contrasts with the same practical activity in Lesson G1 shown below.

*Lesson G1: making compounds*

In lesson G1 on compounds, there were five practical activities and demonstrations involving iron filings and sulphur powder (see lesson summary and summary of practical activities). In the fifth activity, groups of learners heated a mixture of sulphur powder and iron filings in a test tube:

Teacher G: Let's heat ... okay ... let's heat ... let's heat the mixture ... let's heat the mixture now ... of iron filings and sulphur powder.

(learners heat the mixture while the teacher supervises)

Teacher G: Let us observe what is going to happen.

Teacher G then elicited observations:

Teacher G: What do you observe? What do you see? Hm? (nominates learner) What do you see?

Learner: (indistinct)

Teacher G: Heh! A grey colour! So this ... the colour of the mixture of iron filings and sulphur changed to?

Teacher G & Learners: Grey!

Teacher G: It changed to grey. Other observations? (to next group) Other observations? Yes (nominates learner)? (chuckles)

Learner: There was a bright fire.

Teacher G: There was a ... there was a ... bright, a bright ... a bright ... Colour of the ... of the flame?

Same Learner: Blue.

Teacher G: A bright blue flame! There was a bright blue flame! (to another group) What did you observe?

Learner: (indistinct)

Teacher G: Yes, the flame ... okay. So, which means we have a mixture of iron plus ... plus (writing on chalkboard)

### **Iron filings + sulphur**

Teacher G: ... Okay so the colour changed to grey, okay?

Learners: Yees.

Teacher G: Okay. Let's put the remains ... let's put the remains on a test tube. All the contents ... put it ... stuff it with a hard ... a hard object to the test tube ... okay. (learners scrape contents of burning spoon into test tube) (checks groups) ... All the contents ... Okay. It means a new ... a new substance is ... is formed. A new substance now is formed. So (writes on chalkboard) iron plus sulphur give us ... iron ... the new substance that is formed is iron sulphide.

### **Iron + sulphur => iron sulphide**

At the end of the lesson Teacher G told the class the names of the different products formed in the five different experiments and wrote them up as word equations on the chalkboard. She stated that these were compounds and used the last example of iron sulphide to introduce the terms 'reactants' and 'product', but in a procedural manner: 'on the left side of your arrow we get reactants':

Teacher G: Okay, now lets look on our products now ... lets look on our products now. .... Okay. Let's say sulphur (writing on chalkboard) sulphur plus iron ... so we get iron ... iron sulphide.

### **Sulphur + iron => iron sulphide**

**reactants                  product**

Teacher G: So this is .. this is the left hand side of our arrow and this is the right hand side of ... of this arrow. On the left hand side of the arrow we get reactants ... In this case sulphur and iron filings are ...?

Teacher G & Learners: reactants

Teacher G: They are called?

Teacher G & Learners: reactants

Teacher G: And on the right hand side of the ... of the arrow we get a product. In this case iron sulphide is a ...? Is a ...?

Teacher G & Learners: product

Teacher G: It is a ...?

Teacher and & Learners: product.

In the above extract, Teacher G elicited learners' observations of the experiment and then told them the name of the product (iron sulphide); and at the end of the lesson, used this example of a compound to introduce the scientific terms 'reactants' and 'product'. However there was no real explanation of what a compound was beyond stating that it was a product; and there was no linking to any conceptual framework as there was in the case of Lesson B2. So although learners were busily engaged in practical activities with chemicals and test tubes, there was no bridging discourse to link the empirical observations to a theoretical understanding: instead learners were left with fragmented bits of knowledge about particular experiments. This was also the case with the rest of the practical activities in Classes A, F, G and H, where bridging between practical activities and theoretical frameworks was absent.

#### *Oral to written science knowledge – across the mode continuum.*

Instances were counted where learners were required to transfer oral understanding of science concepts into a written form i.e. where learners had to generate their own written texts; and where the teacher provided support to learners, to scaffold the bridge from oral to written understanding across the mode continuum. So instances where learners were required to copy notes were not counted; nor were instances when they wrote down points drawn from their own general knowledge, without this being linked to science concepts; nor were instances where learners wrote class tests which required them simply to recall isolated facts.

There were relatively few instances in the observed lessons where learners were required to generate written texts, based on the science knowledge that had been developed orally in class. All seven of these writing activities took place in Class B when at the end of a lesson, Teacher B routinely required learners to individually produce a written text that related directly to the key ideas generated orally in the lesson. In addition Teacher B closely monitored the writing activity, providing guidance and scaffolding. The activities are listed below and thereafter there is an example of the classroom talk that provided the bridging from the oral to written mode.

#### Lesson B1: mixtures

- Learners were required to tabulate their observations of the properties of iron filings and sulphur powder before making a mixture of the two substances; and in the next lesson, heated the two substances to make a compound. These practical activities were designed to illustrate the difference between mixtures and compounds. Teacher B reminded learners all the way through the lesson to write down their findings – leading to some banter from the learners on the matter.
- At the end of Lesson B1, learners had to discuss a definition for a mixture in groups and then write it down.

#### Lesson B2: compounds

- At the end of Lesson B2 on compounds, learners had to tabulate three differences between mixtures and compounds. This was rehearsed orally in class.

#### Lesson B3: separating mixtures: soil and water

- At the end of Lesson B3, learners were required to draw and label the filtration apparatus and describe the experiment. This was carefully scaffolded, with Teacher B

alerting learners to pay attention, as they would be drawing the apparatus and writing down the method. He provided a set of guiding questions on the chalkboard.

Lesson B4: separating mixtures: salt and water

- At the end of Lesson B4, learners were required to write up the experiment. Teacher B provided a writing frame on the chalkboard and elicited the key point orally, before learners completed the task individually in class.

Lesson B5: separating mixtures: oil and water; alcohol and water; summing up of separation methods covered over three lessons.

- After explaining how to separate the two mixtures by illustrating the processes on the chalkboard (due to lack of equipment), Teacher B elicited a mind map on the chalkboard of the different methods of separation that had been covered over the three lessons, and learners wrote down their own mind maps in their notebooks.
- At the end of the lesson, learners completed a summative exercise from their textbook, on separating mixtures. Teacher B went through the first two examples orally and then learners worked individually.

An example from Lesson B1 is given below:

*Lesson B1: Mixtures*

Learners were given the practical task of testing the properties of sulphur powder and iron filings separately and in a mixture. They had to write down their findings in a table, which they had copied off the chalkboard (see below). They worked in groups and Teacher B moved from group to group checking and prompting:

T: Now you should have a paper where you are going to fill in this table, okay? Copy this table (writes on the board – this is filled in during the reporting back question and answer)

	<b>Appearance</b>	<b>Magnetic or not</b>
<b>Iron filings</b>		
<b>Sulphur</b>		
<b>Iron sulphide</b>		
<b>Mixture of sulphur and iron</b>		

While learners were completing this task, Teacher B reminded them several times to write down their answers:

Teacher B: (to a learner in a group) Write it down now. You must not keep it in your head, you'll forget it. You should record every time you... you come to a conclusion. Record all the time.

Teacher B scaffolded the learners' group discussions with probing questions; learners had mixed the iron filings and sulphur powder and were testing the properties of the substances in the mixture and writing them down.

Teacher B: (to one group) What happens? Can you see what happens?. What happens? Which one is attracted? Are they both attracted? Are both of them are attracted or none of them are attracted?

Learner: One is pulled.

Teacher B: Write that down. If only one (substance) gets pulled is it (the mixture) magnetic or non-magnetic?

Teacher B: (moves to another group) What happens?

Learners: Iron filings get pulled.

Teacher B: Get pulled?

Learners: Iron filings get pulled.

Teacher B: So, your mixture now, is it magnetic or non-magnetic? Mhmm?

Learners in group: Magnetic//non-magnetic.

Teacher B: I do not know. That is what you should decide and give us the answer. What's happened? Mhm?

After the learners had completed the practical activity, Teacher B led them orally through reasoning, to the generalized definition of a mixture, which was then written up on the chalkboard.

Teacher B: Mixture. You should look at the properties of those things, okay? When you have those two substances... let's all listen ... When you have those two substances, iron filings and sulphur, okay?

Learners: Yees

Teacher B: Then we put them together... what happens to the properties, mhmm? Do the properties change or remain the same?

Learners: Remain the same.

Teacher B: They what?

Learners: Remain the same

Teacher B: Good! They remain the same, heh?

Learners: Yees.

Teacher B: So, that's how we should ehh ... define our mixture. A mixture is a substance where you have mixed or you have combined two substances, okay?

Learners: Yees

Teacher B: And the property keys of those two substances remained what?

Teacher B & Learners: The same.

T: Is it clear?

Learners: Yees

Teacher B: (Writes on the board) So, a mixture is eh... where properties... where properties of two substances ... remain the same.

**Mixture – where properties of two substances remain the same**

(Lesson B1, episode 2)

Lesson B1 concluded with Teacher B eliciting other examples of mixtures and the generalisation that the properties of the substances in a mixture remained the same. Throughout the lesson, Teacher B elicited key facts orally which learners then wrote down; and these facts were then linked to the key generalisation, which was written up on the chalkboard and then formed the basis for the next lesson on compounds.

An example of a writing activity in another class, where the bridge across the mode continuum from oral to written science knowledge was not completed, is described below:

### *Lesson G1: Compounds*

In Lesson G1 learners carried out five different practical activities, all concerned with making compounds (see Lesson summaries in Appendix 4). After the practical activities were completed, Teacher G summed up the experiments and the compounds that were produced; and then gave the learners a short written test based on the lesson (written on chalkboard).

#### **NS Assignment**

- 1. What is the difference in smell between hydrogen and hydrogen sulphide?**
- 2. What is observed when a burning match is held at the mouth of a test tube containing hydrogen?**
- 3. Write down the equation for the reaction taking place when**
  - a) dilute hydrochloric acid is added to iron filings**
  - b) dilute hydrochloric acid is added to iron sulphide**

(Lesson G1, episode 20)

However, in the test, the questions were about particular details from the lesson, not the main ideas and there was no reference to a generalisation or conceptual framework – reinforcing the

fragmented nature of the science content in the lesson. Teacher G had given learners the information incidentally and there was no scaffolding of ideas before writing. Accordingly, this was not coded as an instance of oral-written bridging across the mode continuum.

So, the key points that emerged from the analysis of bridging discourses were that there were relatively few instances of bridging discourse (between four and eleven) in the lessons of six of the teachers; there were twenty instances in Teacher A's lessons; and markedly more instances in Teacher B's lessons: 76. The most common form of bridging discourse was from everyday to scientific terms, with at least one such example for each teacher. The next most common form of bridging was everyday knowledge to science knowledge, with examples of this in six out of the eight classes (all except Classes G and H). However of the 35 links between empirical and theoretical knowledge, only one was made by Teacher C and the rest by Teacher B; and all the examples of bridging from oral to written language occurred in Teacher B's class.

The strong bridging discourses, from practical activities to theoretical understandings in Teacher B's lessons, contributed to the strong lesson coherence that was identified in his lessons in the analysis of the science content. Conversely, the almost complete absence of practical –theoretical bridging in the lessons of the other seven teachers, contributed to the relatively low levels of coherence of the science content in their lessons.

The low levels of bridging of science content from oral to written mode in seven of the eight lessons, along with the general low levels of reading of science texts, would together have limited opportunities to develop science literacy.

## Summary of key findings in relation to classroom discourse and the opportunity to learn science in the observed classrooms

To return to the research question: What was the nature of the classroom discourse through which the science content was developed and made accessible to the learners? Did the classroom discourse construct or constrain opportunities to learn science?

### *Teacher-learner talk*

The data showed that the balance of teacher-learner talk in the observed lessons was very much in line with findings in other studies (for example The National Oracy Project in the UK [Norman, 1992]; TIMSS video study [Roth et al., 2006]), namely that lessons were dominated by teacher-talk; in this study teacher-talk accounted for between 80,5% and 98,5% of classroom discourse.

Some probing of the data revealed that more teacher talk did not necessarily mean more science content – for example Teacher A and Teacher H presented almost the same number of ideas over the five lessons but Teacher A used about four times the number of words as Teacher H overall. In the comparison of the teaching of the same lesson content in Lessons A2, B3 and G2, there was likewise a wide range in the numbers of words spoken, to teach the same content: Teacher B taught the content in half the number of words to that of Teacher A; and Teacher G used one tenth of the number of words compared to Teacher A. There does not appear to be anything like an optimum relationship between words and ideas; but Breen (1998, in Walsh 2006) has suggested that a combination of extreme wordiness and lack of focus might result in learners ‘getting lost in the discourse.’ On the other hand, Donovan and Bransford (2005) suggest that concepts need to be supported by ‘multiple representations that are rich in factual detail’ and likewise, that factual detail needs to be ‘placed into a conceptual framework to be

well understood' (p. 6). It seem that something like a sharp focus plus sufficient detail might comprise an appropriate balance.

What the data also revealed is that there did not appear to be a simple inverse relationship between the amount of teacher talk and learner talk. So while Teacher A spoke the most in lessons (91 words per minute) and the learners in his class spoke the least (1,4 words per minute); Teacher B spoke the second most (77 words per minute) but the learners in his class also spoke more (4,8 words per minute) than learners in six of the other classes; and only second to Class E where lessons consisted almost entirely of learners reporting back on group discussion or poster presentation. So it seems that there needs to be a relatively high level of teacher talk to sustain learner talk.

#### *Discourse patterns: building coherence*

Given the claims in the literature about the importance of engaging learners in 'learning discourse', or dialogic exchanges, (Alexander, 2006; Gibbons, 2006; Mercer & Littleton, 2007; Mortimer & Scott, 2003; Wells, 1999) in constructing science knowledge, and in supporting the opportunity to learn science, this research set out in part to investigate to what extent this type of classroom discourse was evident in the observed lessons.

As suggested, classroom discourse patterns might simply reflect teachers' own understanding of the science content and the nature of science knowledge: for a teacher to be contingently responsive to learners' contributions, she or he needs to have a broad and flexible understanding of the science content and the confidence to invite and build on learners' responses. So for a teacher to engage in dialogic or learning discourses requires sound science content knowledge, including an awareness of the nature of science knowledge: the empirical underpinning, broad organizing principles and hierarchical structure.

It appeared from the data that there was little evidence of dialogic exchanges in the classroom discourse of seven of the eight teachers: in the case of six of the eight teachers, the science content was presented to learners predominantly by means of teacher instructional monologue, with some information elicited from learners or reinforced through IRE sequences, and to a lesser extent oral cloze sequences – except in the case of Teacher G who used more oral cloze than IRE sequences. In the case of Teacher E, lesson content came principally from learners reporting, with some IRE sequences that were mainly directed at eliciting marks from the class for the groups who had reported.

By contrast, in Teacher B's lessons, the analysis showed that the science content was constructed mainly through dialogic exchanges (47% of classroom discourse), with some IRE exchanges for reviews or consolidation, or to elicit observations; and occasional use of oral cloze to emphasise a point or a new word. These dialogic exchanges served to both maintain learners' engagement and induct them into the pattern-based reasoning that formed the basis for the cumulation and organization of the science content into clear conceptual frameworks. Teacher B's feedback in these dialogic exchanges was closely tied to the responses of learners, with what Wells (1999) describes as 'contingent responsiveness', thus building learners' contributions into the construction of science knowledge in ways that could be described as scaffolding or mediation within the learners' zone of proximal development (Gibbons, 2006; Wells, 1999).

It appears that this dialogic discourse is necessary for the *vertical* cumulation and patterning of the science content over the lesson/s -through reasoning and links to generalizable principles - into conceptual frameworks. This would account for the greater degree of coherence in the science content in Teacher B's lessons – a necessary condition for the opportunity to learn science. The relative absence of this kind of classroom discourse in the practices of the seven other teachers - between 0% and 5% – would contribute to the relatively low levels of

coherence of the science content in their lessons and learners in these classes would at best be left with a collection of facts, but with little sense of how they connected or of the overall structure of the science content, which would constitute an obstacle to the opportunity to learn science.

### *Bridging discourses: from home to school*

The classroom discourse was also viewed from the perspective of the bridging discourses that teachers might employ to bridge the gap between the languages and ways of understanding the world that learners bring to school – the horizontal discourses of home; and the language and ways of knowing required by schooling – the vertical discourses of education or science in this particular study.

What the data showed was that in fact there was not much evidence of bridging discourses in the observed lessons for six out of the eight teachers: only between four and eleven instances over the five lessons for Teachers C, D, E, F, G and H. In Teacher A's class there was an increase to 20 instances but this too fell far short of Teacher B's lessons where there were 76 instances of bridging in the classroom discourse. The most common form of bridging discourse was that between everyday language and science language, with at least one example in each class. There was some evidence of bridging between everyday knowledge and science knowledge in the classroom discourse of six of the eight teachers; but little evidence of the other two aspects - only one instance of practical- theoretical bridging in Class C, as opposed to 34 instances in Class B; and no other examples of bridging across the oral-written modes, apart from those in Class B.

The markedly higher instances of bridging discourse in Teacher B's lessons appeared to indicate an awareness (either implicit or explicit) on his part of the learners' existing everyday knowledge and experience and the need to provide support in moving them across the home-

school gap and provide access to the more abstracted knowledge and language of school science.

Teacher B's pedagogy showed how the classroom discourse can operate to engage learners, to cooperatively, systematically and cumulatively *build* the science knowledge within and across lessons; and simultaneously to *bridge* the gap between everyday knowledge and language, and science knowledge and language; and between practical experience and theoretical understanding; and support learners in expressing that understanding orally and then in writing.

Such classroom discourse would support opportunities to learn science, but is dependent on the necessary condition of sound and broad science content knowledge by teachers.

An aspect of bridging discourses that has not been considered in this chapter is that of bridging the gap between the learners' home language and the language of reading, writing and assessment: English. This is an area of writing and research that has developed its own field in the literature: that of bilingual education. It is a politically contested issue, in South Africa as well as in other bi- and multilingual contexts and continues to provoke debate within educational circles, amongst policy makers and the public in general. For these reasons it has been accorded a separate chapter.

As noted previously in this chapter and in the description of the analysis criteria in Chapter 3, the bilingual alternations in the lesson transcripts in this chapter were removed, with only the English translations retained, so as to focus attention on the classroom discourse patterns, and to reduce the length of the lesson excerpts provided. This was intended to make it easier to follow the development of science content through the discourse. In the following chapter the focus is on the bilingual alternations in lessons and so the English/isiXhosa alternations, where they occurred are provided in full, along with the English translations. The analysis shows how

these two aspects of classroom language can work together to support opportunities to learn science.

## CHAPTER SEVEN: BILINGUAL CLASSROOM PRACTICES

An aspect of bridging discourses that was not considered in the previous section was that between isiXhosa, the learners' home and community language, and English, the language of schooling. The TIMSS South Africa reports (Howie, 2001; Reddy, 2006) suggested that the language medium of the tests was an intervening factor that might have contributed to the poor performance of learners who were learning through the medium of a second language. As this is a hotly debated issue both in South Africa and other multilingual contexts, it warranted a more detailed analysis.

The research was conducted in schools where the home language of both teachers and learners was isiXhosa and the 'official' language of learning and teaching (LoLT) in Grade 8 was English. As described in Chapter One, this is the most common linguistic context in the Eastern Cape, with isiXhosa being the home language of 87% of learners (Kane-Berman & Holborn, 2012); and this is the case in many rural areas in South Africa, where a local African language predominates but learners have switched to English as LoLT by Grade 8.

In such linguistic scenarios, the language proficiency of learners in English frequently does not match the demands of the curriculum (see for example Macdonald, 1990a. & b.; Fleisch, 2008). I was interested to see how reputable teachers dealt with these challenges and what strategies they employed to overcome the language proficiency gap and support learners' opportunities to learn science. The details of the arguments for and against English or home language LoLT have been discussed in the sections on the research context and conceptual framework so they are not revisited here; suffice it to say at this point that it is a matter that has provoked fierce debates for several decades, but remains unresolved – in terms of policy and teacher education; and for teachers in classrooms.

The analysis of the teachers' and learners' use of both English and isiXhosa was based on *word counts* to determine the relative frequency of use of these two languages; and an analysis of the broad *functions* of teachers' bilingual practices, where these occurred. This analysis has provided a basis for a consideration of the *pedagogical value* of such practices and whether or not they constructed or constrained the opportunity to learn science in the observed lessons. (\*Note that in the illustrative excerpts, the isiXhosa words are in italics and the English translation follows in square brackets.)

## Contexts

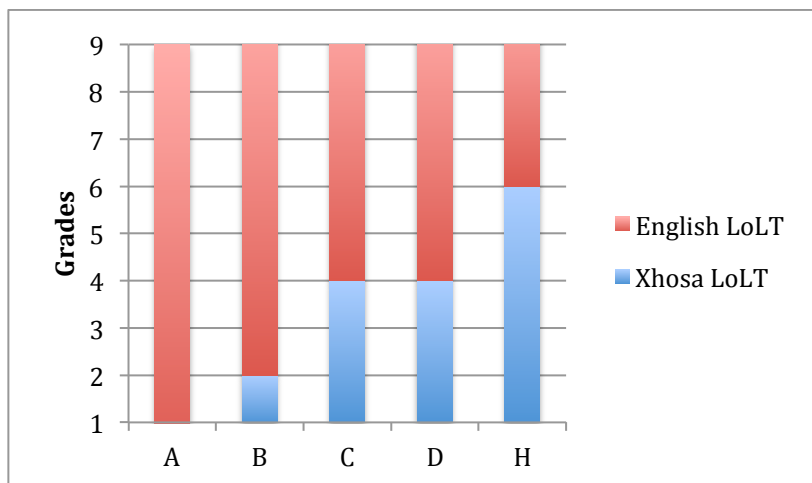
Both teachers' and learners' language practices in the classroom are nested within broader social-political-economic ecologies and are influenced by these contexts (explored in the theoretical framework) as well as by the particular school policies, practices and attitudes towards language use in the classroom; and the individual beliefs and attitudes of the teachers and learners themselves. In order to investigate the particular contexts of the classrooms in this research, the teachers were interviewed after the observation period, about the linguistic context and language policies of their schools, and their own beliefs and practices.

## Language policies and practices

As is often the case in situations where the language of reading, writing and assessment is an additional language (usually English, in South Africa), teachers and learners very often utilize their home language as well as the official language of learning and teaching, in oral classroom interactions. The extent to which they do this may depend on the language proficiency of the learners, the teacher's own language proficiency, school policy and the teacher's beliefs on the matter. Schools might also differ in terms of whether they have any kind of explicit language policy, including the extent to which there are explicit expectations as to teachers' and learners' oral language use in the classroom. The interviews and classroom data revealed considerable

differences between schools and some contradictions between aspirations, expectations and practice.

None of the eight schools in the study had formally adopted language policies as required by the Language-in-Education Policy (LiEP) of 1997 (Department of Education, RSA, 1997). The five rural schools were all junior secondary schools, with classes from Grade 1 to 9, and some with recent additions of Grade R (reception) classes. Their informal language policies varied in terms of the grade at which English was introduced as the language of learning and teaching (LoLT). These are illustrated in Figure 7.1.



**Figure 7.1. Languages of learning and teaching in rural schools in the study**

According to Teacher A and Teacher B, who were also principals of their schools, it was the parents who wanted the LoLT to be English from Grade 1 in School A, and from Grade 2 in School B – although both principals noted that this proved to be unworkable in practice and so teachers were obliged to communicate with learners in their home language, isiXhosa. In Schools C and D, the official change to English LoLT happened at the beginning of the Intermediate Phase, in Grade 4; and in School H this switch occurred at the beginning of Grade 6.

In the three township secondary schools, the LoLT was English from Grades 8 to 12, but as learners would have been drawn from a wide range of feeder schools, there was no way to establish for how long the Grade 8 learners had been learning through the medium of English.

Nevertheless, in all eight schools, in Grade 8, textbooks and other written materials were in English, learners were expected to write notes and tasks in English and assessment was in English; so English was the language of reading, writing and assessment. Outside the classroom, all of the teachers reported that isiXhosa was the lingua franca in interactions amongst learners and between teachers and learners.

All of the teachers also reported that learners were not proficient enough in English in Grade 8 to cope with learning solely through the medium of English and so they and the other teachers in their schools tended to switch to isiXhosa at times to explain an idea when they realized that learners had not fully understood their English explanations and to speed up the learning process:

Teacher C: Mm. I'm sure most of us, in fact all of us usually switch to Xhosa because these people are from rural areas and they are used to the mother tongue so you will find if you are talking English the whole period then they will not understand.

However it seemed there was considerable variation in the expectations of schools and teachers in relation to what constituted acceptable oral bilingual practices in the classroom. At the one end of the scale, Teacher H claimed that the expectation was that in Grade 8, teachers and learners should stick to English and that they all did with only occasional reference to isiXhosa - this was reflected in her classroom practice. Teacher E reported that the school expectation was that 80-90% of oral interactions in the classroom should be in English; but that many teachers themselves had problems with English and so tended to teach in isiXhosa. However he had trained as an English teacher and so did not have such problems and adhered to the '90% English' rule.

Teacher D reported that the expectation by the principal and senior teachers was that only English should be used in the classroom; but that she and the younger teachers did not stick to this and switched to isiXhosa, when they were alone with the learners and they felt it was necessary (see quotation by Teacher D in relation to reactivity later in this chapter).

In the remaining schools (A, B, C, F, H) it appeared that there were no explicitly stated expectations about oral language use and teachers alternated between languages when it suited them and the learners.

### **Word count of teachers' and learners' use of isiXhosa and English**

In the following section, the language use of teachers and learners was analysed according to *word count* and the *functions* of their language alternation practices, in order to draw some conclusions about the pedagogic value of these practices and how they might contribute to the opportunity to learn science in the observed classrooms.

### **Classroom languaging practices**

In order to quantify the languages used by the teachers and learners, I first did a word count of English and isiXhosa for public talk in each transcribed lesson. 'Public talk' is defined by Roth et al. (2006, p. 49) in the TIMSS video study, as talk by the teacher or learners where the intended audience is the whole class. This usually occurred in whole-class interactions but also when learners were engaged in group activities and the teacher spoke to the group loudly enough for the whole class to hear.

Summaries of the teachers' and learners' use of English and isiXhosa are shown in the charts in Figures 7.2. – 7.4.. In Figure 7.2. the teachers' and learners' language use has been scaled to percentages to allow for easier comparison between classes. In Figures 7.3. and 7.4. the teachers' and learners' language use have been separated to make the patterns of learner talk clearer, as the levels of learners' language use was so much less than that of the teachers – note

that the values along the y-axis for the teachers in Figure 7.3. are about ten times that for the learners in figure 7.4..

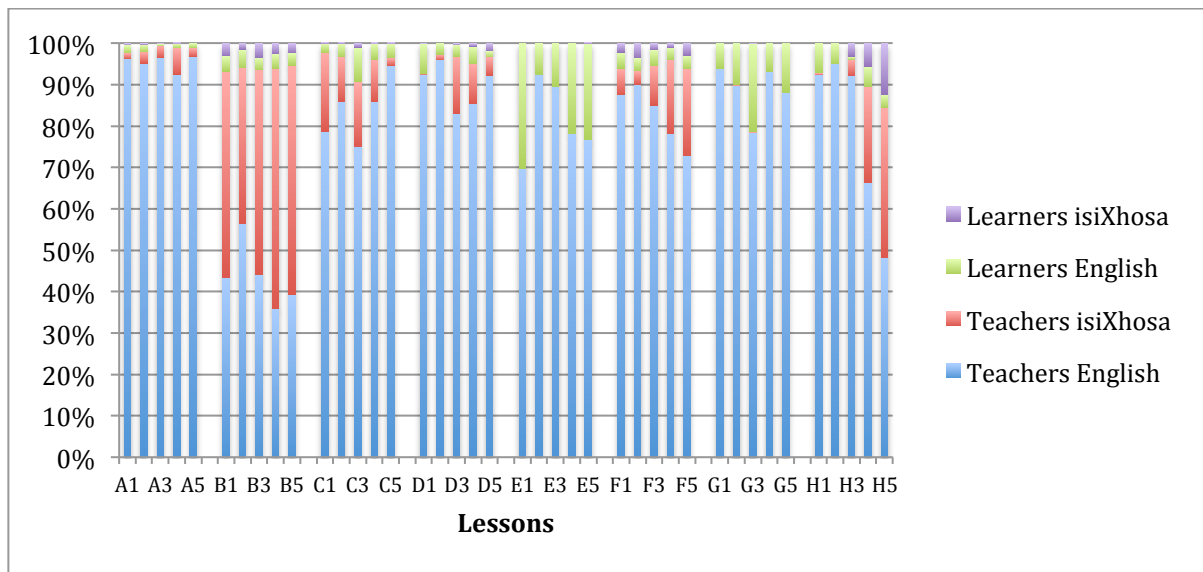


Figure 7.2. Teachers' and learners' use of isiXhosa and English per lesson

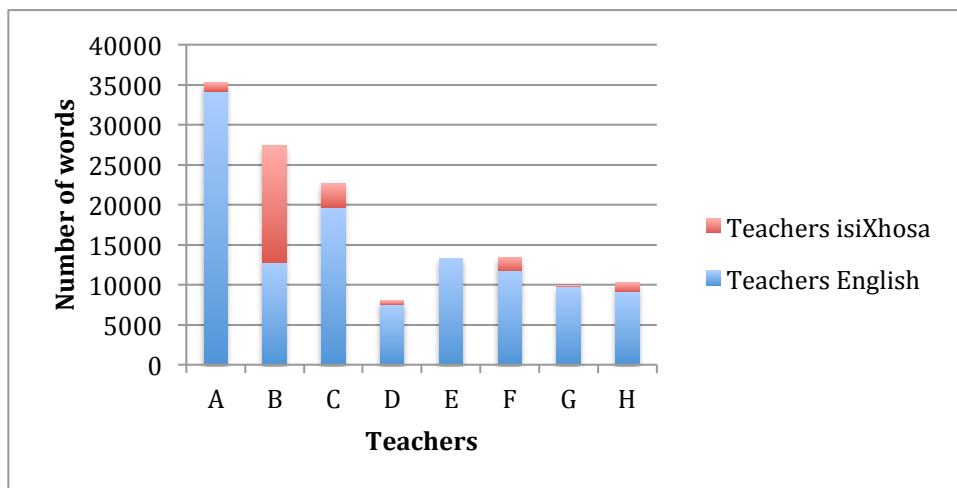
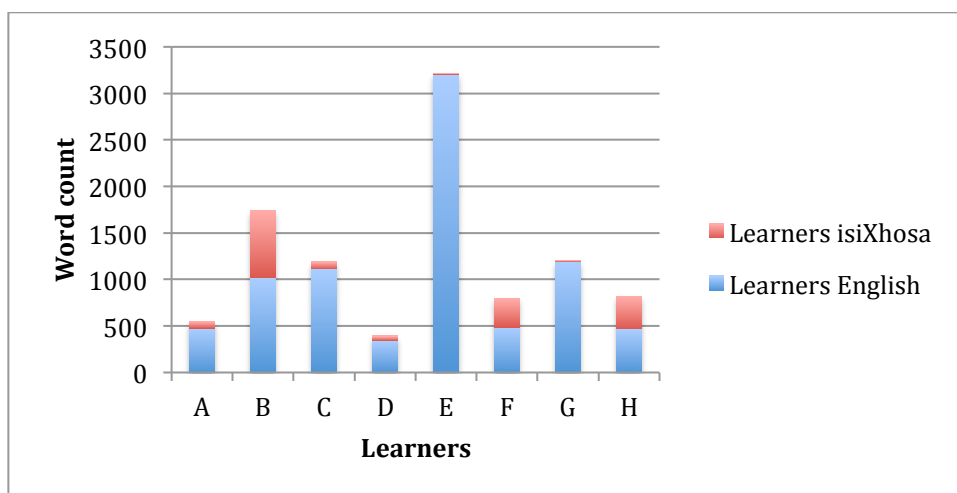


Figure 7.3. Teachers' use of isiXhosa and English by word count



**Figure 7.4. Learners' use of isiXhosa and English**

As the charts in Figures 7.2. and 7.3. show, there was a wide range in terms of the teachers' use of English and isiXhosa: Teacher B used more isiXhosa than English (53% isiXhosa and 47% English), whereas the other teachers used far more English than isiXhosa, ranging from 87% English (Teachers C and F) to 100% English (Teachers E and G) (Teacher G did in fact use a few isiXhosa words, but so few that they amounted to less than 1%).

Similarly there was a wide range of learners' language use (see Figure 7.4.): learners in Classes B, F and H used almost the same balance of languages: 42%, 39% and 43% isiXhosa respectively; while learners in Classes A used 13% isiXhosa; learners in Class D – 11%; learners in Class C – 6%; and learners in Classes E and G used no isiXhosa.

What is surprising, considering the anecdotal reporting of widespread use of isiXhosa in classrooms, and similar claims made by the teachers in the interviews, is that in fact there was so *little use* made of isiXhosa by teachers and learners in seven out of the eight classes.

#### **Classroom language use and possible reactivity**

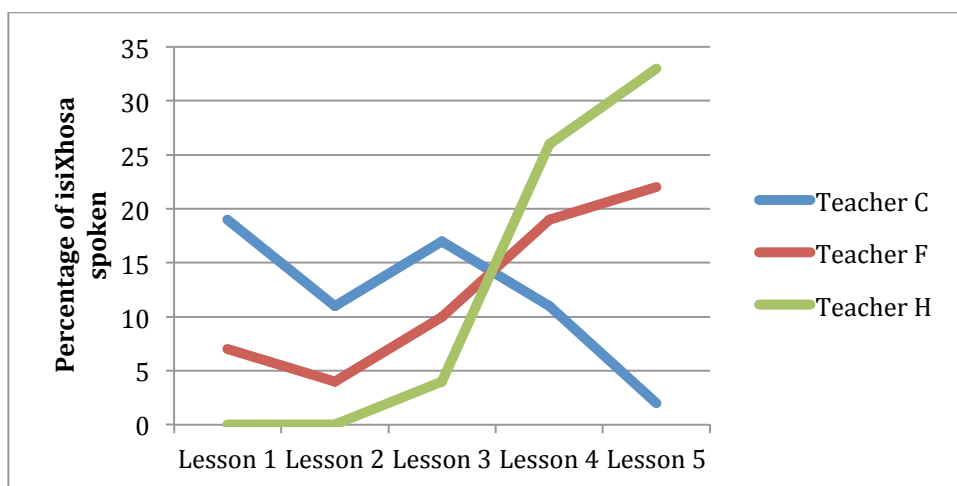
The relatively low levels of isiXhosa use by seven of the eight teachers raises questions about the data and whether it in fact reflects teachers' natural practices or whether teachers had in fact reacted to being observed by changing their usual language practices. Arguments around

reactivity have been made to the effect that teachers' pedagogical practices are so firmly set that they are relatively unaffected by the presence of a researcher in the classroom (for example, Alexander, 2001, p. 277; Stigler, Gonzales, Kawanaka, Knoll & Serrano, 1999, p. 7). However, it may be that as far as their bilingual language practices are concerned, teachers are used to alternating languages quite flexibly in response to different contexts both inside and outside classrooms – i.e. languaging practices are not as set as other pedagogical practices; and given the conflicts and tensions surrounding the language of learning and teaching, that have been discussed, this might well result in teachers changing their practices when being observed.

This was illustrated when teachers were asked in the interviews about their reactions to being observed and having their lessons video-taped: most claimed they had not changed their practices, although some had felt a little self-conscious to start with. However, Teacher D very candidly related that when she had been training as a teacher she was expected to stick to English which she and other student teachers did while being observed for assessment, but that she codeswitched freely once she was not being observed:

Teacher D: You are not allowed to switch to Xhosa at any stage at college. So it is only when you are teaching and you know, 'I am alone, there is no lecturer here, let me switch to Xhosa so that my kids can understand what I'm talking about' (laughs).

What was also notable was that in the case of three of the teachers (C, F and H), there was a marked *shift in language use across lessons*. (Teacher D has been excluded as her use of isiXhosa was relatively low – only 6% overall, although there was also a shift in usage across her lessons.) These shifts in language use are illustrated in Figure 7.5. (see also Figure 7.2.).



**Figure 7.5. Shifts in isiXhosa use over five lessons by Teachers C, F and H**

In the case of Teacher F and Teacher H there were quite sharp increases in isiXhosa use: from 7% to 22% for Teacher F; and even more dramatically from 0% to 33% for Teacher H. In the case of Teacher C the reverse trend was observed: a drop from 19% to 2% isiXhosa use over the five lessons.

It seemed that these shifts were a result of some reactivity: in the case of Teacher C, I was obliged to conduct the interview with her after the fourth lesson, as on the fifth day she and about a third of the class was going to attend an inter-school choir competition; in fact there was no tuition for the rest of the school that day except for the science lesson which she taught especially for my benefit – in return for which I transported her and the learners to the competition in the nearest small town. The logistics and costs of returning to the district the following week seemed to justify this compromise. My fieldnotes for the day read as follows:

I was dubious about doing it [the interview] before completing the lesson observation and videoing as I thought it might influence the teachers' behaviour; on the other hand I reasoned that teachers' behaviour is very resistant to change so probably the interview wouldn't influence her behaviour much – and in any event, I had already made explicit my interest in language. However, it seemed that talking about her implicit language practices especially in terms of codeswitching, did influence her behaviour on day 5 – I noticed that she used much less Xhosa and she confirmed this in informal discussion in the bakkie (colloquialism: small truck) on the way to the music concert.

However the other two teachers (F and H) were interviewed after the end of the observation periods and so the discussions would not have affected their language use. Both said that they had tried to stick to English more than usual to accommodate me, the researcher, on the assumption that I would not understand isiXhosa; and that learners did not think they should speak isiXhosa when being observed.

During the observed lessons, both Teachers F and H signaled to learners that they should use isiXhosa if they wanted to: Teacher F told learners in the first lesson that they should use their home language if they had difficulty with English:

Teacher F: 'But then...*wena* [yourself] you don't have to *ukuzisokolisa, ne* [make it difficult for yourself, okay]? *Thetha ngoluhlobo ufuna ukuthetha ngalo, yaqonda*; of course *ungazama* but *xa ubhideka uthethe ngesintu uyayiqonda* [speak in whatever manner you want, you see; of course you can try but when it is difficult speak your language, understand]?'

(Lesson F1 episode 1)

Likewise, Teacher H gave learners permission to use isiXhosa – but only in Lesson H5:

Teacher H: You can answer in any language, you don't need to answer in English. You can even answer in Xhosa. Or in Afrikaans if you feel like it. Or Sotho, Zulu..

Ls: (Laughing)

Teacher H: The languages that you are comfortable of...

(Lesson H5, episode 5)

From this point on in Lesson H5, the balance of language use shifted abruptly from 8% to 58% isiXhosa by Teacher H; and from 29% to 91% isiXhosa by the learners. Teacher H claimed in the interview this was because it was a new section of work but there was little in the lesson to suggest this was new work; and in fact the sudden switch in language practices occurred halfway through the lesson.

These examples seem to indicate that isiXhosa use in classes C, F and H was marked, as learners needed to be told to use isiXhosa in classes F and H; and in class C, the teacher changed her practice once she felt self-conscious about the language focus of the observation.

So it seems that the bilingual practices by teachers and learners was fairly fluid, fluctuating according to the classroom circumstances – in this case observation by an outsider. Notwithstanding the very real possibility of reactivity, it can be assumed that teachers were at least presenting their *best practice*, which would include their perceived best practice in terms of language use.

The question is of course: *what effect might the bilingual language practices of teachers have on the learners' opportunities to learn science?* Word counts alone do not help to answer this question, and so one needs to have a closer look at the ways in which different teachers and learners utilized the linguistic resources available to them. What follows therefore is an analysis of the *functions* of the teachers' switches to isiXhosa when these occurred; and a consideration of whether these appeared to improve learners' opportunities to learn science.

#### **Analysis of the pedagogic functions of language alternation in the observed lessons**

The following analysis was done from a functional, pedagogic perspective rather than structural, linguistic one.

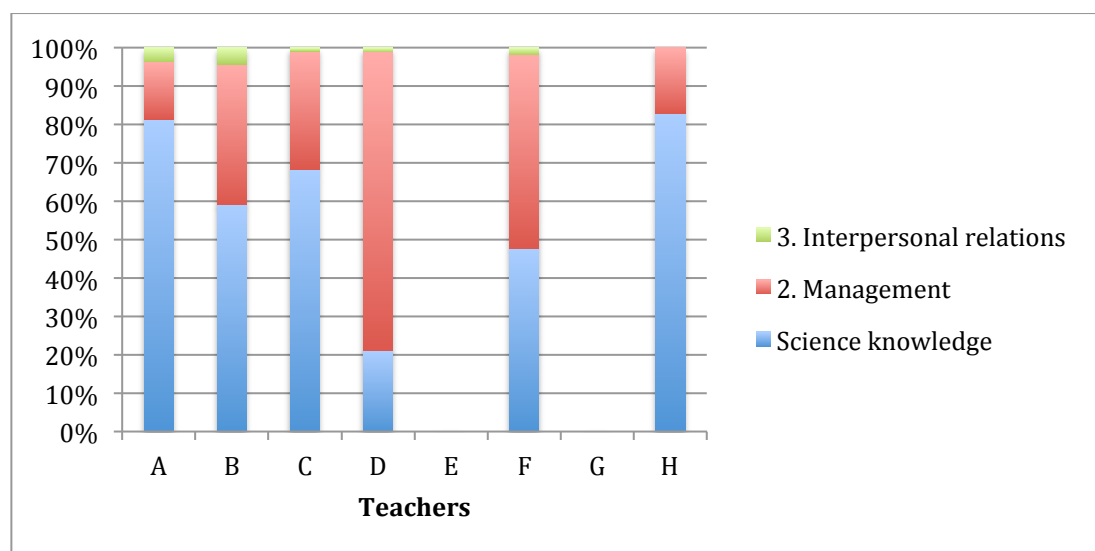
As described in Chapters 2 and 3, Ferguson (2003, pp. 39-43) suggested three broad pedagogic functions for classroom codeswitching (the term he used to cover all classroom language alternation):

- for constructing and transmitting knowledge
- for classroom management
- for interpersonal relations

Ferguson also made the point that instances of language alternation might serve more than one pedagogic function. His categories are elaborated below:

1. *Constructing and transmitting knowledge*: this would include science content knowledge as well as reference to learners' own experiences in support of understanding the science content.
2. *Classroom management*: this would include regulative discourse – instructions intended to organise learning; question tags and words such as 'ngoku' [now], and 'kaloku' [then] that were inserted into English discourse to focus learners' attention; discipline in the form of rebukes.
3. *Interpersonal relations*: 'to humanise the affective climate of the classroom' (Ferguson, 2003 p. 39). This would include banter not related to the lesson content and encouragement such as *Heke!* (good).

The lesson transcripts were coded for teachers' use of isiXhosa according to the functional categories described. The results are displayed in Figure 7.6..



**Figure 7.6. Functions of teachers' isiXhosa use (percentages)**

As the chart in Figure 7.6. shows, four of the six teachers who did switch to isiXhosa (A, B, C, H), did so mainly to construct and transmit knowledge; with the next most frequent function being

that of 'classroom management'. In Teacher D's and F's classes the main function of their isiXhosa use was for 'classroom management' (78% and 51% respectively). As the chart above shows, there was relatively little use made of isiXhosa for interpersonal relations: only five of the teachers did this at all, and for 4% or less of the isiXhosa used in their lessons.

However, if one considers whether the teachers' use of isiXhosa in the observed lessons appeared to improve the opportunity to learn science, then it is helpful to look at the functions of the teachers' isiXhosa use in relation to the total language use in the classrooms, as shown in the charts in Figures 7.7. and 7.8..

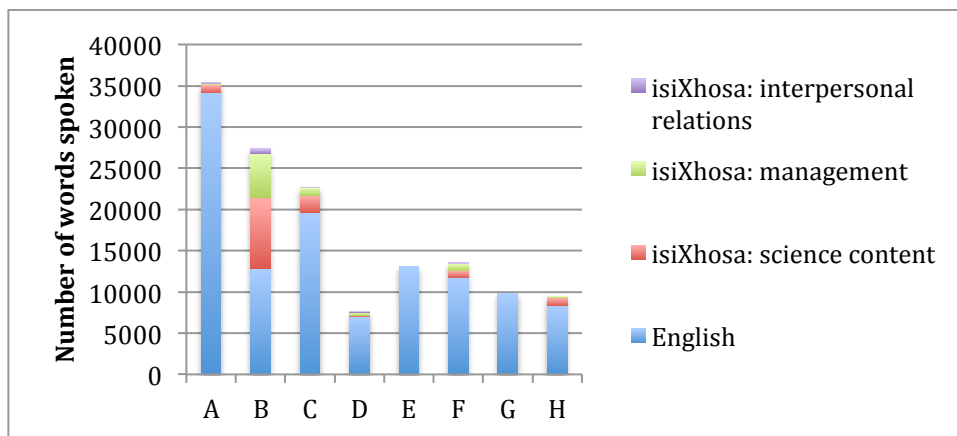


Figure 7.7. Functions of teachers' isiXhosa use in relation to total classroom talk

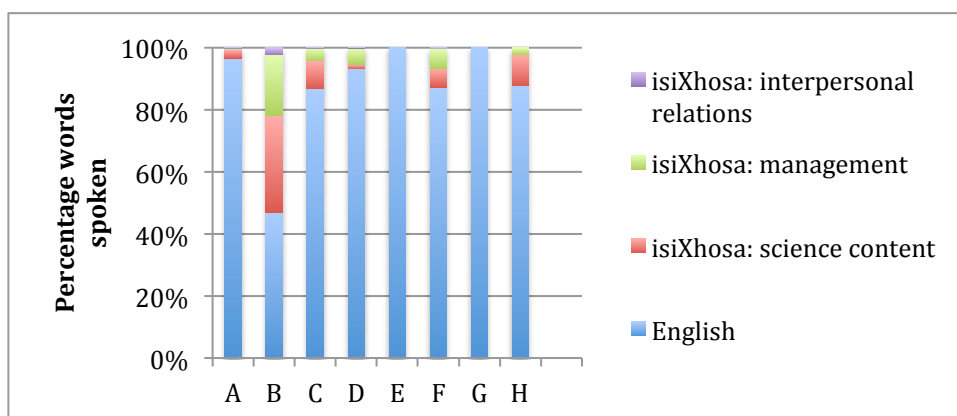


Figure 7.8. Functions of teachers' isiXhosa use in relation to total classroom talk as percentages

What is clear from the charts is *how very little use seven of the eight teachers made of isiXhosa in order to communicate the science content* of the lessons: this ranged between 0% and 10% of classroom talk for all the teachers apart from Teacher B, who used isiXhosa to communicate science content for 32% of classroom talk.

So despite the fact that all the teachers had said in the interviews that they and other teachers would use isiXhosa to explain science content if necessary, there was relatively little evidence of this overall, in the observed lessons of seven out of the eight teachers. As discussed, reactivity might well have contributed to the relatively low levels of isiXhosa use in most of the observed lessons; but this also indicates that seven of the eight teachers did not consider the learners' home language as a legitimate resource to improve learners' opportunity to learn science.

#### **Pedagogical value of classroom language alternations**

The teachers' language alternations need to be unpacked further in order to consider the pedagogical value thereof, and in what ways it might be considered to construct or constrain the opportunity to learn science. A brief return to the literature will help to frame these ideas and provide a guide as to what might constitute bilingual language practices that support the opportunity to learn science.

Literature on classroom codeswitching is based mainly in post-colonial settings, where the medium of instruction is a former colonial language which is not the home language of the learners. As described in Chapter Two, the codeswitching of teachers and learners in relation to lesson content, is generally to compensate for the learners' relatively poor proficiency in the medium of instruction, and as such has very often been regarded as a deficit strategy by the participants; and often practiced covertly. The research community on the other hand have pointed to the value of such strategies and have recommended that they be legitimated and

incorporated more formally into teachers' training and practice (see for example: Adendorff, 1996; Ferguson, 2009 p. 233; Probyn, Setati et al., 2002; Wei & Martin, 2009).

Nevertheless, it appears such strategies are largely unplanned and very often unconscious; and are mostly reactive – in response to the teachers' perception that learners had not understood part of the lesson content being delivered in English.

Constructivist ideas on language and learning in general suggest that face-to-face exploratory talk (Barnes, 1976, 1992) in groups would usually precede more context-reduced 'presentational talk'. Gibbons (2006) has described the teacher's role in mediating and scaffolding this process of moving from exploratory to presentational talk in whole class discussion, which is then a preparation for writing and thus scaffolding a move across the mode continuum.

Science lessons are typically structured in terms of a review of existing knowledge on a topic, introduction of new ideas – often through practical activities - discussion and making sense of the practical work in terms of linking it to science theory; and then writing and consolidation of the new ideas in some form; and so in science lessons the teacher's scaffolding of this process of moving from exploratory to presentational talk would occur in the whole class discussion following practical work in groups (Gibbons, 2006).

In a bilingual context, it would seem logical to develop learners' knowledge in their home language and then transfer this understanding to the second/additional language (L2), what Cummins has described as 'teaching for transfer' (Cummins, 2008), or as Cook (2001) has suggested, to 'build up the inter-linked L1 and L2 knowledge in students' minds.' Setati et al. (2002) referred to teachers and learners moving from 'informal, exploratory talk in the learners' main language(s) to discourse-specific talk and writing in English' (p. 72) and proposed that teachers might take various routes to complete this 'journey'.

This would suggest using the learners' home language for exploratory talk – both in group discussions by learners or teacher-led exploratory talk when making sense of practical work and developing new understandings; and then transferring this understanding to the additional language, first orally (see Clegg & Afitska, 2011) and later in writing.

This would amount to a strategic and systematic use of two languages – what could be described as *translanguaging* - rather than a more reactive codeswitching from the LoLT in response to signs of incomprehension on the part of learners – by which time critical gaps and misconceptions about the science content might well have developed.

What the research data indicated is that only one teacher (B) appeared to use isiXhosa to 'work on understanding' (Barnes, 2008) in a systematic way. The other teachers who made use of isiXhosa to communicate science content for between 3% and 10% of classroom talk (Teachers A, C, F, H) generally did so in the form of fairly brief codeswitching from the LoLT, and in the case of Teacher C, some more lengthy translations. Some examples of the different functions of codeswitching and translation from English to isiXhosa follow:

1. to translate an English word or term into isiXhosa

Teacher G: Outer layer. Outer layer. *Amaxolo* [the peel]. This is the outer layer of the fruit.

(Lesson H3. episode 2)

2. to repeat an explanation/concept in isiXhosa

Teacher C: The solid particles they are closely packed, they are not moving and they are in a low energy state. *Azinawo amandle, kaloku zixinene, andithi* [they don't have energy, because they are closely packed, right]?

(Lesson C1 episode 5)

3. to elaborate a concept

Teacher C: So it means the liquids takes the, the shape of the container, *siyavana?* [are we together?]

Learners: Yes

Teacher C: If *amanzi siyawagalela e jugini athath' i-shape yalo* [if we pour water into a jug they take the shape of that] jug. If *amanzi siyawagalela kula mbombozi athatha i- shape yalo mbombozi, andithi* [if we pour water into a big container, it takes the shape of that big container]? If *siyawagalela e dishini, atheni* [we pour it into a dish what happens]? *Athatha ishpa e yalo dish, siyavana* [it take the shape of that dish, do we understand each other]?

(Lesson C1, episode 3)

4. to repeat or rephrase a question

Teacher F: why do we have a light there? Why do we have a light in that bulb. After you have connected it in a battery? *Kutheni lento sithi sibone ilaythi* [why do we see a light]?

(Lesson F1, episode 1)

5. to alternate between English and isiXhosa in an explanation/exposition

Teacher F: That element *iyabubamba ubushushu apha kuyo* [holds on to heat]. Then after some time *nayo izaba* [it will become] more hot *ne* [okay]? Then the water that is inside the kettle *ne* [okay] will...like the water molecules. Like *ezizilapha* [the ones that are here] they get that heat *ne* [okay] and these water molecules *zizaba nantoni* [will have what]? They get energy because *zifumene-heat pha* [they got the heat there].

(Lesson F4, episode 2)

6. to refer to examples from learners' everyday experience

Teacher A: We call it residue. *Enye iresidue oyaziyo yileya uyisebenzisa kusasa xa unkingisha iti le ihlala esitreyineni yi-residue* [the other residue you know is when you make tea in the morning the one that you find in a strainer is residue].

(Lesson A2, episode 14)

7. to translate an extract from the English textbook into isiXhosa

Teacher C: U-Katleho wanted to make jelly for dinner, *ufuna ukuwenzwa i-jelly for i-dinner yakhe* [he wants to make jelly for his dinner]. *Wamisa amanzi* [he boiled some water], once *amanzi wabila, wawagalela kwi-jelly powder* [once the water had boiled, he poured it into the jelly powder]. *Ngeloxesha uyathini* [meanwhile, what is he doing]? *Uyazamisa, ne* [he is stirring, right]? (demonstrating stirring action)

Learners: Yes

Teacher C: He is stirring, then when the jelly powder has dissolved he added some cold water. *Wathi iyadissolva* [he saw that it had dissolved] *Wagalela ntoni* (what did he pour in)? *Amanzi awabandayo andithi* [water that is cold, isn't that so]? *Wogqiba lo mixture wayifaka phi* [after that, he took that mixture and put it, where]? *Efridgini* [in the fridge].

(Lesson C1, episode 4)

In interviews the teachers who tended to codeswitch and translate to mediate the science content (Teachers A, C, F and H), said that they knew that if they stuck to English for the whole lesson, some learners would not understand the content: 'Because you will be moving ahead alone if you don't do that (codeswitch)' (Teacher F).

These teachers also said that they would switch to isiXhosa in response to cues from the learners that they had not understood:

Teacher C: When I look at them I can see that some of them don't understand... I can see if they are uncomfortable, from their faces and I can see ... mmm ... they don't understand so I must repeat this in their mother tongue.'

Teacher A: You can see their gestures. Now they are about not to understand this ... Then once you see they get it then you switch again to English.

The forms of codeswitching and translation to support learners' understanding of the science content, as identified above, are very much in line with the literature on classroom codeswitching (see Chapter Two); and it seems likely that these forms of language alternation would have helped learners to understand more of the lesson content than if they had not codeswitched or translated at all.

It should be noted however, that in the literature there are some criticisms of direct translations, as it is claimed learners might simply tune out from the additional language in anticipation of hearing the content being repeated in their home language (Wong-Fillmore, 1985). And it seems that the alternation of languages in explanations, as observed in the lessons of teachers C, F and H, might well have had the effect of providing learners with a rather fragmented input.

In addition, given the relatively low levels of isiXhosa use for communicating science content; and the fact that these teachers appeared to wait for a cue from learners that they did not understand before switching to isiXhosa, it seems that learners might well still be left with misconceptions and gaps in their understanding of the science content that the relatively brief and unsystematic codeswitching would be unlikely to fully resolve.

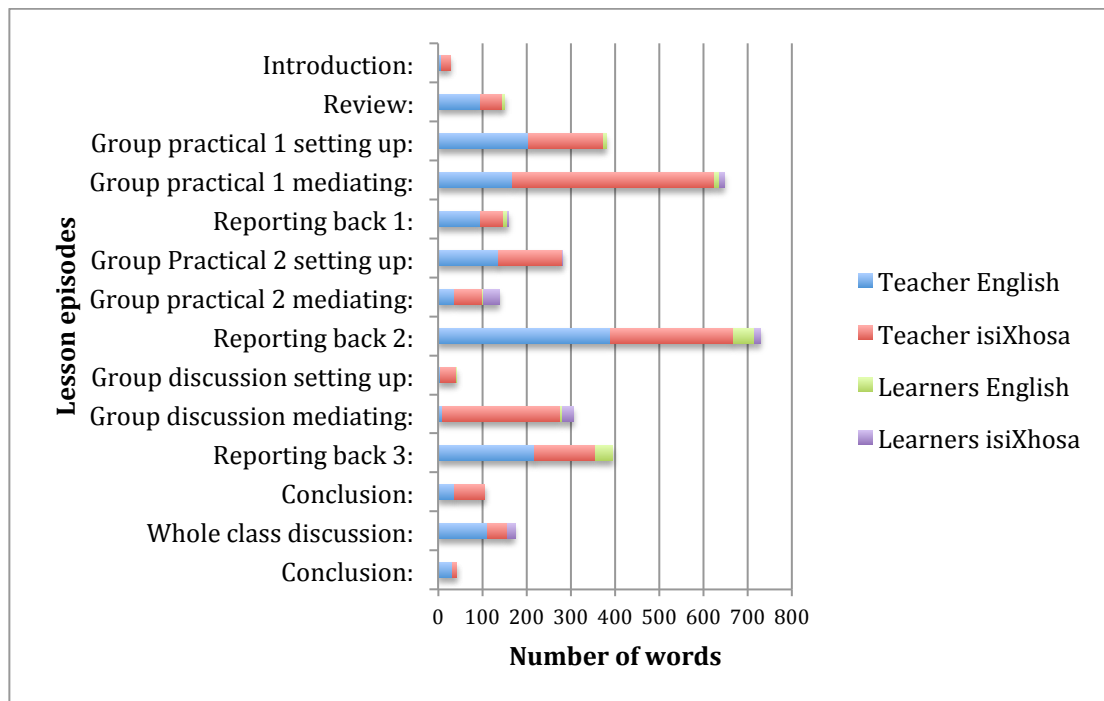
Teacher B on the other hand, used far more isiXhosa for communicating science content (32% of words spoken) than the other teachers; and he seemed to work with both languages in a more balanced and structured way – more in line with the notion of ‘translanguaging’ and the productive use of languages as suggested by Garcia (2009), Creese and Blackledge (2010), Canagarajah (2011) and Lewis et al. (2012a. and b.). When interviewed, Teacher B said that if he were teaching a new concept he would first do so in isiXhosa and then in English. A closer examination of the shifts in language use over the course of one lesson (B1) supported this.

In that particular lesson the teacher was establishing the principle that in a mixture, the properties of the component substances do not change. The lesson followed the following stages:

1. Firstly the teacher led a whole class question and answer to review the key ideas from the previous lesson.
2. Next groups were given 2 teaspoons each of sulphur and iron filings and had to fill in a table identifying the colour and magnetism of both substances.
3. Groups reported back.
4. Then the groups had to mix the sulphur and iron filings and observe and the colour and magnetism of the mixture and fill in the table.
5. Groups reported back.

6. The groups had to discuss and write a definition of a mixture.
7. Groups reported back.
8. The lesson conclusion was interrupted by the teacher asking the class a question – why was it necessary to wrap the magnet in paper before bringing it close to iron filings - and a brief discussion followed before the conclusion stage was resumed and ended.

So, the stages or episodes of the lesson included a whole class question and answer review; three group activities and report back sessions; whole class discussion and a conclusion. The shifts of language use across the lesson are illustrated in Figure 7.9. below. (The same lesson was used to illustrate the shifts in classroom discourse interaction patterns in Figure 6.5.)



**Figure 7.9. Translanguaging across the stages of a lesson (B1)**

As Figure 7.9. shows, the exploratory talk during the three group activities, with the teacher mediating (Group practical 1 mediating; Group practical 2 mediating; Group discussion mediating), was mainly in isiXhosa: 73%, 64% and 95% isiXhosa respectively by Teacher B; and 59%, 92% and 80% isiXhosa respectively by the learners. However during the review and

reporting back activities – presentational talk - both teacher and learners used more English than isiXhosa: 66% English by the teacher and 100% English by the learners during the review; and during the reporting back activities, 66%, 60% and 61% English by the teacher, and 67%, 81% and 100% English by the learners. So Teacher B tended to use more isiXhosa than English when working on meaning and then supported learners in transferring that understanding to English – what Cummins (2008) would describe as ‘teaching for transfer’.

The following extracts from the transcript of the lesson are taken from the group discussion activity on defining a mixture; and the next extract is taken from the reporting back that followed the group discussion. These illustrate the shift from exploratory talk in isiXhosa (100% isiXhosa for both teacher and learners), to presentational talk mainly in English (78% English for the teacher; and 100% English for the learners).

(Note that the isiXhosa is shown in italics in blue and the English translation in square brackets immediately after.)

*Exploratory talk*

	<b>Teacher B</b>	<b>Learner/s</b>
1.	<i>Imixture yintoni kanti?</i> [Then what is a mixture?]	
2.		Learner: <i>uMxube</i> [mixture.]
3.	<i>Nina into eniyenzileyo ngoku nitshintshe eligama eli nalisa esiXhoseni. Anichzi ukuba yintoni kanye kanye le.Yabo? Yintoni umxube?</i> [what you have done is to change the word into isiXhosa, you do not explain what this really, really is. You see? What is a mixture?] <i>Njengalapha, yabona</i> [just like here, you see]? (pointing to mixture) <i>Yabona ukuba kuyacaca ukuba kwenzeka ntoni</i> [can you see it is clear what is happening here]? (Indistinct) <i>kwenzeke ntoni</i> [what happened]?	
4.		Learner: <i>Kudibene into ezmbini</i> [two things have mixed].

5.	<i>Kudibene into ezimbini</i> [two things have mixed]. <i>Kwenzeka ntoni kwiproperties zezozinto</i> [what happened to their respective properties]?	
6.		Learners: <i>Azatshintsha//Zatshintsha</i> [Changed //No change]
7.	<i>Zathini? Lungisani ke lonto.</i> [What happened? Go ahead and fix that then] (refers to answer)	

*Presentational talk*

	Teacher B	Learners
1.	Mixture. You should look at <i>i-properties zezazinto, ne?</i> [properties of those things, okay?] When you have those two substances... <i>masimamele sonke.</i> [let's all listen] <i>Xa si ne zazinto</i> [when we have those things]. When you have those two substances, i-iron: iron filings <i>nesulphur, ne</i> [and sulphur, okay]?	
2.		Yes.
3.	Then we put them together... what happens to i-properties, mmmm? Do i-properties change or remain the same?	
4.		Remain the same.
5.	They what?	
6.		Remain the same.
7.	<i>Heke</i> [Good]! They remain the same, heh?	
8.		Yes.
9.	So, that's how we should ehh... define <i>imixture yethu</i> [our mixture.] i-mixture is a substance where you have mixed or you have combined two substances, <i>ne</i> [okay]?	
10.		Yes.
11.	And the properties of those two substances remained what?	
12.	The same	//the same.

In the following section, an extract illustrates the nature of the bridging across discourses and languages that is accomplished through the systematic translanguaging practices of Teacher B.

### Pedagogical translanguaging: building bridges across languages and discourses

The translanguaging practices of Teacher B - working on understanding in the learners' home language and then transferring that understanding into English - could be regarded as a further aspect of a 'pedagogical bridging discourse' as described by Gibbons (2006) (as noted, Gibbons' analysis did not include bilingual practices).

A closer examination of the classroom talk of Teacher B illustrates this. The following transcript extract is from a whole class question and answer session during the review stage at the start of a lesson (B3), where Teacher B elicited key points derived from the practical work of the previous lesson. An edited version of this lesson transcript was used in section 2.1. to illustrate the classroom discourse and how Teacher B engaged learners in dialogic exchanges to develop the scientific argument, following the explanatory arc from description to explanation to generalization. In this extract from the same lesson episode, the focus is on the teachers' pedagogical translanguaging practices and how the teacher establishes understanding in the learners' home language and then supports them in transferring this understanding into English.

	Teacher B	Learner/s
1.	<i>Ithetha uk'thini xa kuthiwa</i> [what does it mean when it is said to be] <i>i</i> -magnetic? What does it mean when we say iron filings are magnetic? <i>Lanto ibisenzeka siyesathini</i> [that thing that that happened what did we say]? Iron filings are magnetic. Mhmm? <i>Ithethuk'thini</i> [what does it mean]? When we say iron filings are magnetic what do we mean by that? What does the magnet do to the iron filings? <i>Izenza ntoni</i> [what does it do to them]? <i>Anithethi ngoku</i> [you are not talking now]. <i>Uthini</i> [what do you say]?	
2.		Learner: <i>Iyazdibanisa</i> [it combines them].

3.	Mhmm?	
4.		Same Learner: <i>Iyazidibanisa</i> [it combines them].
5.	<i>Iyaz'thini</i> [what does it do]?	
6.		Same Learner: <i>Iyazidibanisa</i> [it combines them].
7.	<i>Iyazidibanisa</i> [it combines them]? <i>Andinawthi iyazdibanisa, lelphi elinye igama esinokulisebenzisa</i> [I would not exactly say combines them, what other term can we use]? <i>Wena kaloku xa usithi iyazidibanisa, utheth'ba iyazisondeleanisa, ne</i> [when you say it combines them, you mean it brings them closer, okay]? <i>Izenza ntoni</i> [what does it do to them]? <i>Iyazthini</i> [it does what to them]? What happens?	
8.		Learner: <i>Iyaztsala</i> [it pulls them].
9.	<i>Iyaztsala, iyaztsala. Ngesilungu sizak'thi iyazthini kaloku uk'tsala</i> [pulls them, pulls them. In English what're we going to say it does, pull]? Mhmm? What can we say in English. <i>Iyaz'tsala</i> [it pulls them]?	
10.		Learner: Pull.
11.	Pull, pull. It pulls them, heh? Another word which we can use? <i>I</i> -scientific word <i>esinokuyisebenzisa, besiyisebenz's'izolo</i> [a scientific word that we can use, we used it yesterday]. <i>Ithini</i> [it what]? <i>Kula</i> [in that] pulling? <i>Xa usondeza</i> [when you bring] when you bring <i>i... i...</i> iron filing <i>i...i</i> -magnet <i>kwi</i> [to]iron filings <i>ziyatsaleka andithi</i> [they get pulled isn't it]? <i>Sathi iyazithini</i> [what did we say it does to them]? Which word did we use <i>kokwak'tsala</i> [for pulling]? (nominates learner) Sindiswa?	
12.		Sindiswa: We put up.
13.	You put up ... no, we did not use that name. <i>Asisebenzisanga elogama</i> [we did not use that word]. <i>Eloqala ngo A</i> [it starts with A]. <i>Eqala ngo A</i> [it starts with A]. (gesticulates pulling action with hand) Heh? We said <i>i</i> -iron filings <i>ziyathini</i> [do what]? <i>Eqala ngo A</i> [it starts with A]. Are what?	
14.		Learner: Identify.
15.	Identify. <i>Hayi khona</i> [no ways]. Not identify. Identify. <i>Kaloku besithe ... besithe uthini? ... Kanene</i> [remember we said ... we said they? ...remember] <i>Impawu esibona ngazo ngu A..</i> [the distinguishing characteristics is A...]? Heh? <i>Itsho</i> [speak] (Pointing to a learner).	

16.		Learner: Attract .
17.	<p><i>Heke</i> [Good]! Attract, attract. <i>Besithe kanene kwiiron filings imaghet iyazithini ezanto</i> [for iron filings what did we say does to those things]? Attracts. (writes on chalkboard:</p> <p style="text-align: center;"><b>Attracts</b></p> <p><i>Iyayiattracta naliya elagama</i> [It attracts it, there is the word]. Attracts, heh?</p>	
18.		Learners: Yes.
19.	<p>A <i>i.i.</i> <i>i</i>-magnet attracts <i>intoni</i> [what]? <i>I</i>-iron filings. <i>Iyazitsala kokwakutsala besithetha ngako</i> [it attracts them; it is that pulling we were referring to].</p>	

This teaching episode demonstrates the following:

- Teacher B asked a question in isiXhosa, then repeated it in English: ‘What do we mean when we say iron filings are magnetic?’ He then repeated the question in both English and isiXhosa several more times (turn 1).
- A learner suggested an answer in isiXhosa: *iyazidibanisa* [it combines them] (turns 2-6).
- Teacher B then probed in isiXhosa for a more precise answer: *Andinawthi iyazdibanisa, leliphi elinye igama esinokulisebenzisa* [I would not exactly say ‘combines them;’ what other term can we use]? (turn 7).
- A learner offered ‘*Iyaztsala* [it pulls them]’ (turn 8).
- Teacher B accepted the learner’s isiXhosa term (*iyatsala*) and asked for the English translation (turn 9).
- A learner offered ‘pull’ which Teacher B accepted and asked for a scientific word for ‘pull;’ he repeated the question in isiXhosa (turns 10-11).
- A learner offered an incorrect answer: ‘put up;’ the teacher then provided a clue ‘it starts with A;’ another learner guessed ‘identify’ which was firmly rejected; the next learner

offered the correct scientific term 'attract' which the teacher accepted with praise; and then repeated the term and wrote it up on the chalkboard (turns 12-16).

As this transcript demonstrates, Teacher B shuttled between languages (Canagarajah, 2011) in eliciting from learners the key ideas, first in everyday language in isiXhosa, then in everyday language in English, then in scientific language in English – in so doing, supporting learners' understanding in isiXhosa; then transferring that understanding to English; and at the same time, moving from everyday language to the language of science. This demonstrates a possible route on the 'journey' between isiXhosa and English; and between everyday language and the discourse of science, as suggested by Setati et al. (2002); and at the same time, provides an overlay of pedagogic translanguaging, onto Gibbons' (2006) notion of a pedagogic bridging discourse.

### **Summary of key findings in relation to the bilingual language use and opportunity to learn science in the observed classrooms**

The contexts for language use differed between schools in terms of language policy and expected language practices by teachers and learners: nevertheless, in all eight schools English was the accepted LoLT in Grade 8 in all of the eight schools; and as such, the language of reading, writing and assessment. However schools differed as to their expectations for oral language use by teachers and learners, along a continuum from ranging from full adherence to English LoLT in School H, to the expectation in School E that English should be used for 80% to 90% of the time; to School D where the school management and senior teachers apparently adhered to English LoLT in class, but the younger teachers covertly used isiXhosa when they felt it necessary; to a fairly *laissez faire* situation for the remaining five schools, where teachers felt able to use whichever languages they felt were necessary to communicate the lesson content.

All of the teachers reported that most Grade 8 learners were not able to cope with learning thought the medium of English alone and so they and most teachers in their schools would codeswitch to accommodate this perceived lack of English proficiency. However, when the actual language use by teachers and learners was quantified it was notable that in the case of seven out of the eight teachers, relatively little or no isiXhosa was used in the observed lessons with the usage of isiXhosa ranging from 0% (Teachers E and G), to 3% (Teacher A), 6% (Teacher D), 11% (Teacher H) and 13% (Teachers C and F). By contrast Teacher B used more isiXhosa (53%) than English.

Learners in Classes E and H used no isiXhosa – in line with their teachers' language use. In the other classes, isiXhosa use by learners ranged from 6% (Class C) to 42% (Class B) and 43% (Class H).

It appeared that reactivity might have inhibited teachers' use of isiXhosa in classes C, D, F and H; nevertheless it can be assumed that teachers were presenting their 'best practice'; and if they reduced the amount of isiXhosa they used when being observed, then this indicated that this was not regarded as a legitimate teaching strategy.

Coding of the functions of teachers' use of isiXhosa, when it occurred, showed that most teachers who did codeswitch, did so mainly to communicate science content and secondly to manage classroom activities; for Teachers D and F, most switches to isiXhosa were to manage the class (78% and 52% respectively). There was relatively little codeswitching 'to humanize the affective climate of the classroom' (Ferguson, 2003, p. 39) in the form of joking or banter, although instances of codeswitching that were coded for managing classroom activities – for example discipline and encouragement – would also have impacted on 'interpersonal relations.'

The use of isiXhosa to communicate science, measured as a percentage of classroom language, was low for seven out of the eight teachers, ranging from 0% to 10% of classroom talk. This

was considerably higher for Teacher B who used isiXhosa to communicate Science in 32% of classroom talk.

Five of the six teachers who did use isiXhosa to communicate science, tended to codeswitch when they observed from learners' expressions or responses that they did not seem to be understanding; so their codeswitching tended to be unplanned and reactive, rather than a systematic and purposeful strategy. By contrast, Teacher B tended to use more isiXhosa to communicate science content. The balance of language use in Teacher B's lessons tended to shift over the lesson with exploratory talk or working on understanding in isiXhosa; and more English used in presentational talk, which was then an oral rehearsal for writing in English.

In addition, in Teacher B's lessons, there was evidence of Teacher B mediating a bridging discourse which made explicit links first orally from learners' everyday knowledge in their home language, to everyday knowledge in English, to scientific language in English, and lastly to written language in English – thus completing the 'journey' described by Setati et al (2002) .

While the codeswitching by Teachers A, C, D, F and H might well have contributed to a better understanding of the science content than if these teachers had not used isiXhosa at all; it seems also that learners might well still have been left with a partial understanding of the science content given the brief and reactive nature of their teachers' use of isiXhosa to communicate the science content.

On the other hand, Teacher B's use of isiXhosa and English seemed likely to provide a more systematic and purposeful 'translanguaging' – using both languages in 'an integrated and coherent way to organize and mediate mental processes in learning' – as suggested by Baker (2011, p. 288); and 'teaching for transfer' of both concepts and language (Cummins, 2008). The translanguaging practices of Teacher B, combined with the bridging discourses described in the

previous section, provided learners with improved opportunities to learn science in the observed lessons.

In the following chapter, the research findings presented in Chapters Five, Six and Seven are discussed and synthesized to provide an integrated analysis of the opportunities to learn science in the observed Grade 8 classrooms.

## CHAPTER EIGHT: DISCUSSION OF FINDINGS, SIGNIFICANCE, LIMITATIONS, RECOMMENDATIONS AND CONCLUSION

This chapter provides a discussion of the research findings, the significance of the study, some limitations and concludes with recommendations for educational policy and practice.

### Revisiting the analytical framework: two lenses

The context for this research was the poor performance of Grade 8 learners in South Africa in the international TIMSS studies (Howie, 2001; Reddy, 2006). The TIMSS Video Study (Roth et al., 2006) was a follow up study to the international TIMSS and sought to investigate and compare the 'opportunity to learn science' in five of the participating countries (Australia, Czech Republic, Japan, Netherlands and the USA). The TIMSS video study provided the inspiration and starting point for this research.

The notion of 'opportunity to learn' (OTL) holds that 'students can only be accountable for their academic performance to the extent that the community, broadly defined, has offered them the tools to master the content expected of them' (McDonnell, 1995, p. 312). Given the very poor performance of South African learners in the TIMSS assessments it seemed appropriate to ask the same kind of question to gain some sense of what might be the factors that supported or restricted learners' opportunities to learn science in the observed classrooms. So the main research question was:

*In what ways did the lesson content and the classroom language practices combine to construct or constrain the opportunity to learn science?*

The language medium of the TIMSS tests, where it was different from the learners' home languages, was identified in the TIMSS South Africa reports (Howie, 2001, Reddy et al., 2006) as a factor probably contributing to the poor results and limiting the learners' opportunity to

learn. As discussed in Chapter 1, the language medium or language of learning and teaching (LoLT) is a highly politicised and unresolved issue in South African education and one of personal interest. So this study set out to investigate the interplay between science content and language in Grade 8 classrooms in terms of the opportunities lessons provided for the learning of science.

OTL in this study was viewed through 2 lenses: the *science content* in the lessons (the what); and the *language* used to construct the science content (the how). The analysis of the language of the lessons was in turn framed by a consideration of the *classroom discourse* - the interaction patterns that engaged learners in constructing a coherent understanding of science knowledge (or not), (drawing on the work of Alexander, 2000, 2006; Barnes, 1976, 1992; Christie, 2002; Gibbons, 2006; Halliday & Martin, 1993; Lemke, 1990; Mercer, 1995; Mortimer and Scott, 2003; Sutton, 1992; Vygotsky, 1962; Wellington & Osborne, 2001; Wells, 1999); and the bilingual languaging practices of teachers and learners, and a consideration of whether these appeared to support or restrict learners' opportunities to learn science, (drawing here on the work of Baker, 2011; Canagarajah, 2011; Creese & Blackledge, 2010; Cummins, 2008; Ferguson, 2009; Garcia, 2009; Setati et al., 2002). Neither of these language aspects of constructing science knowledge was considered in any depth in the TIMSS Video Study (Roth et al., 2006) which did not go beyond measuring the public talk of teachers and learners by time and by word count; and the amount of lesson time spent on reading and writing activities.

This study therefore draws together theories from the fields of science learning, classroom discourse and bilingual classroom practices – fields which more usually have been considered separately.

On the basis of the above, subsidiary research questions were:

a. What is the nature of the science content knowledge that was developed in the observed lessons? Does the science content knowledge support or restrict opportunities to learn science?

b. What is the nature of the classroom discourse through which the science content is developed and made accessible to the learners? Does the classroom discourse support or restrict opportunities to learn science?

c. What are the bilingual classroom practices of teachers and learners in the observed lessons? Do the bilingual practices support or restrict opportunities to learn science in the observed lessons?

The factors that formed the basis for the analysis - science content and language - in fact interact and are intertwined in the process of teaching and learning; but they have been analytically teased apart from one another.

### **The teachers**

Before discussing the findings, a note about the teachers who participated in this study: the teachers who were approached and agreed to participate were identified by subject advisors and colleagues on the basis of their reputations as 'excellent' teachers. It was not possible to narrowly define the term 'excellent', but it can at least be said that all the teachers in the study were respected as hard working, committed science teachers by their colleagues and so were selected on the basis of their good reputations. This was intended to eliminate from the study any teachers whose lack of commitment might result in practices that obstructed the learners' opportunity to learn science. That being said, it became apparent fairly early on in the observation and analysis that one of the teachers (Teacher B) stood out from the others in terms of the focused and coherent nature of the science content in his lessons; and how his language practices supported this. So the findings have repeatedly shown Teacher B's practices as standing in contrast to those of the other teachers on the range of analysis criteria. The

fortunate coincidence of the inclusion of this particular teacher in the sample has provided a useful example of what kinds of practices might helpfully support opportunities for learning science, particularly in the challenging conditions of township and rural schools, characterized by deep poverty and the demands of teaching and learning through the medium of a poorly acquired additional language.

## **What did the analysis of the data reveal?**

### **The first lens: The science content of the lessons**

The science content in the lessons was coded and analysed on the basis of five criteria: four of these were drawn from the TIMSS Video Study (TVS) and a fifth one: accuracy of science knowledge, was added, as the lesson observations indicated that this was a problem in some lessons and obviously would impact on the opportunity to learn science. This was clearly not an issue that was considered in the TVS; but this research seems to indicate that it is a factor should not be overlooked in the context of developing countries, where teachers' sound content knowledge cannot necessarily be assumed.

The five criteria are listed below:

1. Types of science knowledge
2. Source of science knowledge
3. Accuracy of science
4. Density of science knowledge
5. Coherence of science knowledge

The teachers' practices were coded and scored for OTL science for each of the five criteria over the series of five lessons observed for each teacher; and on the basis of the cumulated scores, teachers' practices were ranked overall for the OTL science that their lessons provided.

The criteria for the OTL science content can be grouped into those relating directly to the content of the lessons and those relating to how the lesson content was mediated by the teachers. The different aspects of science content in the lessons were coded as canonical knowledge (propositional knowledge about 'science facts, concepts, ideas, processes, or theories'); procedural and experimental knowledge (how to do science-related practices such as manipulating materials, and performing experimental processes'); and real life issues (how science knowledge is used, applied or related to societal issues or to learners' personal lives) (Roth et al, 2006 pp. 48-49). These three forms of science knowledge relate directly to the three learning outcomes and aims identified in the South African curricula (Department of Education, RSA, 2002; Department of Basic Education, 2011) and reflect the nature of science knowledge: namely that it seeks to explain what can be observed (directly or indirectly) in the natural world in terms of generalizable truths, that can in turn be applied to real life situations to predict and solve problems.

The second group of criteria related to how the lesson content was mediated by the teachers, and included the following: the sources of the lesson content; the accuracy of the lesson content; the density of the lesson content; and the coherence of the science content.

In considering the criteria contributing to the OTL science content, it seems that these constitute a *hierarchy of necessary conditions*. The starting point would seem obvious: that there should be some science content in lessons; yet as Roth et al. (2006, pp. 61-62) noted, it is possible for learners to be busy in science lessons without having the opportunity to learn much canonical science knowledge. So for example in Teacher E's lessons there was very little science content at all, as in all five lessons, learners were engaged in group discussions and presentations on various forms of pollution, but these were based on the learners' own general knowledge which was not extended by any references to additional reading material or input from the teacher; nor were learners' contributions linked to broader conceptual frameworks.

Teacher E appeared to have abdicated his role as teacher of science in favour of that of facilitator and his input was mostly focused on managing the procedures of groups reporting. So any further consideration of factors in relation to the OTL science in this class were compromised by the absence of this first necessary condition. In addition, in all but Teacher B's lessons, there was very little explicit procedural and experimental knowledge. This would undermine the opportunity for learners in the other classes to develop a sense of the empirical basis of science knowledge and empirical processes.

Secondly, for learners to be provided with the opportunity to learn science, it seems obvious that the science content should be factually correct. This is not a factor that was considered in the TIMSS Video Study where the participant countries were developed countries from the global north. However this is clearly an issue in developing countries and in South Africa in particular where the legacy of apartheid in terms of inferior training for the majority of teachers continues to play out in classrooms. The nature of science knowledge is that of a vertical and hierarchical knowledge structure and so if part of the knowledge structure is weakened by gaps, misconceptions or errors, then the whole will be at risk.

The accuracy levels of the science content in the lessons was 'truly sound' (Taylor, van der Berg & Mabogoane, 2013) for only one of the eight teachers (Teacher B), which meant that for the learners in the remaining seven classes, the opportunity to learn science was constrained at this most basic level.

It appeared that in this sample, teachers' qualifications in science teaching were more important than years of teaching experience in relation to a sound subject knowledge; but it was also notable that of the eight teachers, only one had been engaged in further education in science education (Teacher B); and the six other teachers who had furthered their studies had done so in leadership and management studies, rather than science education.

It also seemed that some of the misconceptions presented by teachers could be traced back to a misreading of the textbooks, which indicated a problem with teachers' accurate reading skills; and so this combined with weak subject knowledge would provide a shaky foundation for developing accurate science knowledge. The structure of the textbooks themselves might have contributed to this problem as the science content knowledge in the textbooks used by the teachers was relatively fragmented – dispersed in small bites amongst activities, with little coherent and extended exposition of concepts. What might also apply is Parry's (1996) intriguing suggestion that those growing up in a multilingual society and who had learned to read in an additional language, might be used to living with partly understood meanings and so be 'tolerant of ambiguity'; this would be a valid coping strategy in social situations but inimical to developing the precise meanings that underpin science knowledge.

Thirdly, the source of the science knowledge seems to constitute a necessary condition to the extent that there should be some reliable factual written sources, such as a textbook, in addition to oral presentations by the teacher – partly to ensure that learners have the opportunity to read science and develop science literacy; and also to provide an accurate reference source. What was striking was that the sources of science knowledge in the observed lessons were mainly the teacher – or in the case of one class, the learners – and little use was made of written sources, even when they were available in the form of textbooks. So this lack of opportunity to read science would have impacted negatively on learners' science literacy; but it also had serious implications when the teacher's own science knowledge was poor as learners would not have a reliable alternative source of science knowledge.

Fourthly, the density of the science content of lessons, relating to pacing of the science content in lessons, was a criterion adopted from the TIMSS video study analysis of OTL science. However, what exactly a necessary condition of 'just right' would be in this regard, is open to question: too much science content in one lesson could lead to cognitive overload for learners;

and too little science content would mean that the curriculum would not be completed; and how much content could be covered in one lesson would also depend on the cognitive demand of the concepts involved. What the research did show was that the density of ideas in five of the eight classes, fell within a fairly narrow range, but in the case of the other three teachers, there was so little science content in one set of lessons (Class E) that this obviously did not meet the necessary condition. In the case of Teacher H, the lesson density was very much higher, indicating the lecturing and regurgitation mode of teaching in most lessons, which did not allow for active participation by learners. In the case of Teacher A, an analysis of ideas per number of words spoken showed a relatively low number of science ideas – partly because of the lengthy, albeit entertaining digressions which characterized his teaching; but this suggested that learners might well have lost the thread of the science content and ‘got lost in the discourse’. So it is perhaps the cases where there were problems with the density of the science knowledge, that illustrate or mark out the middle range within which the necessary condition on this criterion might be met.

Fifthly, assuming that the above necessary conditions were met: the science content was present and correct, and supported by written sources, and the density of ideas and lesson pacing was not too low or too high, these would not constitute sufficient conditions for the opportunity to learn science. A key aspect of learning science with understanding is that facts should be linked to generalised conceptual frameworks; and that conceptual frameworks themselves should be supported by rich factual detail (Donovan and Brandsford, 2005, p. 6). It was in this respect that the practice of one teacher (Teacher B) stood out from the rest in that the science content of his lessons was systematically linked, through argument, to key generalisations and conceptual frameworks. This appeared to be a key strength in the practice of Teacher B and correspondingly, a key shortcoming in providing opportunities to learn science in the lessons of the other seven teachers.

As the analysis of the data showed, Teacher B's practice stood out from the practices of the other seven teachers in that it appeared to offer a considerably greater opportunity to learn science across the five criteria. As far as the practices of the other teachers were concerned, the breakdowns in OTL science occurred at different points: for Teacher E, this occurred at the most basic level of providing some lesson content; with Teachers A, C, D, and F, the accuracy of the science content in their lessons fell below 80% (58 – 78%); in the cases of Teachers G and H, science facts were not clearly linked to conceptual frameworks, so learners at best would have been left with a collection of facts, rather than a well integrated conceptual framework – necessary for both learning in general as well as for developing the hierarchical knowledge structure of science.

What the analysis of the data showed in relation to the science content of the observed lessons is that there was a range of teaching practices and that the opportunity to learn science broke down at different points in the enacted curriculum. However, identifying the *points of breakdown* in the hierarchy of necessary conditions for the opportunity to learn science, by the same token identifies *points of potential leverage* in the curriculum and a focus for future teacher development.

### **The second lens: The classroom language**

#### ***The classroom discourse: building and bridging***

The analysis of the classroom discourse has drawn on socio-cultural understandings of how learning in classrooms is enacted through the classroom discourse (Barnes, 1976, 1992; Christie, 2002; Mercer, 1995; Wells, 1999). Along with these understandings have been concerns with the dominance of teacher talk in relation to learner talk; and an awareness of how different discourse patterns may close down or support *learners' engagement* in meaning making. Gibbons (2006), Mercer and Littleton (2007), Alexander (2006) and others have described how

*dialogic or learning discourse* can engage learners in meaning making while simultaneously *linking ideas cumulatively and **building** coherent conceptual frameworks* in a vertical knowledge structure. A key aspect of this learning discourse is what Wells (1999) has referred to as 'contingent responsiveness', where the teacher provides feedback (instead of simply evaluation) based on learners' responses, and the feedback then provides the springboard for the next round of question and answers. In this way the teacher builds on and extends learners' understanding and incorporates learners' contributions in constructing meaning.

As Christie (2002), Mercer and Littleton (2007), Mortimer and Scott (2003) and others have noted, in many studies of classroom discourse the lesson content has merely been a contextual factor; and they have argued instead that the lesson content needs to be an intrinsic part of any analysis of classroom discourse. The analysis in this study has shown how the science content of the lessons was structured through the classroom discourse and how this contributed to coherent conceptual frameworks – or whether the ideas in the lesson remained fragmented. This entailed tracing the development of meaning through the discourse within and across lessons.

A further aspect of classroom discourse that was considered in the analysis was that of ***bridging** discourses* - described by Gibbons (2006) as the ways in which teachers support learners in bridging the gap between the language of home and the language of school or in Bernstein's terms, the everyday horizontal discourses of home and the vertical discourses of schooling.

The classroom discourse was analysed firstly according to a word count of *teacher talk and learner talk*; then the *discourse interaction patterns* for each class were identified; and lastly instances of *bridging discourses* were identified and quantified.

A straightforward count of the relative balance of teacher and learner input in the public talk in the observed lessons showed the overwhelming dominance of teacher talk: between 81% and 99% - although this did exclude learners' talk in groups. These figures are very much in line with research findings more generally that the dominant discourse patterns in classrooms (IRE) tended to limit learner talk. Such research (Norman, 1992) has been critical of high volumes of teacher talk on the basis that this would close down learner talk. However a closer look at the data showed that there was not necessarily an inverse relationship between teacher talk and learner talk: while in class A, it seemed that it was the case: the teacher spoke the most words per minute and the learners the least words per minute; but in Class B, the teacher spoke the second most words per minute, while the learners also spoke the second most per minute of all the classes and 3,5 times that of the learners in Class A. It appeared that perhaps relatively high levels of teacher talk were necessary to support and sustain learner talk.

The density of classroom talk also relates to the density of lesson content - as described in the research findings - and could also influence opportunities to learn science. When the discourse of three teachers teaching the same lesson content was compared, the quantity of teacher talk varied widely between teachers: Teacher A used almost twice as many words as Teacher B; and ten times as many words as Teacher G. It appeared the volume of talk by Teacher A combined with several lengthy digressions and a lack of focus - as was evident in the comparative example - might well have meant that learners in Teacher A's class would have got 'lost in the discourse' (Breen, 1998, as cited in Walsh 2006). But by the same token, the very scant discourse that accompanied the same practical activity and discussion, in Class G indicates a lack of the necessary rich detail considered for learning with understanding. So although the data points to problems of too much or too little talk in relation to learners' engagement and the lesson content, it is difficult to identify what constitutes 'just right' in this aspect of classroom

discourse. As suggested, perhaps a sharp focus plus sufficient detail might strike an appropriate balance.

The data showed little evidence of the kind of dialogic exchanges or learning discourses (Alexander, 2006; Gibbons, 2006) in the lessons of seven out of the eight teachers: the science content in their lessons was developed mainly through teacher exposition with some facts elicited and reinforced through IRE sequences and oral cloze. By contrast the discourse patterns in the eighth class (B) showed that the science content was developed mainly through dialogic exchanges, based on linked IRFRFRF interactions, which served to both engage learners in co-constructing the science knowledge and also to link and pattern that knowledge into clear conceptual frameworks; and in so doing, to support the learners' opportunity to learn science. It appeared that this form of classroom discourse was central to the development of coherence in the science content that characterised Teacher B's lessons. Conversely, it appeared that the lack of sustained dialogic exchanges in the other seven classes contributed to the fragmented nature and lack of coherence of the science knowledge in those classes and so constrained the learners' opportunities to learn science.

However, for teachers to engage in dialogic exchanges, it is necessary that they have a sound subject knowledge that includes an understanding of the nature of science as an empirically based vertically structured body of knowledge that seeks to explain the observable world in terms of generalizable principles and conceptual frameworks. Such a sound subject knowledge would also enable teachers to respond to learners' contributions in ways that were flexible and contingently responsive; but without the security and flexibility afforded by the necessary subject knowledge, teachers might be less inclined to risk taking on unexpected and unscripted responses by learners.

As Mortimer and Scott (2003) have pointed out, skilled teachers employ different discourse interaction patterns at different points in a lesson; and what is important is that these are fit for

purpose. In line with this, the analysis of Teacher B's lessons showed shifts in the discourse patterns, with high levels of dialogic exchanges when teacher and learners were working on meaning and when Teacher B was leading learners through an argument, linking observations to explanations and generalisations; and other stages in lessons there were more IRE interaction patterns when Teacher B was eliciting observations or conducting a brisk review of key points.

The analysis of the occurrences of bridging discourses in the lessons again revealed a wide gap between the practices of Teacher B and the other seven teachers: there was some evidence overall of teachers explicitly bridging the gap between everyday and science language; and between everyday and science knowledge; but it was only in Teacher B's class that there was regular and systematic bridging of practical and theoretical knowledge and bridging across the oral and written modes. The lack of bridging from practical to theoretical knowledge was not because of a lack of practical activities overall, but because teachers tended not to move beyond eliciting descriptions of observations rather than moving on to generalizing the finding and using practical activities to exemplify broader concepts.

The data showed how it was possible for a teacher to engage learners in cumulatively constructing the vertical knowledge structure of science through the classroom discourse; and at the same time to support learners in bridging the everyday knowledge and everyday language of home and the scientific knowledge and language of school; to bridge practical experience and observation and theoretical understanding; and to support learners in bridging the oral-written mode continuum.

#### *The languages of learning and teaching – bridging languages*

The bilingual languaging practices of teachers were considered through a separate analytical lens, partly because of the importance of this issue in the multilingual context of South Africa

and also because it draws on a different body of research and literature to that of classroom discourse analysis. The tensions in South Africa between language policies and classroom practices have been outlined in the conceptual framework and the analysis section; suffice it to say at this point that the tensions remain and teachers' use of the learners' home language when the official language of learning and teaching is English has frequently been covert and particularly sensitive to reactivity (Adendorff, 1996; Ferguson, 2009; Setai et al, 2002; Probyn 2009; Wei & Martin, 2009). So although the teachers all claimed that even in Grade 8, learners were not sufficiently proficient in English to cope with learning entirely through the medium of English, and that they, the teachers, would make use of the learners' home language, isiXhosa, if necessary, there were surprisingly low levels of isiXhosa use by seven of the eight teachers: two teachers (E and G) did not use isiXhosa at all, and the other five used isiXhosa for between 3% and 13% of classroom talk. As suggested in the analysis, this might well have been a result of reactivity, despite the precautions taken to mitigate such a possibility. But one can assume that teachers were presenting their best practice and if they were using less of the learners' home language in class while being observed than they usually might have, then this showed that they did not consider the learners' home language as an important and legitimate linguistic resource in the classroom.

In this respect, the practice of Teacher B stood out in contrast to that of the rest of the teachers in that he used more isiXhosa than English when teaching science: 53% isiXhosa.

The patterns and functions of language alternation in the six classrooms where teachers did make use of isiXhosa were different for the group of teachers who only used a little isiXhosa and Teacher B. For Teacher D, the main function of her use of isiXhosa (78%) was for classroom management or regulative discourse; this was also relatively high for Teacher F – 52% of isiXhosa use. The rest of the teachers tended to use isiXhosa mainly to communicate the science content of the lessons; but crucially when they were asked why they had switched to isiXhosa at

a particular point, they responded that they did so in response to signs of incomprehension in the faces of learners. So the base language for teaching was English but teachers codeswitched to isiXhosa when they received a cue from the learners that there was a breakdown in understanding. However this raises the question as to whether this relatively brief and reactive codeswitching would in fact support learners' opportunity to systematically build their science knowledge; or if it might only provide them with relatively patchy comprehension and leave them with critical gaps in their science knowledge.

Teacher B on the other had a very different approach to teaching in this bilingual context. He claimed in his interview that his approach was to first build understanding in the learners' home language and then transfer that understanding to English. This was evident in his practice: when the focus was on working on meaning – exploratory talk – Teacher B used more isiXhosa than English; and when learners were required to review ideas or in the consolidation phase of a lesson – presentational talk – then Teacher B used more English than isiXhosa and required learners to do the same.

This kind of language alternation practice is more in line with what has recently been identified in the literature as 'translanguaging' – a deliberate and systematic use of both languages to mediate learning; and in the case of learners in this study, who are faced with the challenge of learning through the medium of an unfamiliar language, this kind of translanguaging appears to offer an additional bridge to the knowledges and languages of schooling.

In this analysis I have mapped the language alternation practices of teachers onto the classroom discourse; and in turn have mapped the language practices onto the cumulation and building of science knowledge in the observed classrooms. What the research reveals is that science teaching in such bilingual contexts involves a complex and nuanced interplay of subject knowledge and language; and how in the case of one teacher this appeared successfully achieved in supporting learners' opportunity to learn science. By contrast the practices of the

other seven teachers in the study show the challenges inherent in teaching in such contexts and the various points at which the opportunity to learn science broke down in their practices. The points of breakdown conversely indicate possible points of leverage in the curriculum and issues to address in teacher training in the quest to develop 'pedagogies to break cycles of school failure' (Christie, 2002, p. 19) and so improve the opportunity to learn science for all learners in such contexts.

### **Significance of the study**

The intention of this study was that it should have some practical significance – that it should address a practical problem and have practical outcomes.

The backdrop and motivation for this research study was the large-scale international TIMSS studies and in particular, the poor results in the TIMSS South Africa studies, that indicated that Grade 8 learners in South Africa were not being offered the appropriate opportunity to learn science. This small scale, multiple case study has drilled down from large scale TIMSS studies to take an in depth look at the enacted curriculum in eight Grade 8 science classrooms in township and rural schools, to investigate the factors contributing to or constraining the opportunity to learn science.

The study was intentionally set in township and rural schools in the Eastern Cape Province, a province bedeviled by the historic deprivations of the apartheid homeland system; and by ongoing social, economic and political challenges that have limited educational development. Rural and township schools the Eastern Cape Province serve amongst the poorest communities in South Africa and rural schools particularly, because of their inaccessibility, are relatively under-researched.

This fine-grained study of classroom interactions has shown how meaning was developed in science classes through language over time; and how the factors identified in the analysis combined to construct or constrain the opportunity to learn science.

These factors then can go some way in explaining the poor performance of learners in the TIMSS South Africa assessments; and likewise provide trigger points for teacher development, particularly in the challenging conditions of township and rural schools which cater for the majority of South African learners.

In addition the research is significant theoretically as it pragmatically draws together theory and research on science education, classroom discourse and, more unusually, on bilingual classroom practices, to develop a more holistic and nuanced view of science teaching and learning, through the classroom discourse in the kinds of bilingual settings that are common in South Africa.

## **Limitations**

As with all small-scale research studies, the major limitation is that of generalisability: 'Interesting - but so what?' However it is possible to claim 'face-generalisability' (Maxwell, 1996; Schofield, 1993) on the basis of the typicality of the schools and their linguistic contexts and settings; and the descriptive context provided in Chapter Four provides researchers and teachers with some basis for comparison with their own contexts and classrooms.

The research analysis was a painstakingly slow process, undertaken by one researcher, on a very part-time basis. This has contributed to a major limitation of the study, namely the long time lapse between data gathering (2004-2005) and final writing up of the research in this dissertation, although several journal articles based on the data have been published in the interim. In many areas of research this would render the findings obsolete as conditions and contexts change rapidly. Would it were so with education in the Eastern Cape. However, as has

been outlined in Chapter One, there have not been dramatic improvements in learners' achievement in science generally; and the educational problems in the Eastern Cape remain systemic and relatively unchanged. The waste of human potential and opportunity makes one weep; but then education in South Africa is the preserve of the eternal optimists.

### **Recommendations for policy and practice**

The research unearthed particular challenges which point to the need for action, some of which could be achieved relatively easily and others that would need longer term interventions and would likely be more challenging. These can be broadly grouped as resources and teacher development needs.

#### **Resources**

At the most basic level, all teachers and science teachers in particular, need classrooms that are comfortable to teach in, with adequate secure storage for science equipment. In addition they need water, electricity, toilets. This much is self-evident. As described in Chapter One, in all the rural schools in this study, this basic infrastructure was at best extremely basic or shockingly absent. NGOs such as Equal Education have doggedly pursued such matters with the Eastern Cape Provincial Government and nationally with the Minister of Basic Education – but the problems remain, despite being straightforward to fix. It is extraordinary that teachers have had the resilience to persevere under such conditions.

In all of the schools, the possibility of practical work was severely curtailed for many aspects of the science curriculum, by the almost complete lack of science equipment. This is also not a difficult problem to fix: there is a long history of NGOs such as the Urban Foundation and school development units attached to universities, developing portable science kits intended for precisely such schools; and so the solution is again simply one of funding, organisation and political will.

The same solution applies to the evident shortages of textbooks in the schools in the case studies. It was notable that only in one school did each child have a textbook; and in two schools, only the teacher had a textbook. The National Department of Basic Education has in recent years invested huge funding in the provision of textbooks, but there are still annual reports of shortages or breakdowns in the system of distribution and it is questionable whether the system has improved since the research was conducted.

### **Teacher development**

The shortcomings in the accuracy of the subject knowledge of all but one teacher in this study, raised obvious alarm bells, although this was not a new revelation. While all but one teacher had some science specialisation in their initial teacher education, only one teacher had continued with further studies in science teaching; the remaining six teachers who had engaged in further studies had done so in management rather than science. So this study must add to the chorus calling for serious attention to be paid to in-service training to upgrade the subject knowledge of science teachers; and for pre-service training to prioritise teachers' subject knowledge.

As noted, the shortages of textbooks in all but one class was identified as a constraint on the opportunity to learn science: the remedy is clear. However what also emerged from the study was that lessons were largely oral, and teachers made relatively little use of textbooks in classroom activities, even when they were available. This has clear negative implications for the opportunities for learners to develop science literacy and points to the necessity for training for teachers in how to use textbooks effectively; and to include regular reading and writing activities in science lessons. Learners need access too, to interesting and exciting science texts, beyond the textbooks. There are wonderful illustrated science books for children and a small classroom library would do much to broaden and enrich learners' (and teachers') interest in science and science literacy.

Although there was not much evidence of learners using textbooks, it appeared from the lesson content that in many cases teachers based their lessons on the textbook content. Some of the inaccuracies in lessons could be directly traced to misreadings of the textbooks by teachers. This suggests that pre-service training should include developing the accurate reading skills of teachers' themselves; and the need for teachers to understand the nature of science knowledge as dependent on accurate and precise meaning.

A further point in relation to science textbooks is that the Grade 8 science textbooks appeared to assume teachers had the requisite subject knowledge and the focus was on learning activities, with the science knowledge fragmented across a chapter. So if teachers were to depend on the textbook as a source of science knowledge, they would be unlikely to find a clear comprehensive exposition on a topic. It seems that what teachers need to supplement textbooks is a good science reference book for their own use – in hard copy or electronic format – with the necessary science concepts clearly explained and illustrated. Again, the effectiveness of such an intervention would depend on teachers' accurate reading skills.

Related to the above recommendation, is the relative lack of coherence in the science content in the observed lessons. This too points to a lack of understanding by teachers of science as a hierarchically structured body of knowledge, with facts linked through logical argument to generalising principles and conceptual frameworks. Likewise this points to the need for teacher training in this important aspect of science teaching: the need to join the dots instead of leaving them floating.

All the above recommendations relate to teachers' subject knowledge. The research findings also point to the need to include specific training for science teachers in the role of classroom discourse in engaging learners in constructing science knowledge: how to be contingently responsive to learners' contributions and how to lead learners in modelling the explanatory arc of description => explanation => generalisation.

Lastly, teacher training needs to address the question of how best to utilise the linguistic resources of the classroom in the kinds of bilingual contexts exemplified in this research study. Teachers need to be freed from the unrealistic and uneducational expectation of sticking to one language while covertly codeswitching as a last resort; but rather adopt a more flexible and responsive mode of translanguaging in the classroom, that it based on teaching for transfer across languages; and has at it heart the needs of learners and their opportunity to learn science.

## Conclusion

Education is perceived as a human right in the South African Constitution (section 29) (Republic of South Africa, 1996) and more generally society has vested in education the ideals and means for addressing the historical inequalities of the apartheid past. However as international studies have shown, South African learners are far from performing at internationally benchmarked levels and the education system as a whole continues to fail the poorest learners. Thus the question of whether learners have the necessary 'opportunity to learn' is one that is central to redress and social justice. It is in this light that this research was undertaken.

This study has shown that the opportunity to learn science in bilingual contexts such as the township and rural schools in South Africa, is contingent on learners being provided with correct and coherent science knowledge; and that access to this science knowledge is constructed through a nuanced interplay of classroom discourse practices that engage learners in co-constructing the science knowledge; and classroom translanguaging practices that systematically bridge the gap between learners' everyday knowledge expressed in their home language, and science knowledge, expressed in English.

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## **APPENDICES**

### **Appendix 1: Teacher interview schedule**

#### **TEACHER INTERVIEW SCHEDULE**

##### **Research principles – to outline**

- The research process will be an open and transparent one and teachers will have access to research data.
- The research respects the privacy and anonymity of the teachers and learners involved.

##### **Personal history**

Share own personal background, then ask teacher following

1) Name

2) Education background:

- Own schooling
- Teacher training
- Further training
- In-service training

3) Teaching experience

4) Teaching goals

##### **School context**

- School details:
- number of learners

- numbers of teachers
- learners' backgrounds – where do they come from; socio-economic status

### **Resources**

- How many textbooks are there for the class?
- What kind of science equipment does the school have?

### **Language and learning**

1) Share own background – learning as well as teaching – learnt through HL but majority of learners learn through medium of L2/FL

2) Teachers faced with challenge of teaching content and language – two goals in conflict

3) Need for training for teachers – need to learn

4) Teacher's views on language and learning science in Grade 8

- Learners' proficiency in grade 8?
- Effect on teaching and learning in science lessons?

5) How does teacher cope with challenges of teaching content and language?

- Main focus content or language?
- Strategies for meeting challenges?
- Any training for this?

6) Language policy allows for schools to choose language medium

- Does school have formal language policy – if so what is it?
- If there is no formal language policy, what are the attitudes of the principal/staff to language use in the classroom?

- What are the language practices in the school – in classroom and informally outside classroom?
- What is teacher's attitude towards learners' language use in the classroom i.e. towards learners' codeswitching?

### **Classroom practice**

#### 1) Reactivity

- teacher's response to researcher and camera
- learner's response to researcher and camera

#### 2) Look at examples of codeswitching in lessons – teachers' comments

#### 3) Look at examples of language support

#### 4) Opportunities for language development – speaking, reading and writing

Thank teacher for willingness to participate, cooperation and time.

## Appendix 2: Research outline – informed consent

### LANGUAGE IN EDUCATION RESEARCH

#### DEVELOPING EFFECTIVE STRATEGIES FOR TEACHING SCIENCE THROUGH THE MEDIUM OF ENGLISH AS AN ADDITIONAL LANGUAGE

**Proposal submitted by Margie Probyn, Institute for the Study of English in Africa, Rhodes  
University, Grahamstown**

#### **Problem identification**

The role of language is central to any discussion of classroom teaching and learning in South Africa where the school language policy for the majority of students requires they learn through the medium of English as an additional language (EAL), switching from mother tongue medium of instruction sometime before grade 5. In such classrooms, there is frequently a breakdown between language policy and practice as the language proficiency of the learners to a large extent moulds the classroom practice of the teacher (Macdonald, 1990:44). The language of the classroom is very often not English but a mixture of English and mother tongue (Young, 1995:108) and learners are usually engaged in passive rather than active productive language skills in the classroom and so seldom engage in meaningful discourse in English (Wright, 1993). Teachers claim that learners cannot understand textbooks (Langhan, 1993:94) and so resort to giving learners simplified notes to learn off by heart, entrenching practices of rote-learning and dependency on teachers as sources of knowledge, that persist through secondary school. The new national curriculum, introduced in 1997, seeks to move teachers away from such practices but neglects to address the language issues that hold them in place.

In a national survey nearly 80% of the teachers responded that the language of instruction was to some extent or to a great extent responsible for learners' poor performance (Strauss, 1999). The TIMMS-R study found that " ...the majority of South African pupils cannot communicate

their scientific conclusions in the languages used for the test (i.e. English and Afrikaans which were the medium of instruction and are the languages currently used for matriculation examinations). In particular, pupils who study mathematics and science in their second language tend to have difficulty articulating their answers to open-ended questions and apparently had trouble comprehending several of the questions" (Howie, 2000).

Much of the current debate around language in education is caught up in policy issues and there is little research and debate around the practicalities of developing effective classroom language practice, particularly at secondary school level. At present there is little training for teachers at secondary level to teach through the medium of EAL (NEPI, 1992:4; JET, 1997:26-29). Two small-scale research studies (Probyn 1995, 1998) provide evidence of experienced teachers having developed practical classroom strategies to mediate teaching and learning through EAL, but these seem to have been largely reactive, implicit and unsystematic. **Thus there is a need to develop a conscious, coherent, systematic approach to teaching and learning through the medium of EAL, developing both conceptual understanding and language learning, in the context of the new curriculum; and for this approach to be the basis for broad-based teacher development.**

### **Research outline**

#### **Research aims:**

The purpose of the research is to develop a detailed understanding of what Grade 8 science teachers do in their classroom practice to mediate the learning of science through the medium of EAL; and what the contextual factors and teachers' beliefs are that shape their practices. Further, to analyse their practices in terms of the opportunities they offer for language learning and the development of science concepts.

This detailed understanding and analysis is a baseline study intended to inform the development of an explicit, systematic and contextually appropriate approach to teaching science through the medium of EAL, that provides teachers with a theoretical and practical framework for language use in the classroom aiming to maximise learners' opportunities for both conceptual understanding and language learning.

It is proposed to focus on the teaching and learning of Grade 8 science, as the TIMMS-R study (Howie, 2001) has highlighted language problems and also provides a national base-line indicator of Grade 8 learners' performance in science content and language. It is also proposed to work with teachers and learners who share Xhosa as their home language as this is the situation in the majority of Eastern Cape schools: 78% of teachers and 86% of learners have Xhosa as their home language (EMIS, 2001).

Classroom language to be investigated includes three intersecting aspects:

- the uses of Xhosa and English to mediate understanding of science concepts and the learning of English;
- the uses of language for learning in explanations, class discussions, group discussions, reporting back, reading and writing;
- the development of the cognitive academic language skills required by the discourse of science.

**Main research question:**

The following question will guide the research: What language teaching strategies are appropriate and effective in an approach to teaching science through the medium of English as an additional language, that will maximise learners' opportunities for both conceptual and language development, in the context of Curriculum 2005?

**Research sample:**

The purpose of the research is to provide an informed basis for the development of appropriate teacher training for Xhosa-speaking teachers teaching science through the medium of English in

township and rural schools in the former homeland areas of the Eastern Cape. The schools will be selected for the research so that as far as possible they matched the profile of 'typical' rural and township schools in the Eastern Cape, allowing some measure of generalizability of the research findings. According to EMIS data for 2001, almost 70% of Grade 8 learners in the Eastern Cape are in rural schools and 86% of learners and 78% of teachers are home language isiXhosa speakers. Therefore the sample school sites includes three urban schools and seven rural schools where science teachers and learners share Xhosa as their common home language. However the research findings will be applicable to teaching and through the medium of English as an additional language, where the home language of learners and teachers is not necessarily Xhosa.

**Research process:**

Permission and access to schools will be obtained from the relevant authorities.

Each school will be visited for one week and 5 consecutive science lessons videotaped for each of the selected Grade 8 science teachers.

Teachers will be interviewed about their attitudes towards language and learning, and their classroom practice, using the videoed lessons as the basis for the interviews.

The Grade 8 learners will complete a questionnaire about their language attitudes and practices.

The fieldwork is to be completed by the end of August 2004.

The research data will be analysed, using computer software designed for the TIMSS Video Study (Stigler et al, 1999).

The research will be written up by July 2005.

Recommendations for teacher training, based on the research, will be widely disseminated to interested parties, including the teachers participating in the research and the Eastern Cape Education Department.

### **Research impact:**

The research will provide a much needed empirical basis for the development of teacher education for science teachers teaching through the medium of English as an additional language in the Eastern Cape. In addition it is hoped that the teachers involved in the research will benefit through the process of viewing videotapes of their teaching with the researcher and through having the opportunity to reflect on their practice.

### **Ethical issues:**

The use of videotapes raises ethical issues in terms of ownership of data and anonymity of teachers and learners. The researcher undertakes that the teachers' anonymity will be preserved in any reporting. The videotapes will not be used for any dissemination without the expressed permission of the teachers and learners involved. These issues will be clarified at the outset of the research.

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## Appendix 3: Analysis criteria

### CRITERIA FOR CODING OF DATA

The videotaped lessons were transcribed, and translated where necessary. The *public talk* in the lesson transcriptions will be analysed according to the criteria below. 'Public talk' is defined as talk by teacher or students where the intended audience is the whole class.

The unit of analysis for mapping the *lesson content* will be the *series of five lessons* per teacher.

In order to map the *lesson structure* and to provide a framework for the analysis of the *development of content through language*, each lesson will be divided into lesson '*episodes*': these are defined by Gibbons (2006 p. 95, following Lemke, 1990, p. 50) as 'a unit of discourse with a unifying topic and purpose' – roughly equated to a teaching activity. A lesson episode has the following features:

- it is framed linguistically with markers such as 'okay' or 'now we are going to ...';
- a particular participant structure which might change in following episode;
- physical seating arrangements which might change in the next episode;
- fulfils a particular purpose or function;

#### **1. Science content: What was the nature of the science content knowledge that was developed in the observed lessons?**

The science content of the lessons (facts, concepts, principles & theories) were identified and analysed as follows, with criteria adapted from the TIMSS video study (Roth, 2006):

- 1.1. Types of science knowledge
- 1.2. Source of science content
- 1.3. Accuracy of science knowledge
- 1.4. Density of science knowledge (pacing)

## 1.5. Coherence of science knowledge

**1.1. Types of science knowledge** (from TIMMS 2006 – represents the range of types of science knowledge) categorised as follows:

- SKC: canonical knowledge: ‘science facts, concepts, ideas, processes, or theories’ (include observations made during practical work); ‘an idea is canonical in the sense that it is generally shared by members of the scientific community’ (Roth et al., 2006 p. 62)
- SKRL: real life issues: ‘how science knowledge is used, applied or related to societal issues or to learners’ personal lives’ [include analogies]
- SKPE: procedural and experimental knowledge: ‘how to do science-related practices such as manipulating materials, and performing experimental processes’

## 1.2. What is the source of science content?

Science facts per lesson were coded according to their source:

- teacher
- learner/s
- textbook
- chalkboard
- worksheet

**1.3. Is the science content in the lesson accurate?** (this criterion is not included in TIMSS analysis; however necessary for this analysis; applied to all categories in 1.1.)

- AC - 2: science content accurate and complete
- AC – 1: content unclear/not quite accurate/incomplete concept

- AC - 0 : content incorrect

#### **1.4. How much science content is there in the lessons? (density)**

The TIMSS video study looked at one lesson per teacher, so the possibility of identifying how much in lessons was review of previous lessons within the data set, was not possible. I have also included in the reference to previously taught ideas e.g. teacher reminds learners of ideas; and repetition of ideas within a lesson.

- DNEW Number of publicly presented canonical ideas – new content (count/time)
- DREV Number of publicly presented canonical ideas – review of previously presented content; include ideas from lessons in data set or ideas marked by teacher as previously presented e.g. ‘remember ...’ (count/time)
- DREP Repetition of ideas – within a lesson at *different points* in the lesson e.g. a recap before moving on to a new idea or activity; not repetition at the same point in a lesson (count/time);
- DPREV repetition of an idea/fact from a previous lesson but no explicit link made by teacher (count/time)

#### **1.5. How coherent in the science content within and between lessons? (these scores were scaled to percentages for inclusion in one chart)**

TIMSS report (Roth et al., 2006 p. 57) refers to the need for ‘providing students with the opportunity to develop connected, evidence-based scientific understandings that students can apply to make sense of a variety of phenomena’ as a key idea coming from international research on science teaching and learning; in addition ‘research on human learning suggests that unrelated ideas hold less meaning than those that are richly interrelated...’

Thus the issue of coherence in science teaching and learning seems central.

### 1.5.1. Conceptual links across and within lessons

1.5.1.1. Conceptual links across lessons: (this is an addition to the TIMSS analysis – possible because the data sets extend beyond one lesson)

- LCA2: strong inter-lesson conceptual links: topic links and teacher makes links explicit
- LCA1: some inter-lesson conceptual links: topic links but teacher does not make links explicit
- LCA0: no inter-lesson conceptual links

1.5.1.2. Conceptual links within lessons (taken from TIMSS video study, 2006)

- LCW-2: strong intra-lesson conceptual links within lessons to generalising principles and theories – ‘The lesson is focused on content with conceptual links that strongly connect and integrate the information and activities. The information presented consists primarily of interlocking ideas, with one idea building on another with strong conceptual links [this links with dialogic discourse, the idea of cumulation of ideas and ‘contingent responsiveness’ by the teacher to learners’ contributions]. The lesson contains a strong conceptual thread that weaves the entire lesson into a conceptual whole (TIMSS, 2006 p. 68); in addition, concepts are supported by rich factual detail (Donovan and Bransford, 2005, 6).
- LCW-1: weak conceptual links within lessons – ‘The lesson contains some content but there are only weak or no conceptual links that integrate the information and activities. The information and tasks presented are connected only by a shared topic or by one or two concepts that tie together some of the ideas or activities but do not connect all the information together’ (TIMSS, 2006 p. 68); or there is a focus on principle/concept but not supported by factual details.

- LCW-0: no conceptual links within lessons – ‘The teacher focuses students’ attention primarily on carrying out an activity or procedure rather than learning a content idea. Students may encounter some science content in the process of carrying out an activity but the information is presented as isolated bits of information without being linked to a larger concept’ (TIMSS, 2006 p. 68). OR information presented is incorrect. (OR concepts presented are incorrect – thus there is not the opportunity to develop conceptual frameworks)

1.5.2. Goal statements & summary statements: ‘one way in which teachers can make the content organization of a lesson more explicit for students... (TIMSS, 2006 p. 70)

- GS - 1: goal statement/topic present
- GS - 0: goal statement absent
- SS - 1: summary statement present
- SS - 0: summary statement absent

1.5.3. Consolidation of ideas/concepts by learners in and/or across lessons (e.g. with a written task or assessment); does not include notes copied down – these are coded as input; does not include practical activity; consolidation should come at end of lesson.

- CI/WL -2: consolidation activity within lesson present and appropriate
- CI/WL - 1: consolidation activity within lesson present but inappropriate or confusing; or does not address key ideas; or based on partly/incorrect information
- CI/WL - 0: no consolidation activity within lesson
- CI/AL - 2: consolidation activity across lessons present and appropriate
- CI/AL - 1: consolidation activity within lesson present but inappropriate or confusing (weak link or unrelated to learners' context e.g. skating on ice)
- CI/AL - 0: no consolidation activity across lessons

## **2. Classroom language**

The classroom language was analysed from two perspectives: the classroom discourse and the bilingual languaging patterns.

**2.1. Classroom discourse:** Did the classroom discourse appear to construct or constrain the learners' opportunities to learn science?

The classroom discourse was in turn analysed in terms of the balance of teacher-learner talk; the discourse interaction patterns; and 'bridging discourses'.

### **2.1.1. Balance of teacher-learner talk**

The public talk in each lesson was coded and counted for teachers and learners.

### **2.1.2. Interaction patterns**

The discourse structure and function were coded for whole class talk per episode, and a word count was done for each stretch of a particular discourse pattern. The following categories of classroom talk represent a cline along an 'authoritative-dialogic' continuum (Mortimer and Scott, 2003).

2.1.2.1. Teacher monologue/learner listening quietly or murmuring attention response; e.g. explaining, demonstrating (authoritative), instructing, discipline.

2.1.2.1.1. Teacher monologue: instructions (regulative) – differentiate between instructions for purposes of classroom management and instructions of how to do an experiment – include latter in 2.1.2.1.2. below as it is science knowledge.

2.1.2.1.2. Teacher monologue: explaining content (instructional)

2.1.2.2. Oral cloze – teacher monologue with learners providing key words in response to pause and raised tone; the function would generally be teacher exposition, with participation by learners. Include learners reading off words as instructed by teacher.

2.1.2.3. IRE: teacher led question and answer which follows a ‘triadic dialogue’ pattern of teacher question (I -initiation), learners response (R) learners provide one word/short answers which the teacher evaluates (E) as correct or not; the purpose is generally to check on learners’ understanding.

2.1.2.4. Dialogic exchanges (Initiation-response-feedback-response-feedback): teacher-led question and answer with the teacher providing feedback that prompts a further exchange. This provides the opportunity for the development of chains of meaning; start with the initiation of an idea and follow it through to completion; differs from the IRE exchanges in terms of ‘cumulation’ and the ‘contingent responsiveness’ of the teacher’s response i.e. the teacher responds to and builds on the learner’s response and in so doing co-opts learners into the construction of conceptual frameworks, by modelling the linking of facts and observation through argument (Alexander, 2000 & 2006; Gibbons, 2006; Wells, 1999); this will usually follow a pattern of description => explanation => generalisation (Mortimer and Scott, 2003 pp. 26-27). Alexander refers to this as ‘scaffolded dialogue’ (2000, pp. 526-527); Gibbons as ‘dialogic exchanges’ (2006 pp. 116-117); and Mortimer and Scott as an ‘interactive-dialogic’ approach (2003, p. 105). Indicators of this form of classroom interaction are as follows: (count learners’ contributions into the total for stretch of discourse)

- IRFRF interactions are extended over several turns;
- Teacher’s feedback responds to and builds on learners’ responses (contingent responsiveness);

- Meaning cumulates over several turns and is focused on patterning facts into conceptual frameworks through logical argument – thinking aloud;

2.1.2.5. Learner reporting back from group discussion: exposition by a learner which might be supported by the teacher, but initiated by the learner

2.1.2.6. Learners asking questions: learners ask questions to class or group and teacher manages process. Structure is that of IRE; occasional extended exchanges.

**2.1.3. Bridging discourses** (horizontal connections)– identify and quantify instances per lesson: the teacher creates links between horizontal and vertical discourses (Bernstein in Gibbons, 2006) and provides access to the vertical discourses of schooling: if ‘bridging’ is not achieved, do not count example.

2.1.3.1. Everyday knowledge to science knowledge [include analogies] or science knowledge applied to everyday knowledge

2.1.3.2. Everyday language to science language – science terms or concepts;

2.1.3.3. Empirical to theoretical knowledge – actual experiment rather than everyday knowledge; and look for evidence of links to conceptual framework – not simply teaching of science language

2.1.3.4. Spoken to written language – mode continuum - by learners; include chalkboard writing by teacher if this is part of the bridge for learners but not notes on chalkboard for learners to copy or words jotted down if not linked to writing activity; may include written exercise; include oral rehearsal for writing

### **2.3. Bilingual classroom practices:**

2.3.1. Discourse coded for whole class language use, by word count per lesson TX: teacher – primary language isiXhosa

- TE: teacher – primary language English may include ‘Xhosalised’ words - ‘ibattery’, ‘isulphur’ etc.
- TX: teacher isiXhosa
- LE: learner/s – English
- LX: learner/s – Xhosa

### 2.3.2. isiXhosa coded for function

1. for constructing and transmitting knowledge
2. for classroom management
3. for interpersonal relations

## Appendix 4: Lesson summaries

### Lesson summaries Teacher A

<b>Lesson: A1</b>		
<b>Topic: Relationships in natural world</b>		
<b>Time: 1h15</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher Q&A  Learners read off information from photocopied page (one page per group of 6)	Relationships between air, sunlight, water, soil, plants, animals & humans.
2.	Group discussion	Learners identify food chains from photocopied exercise from textbook
3.	Groups report	Teacher writes up food chains on chalkboard
4.	Teacher explanation	Meaning of 'food chain' through reference to chain learner is wearing
5.	Group discussion	Learners compare their food chains to those from photocopied page from textbook
6.	Teacher explanation	Food web compared to webbed feet of goose and umbrella
7.	Teacher exposition	'Survival of the fittest' & photosynthesis
<b>Lesson: A2</b>		
<b>Topic: Separating mixtures</b>		
<b>Time: 1h59</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher explanation	Concept of separating mixtures – uses analogy of separating sheep and goats for dipping
2.	Group practical activity 1	Separating a mixture of beans and copper pieces
3.	Reporting back – teacher asks (and answers) questions	<ul style="list-style-type: none"> <li>• Copper pieces and beans were separated by hand</li> <li>• Spelling of 'hand' (correction of incorrect use of 'head' by learner)</li> </ul>

		<ul style="list-style-type: none"> <li>• Meaning of 'constituents'</li> </ul>
4.	Group practical activity 2	<ul style="list-style-type: none"> <li>• Separating iron filings and sulphur</li> <li>• Teacher elicits colour of sulphur</li> <li>• Teacher suggests methods of separation – tells learners re magnet and that metal will stick to it</li> <li>• Learners mix sulphur and iron filings; teacher takes magnet to each group to show how it affects mixture; asks learners what 'baby hairs' are; learners unable to identify iron filings</li> </ul>
5.	Reporting back	<ul style="list-style-type: none"> <li>• Teacher role play and explanation that iron filings come from sharpening a hoe</li> <li>• Teacher demonstrates that sulphur on its own does not stick to magnet</li> <li>• Teacher elicits that it was iron filings that stuck to the magnet</li> </ul>
6.	Practical demonstration 3	<ul style="list-style-type: none"> <li>• Separating solution salt and water</li> <li>• Teacher elicits that salt cannot be seen; has dissolved in water</li> <li>• Explains term 'solution' – analogies re soup and medicine</li> <li>• Elicits method to separate salt and water; learner suggest filter paper; teacher filters salt solution – learners taste filtered product</li> </ul>
7.	Reporting back	Liquid is still salty
8.	Teacher explanation	Separate salt and water through boiling (no demonstration)
9.	Practical demonstration 4	<ul style="list-style-type: none"> <li>• Sugar and water solution</li> <li>• Teacher mixes sugar and water – elicits that sugar cannot be seen</li> <li>• Learners taste sugar solution</li> </ul>
10.	Reporting back	<ul style="list-style-type: none"> <li>• Liquid tastes sweet</li> <li>• Teaches terms 'solute' and 'solvent'</li> </ul> <p>(no separation of sugar and water done or discussed)</p>
11.	Practical demonstration 5	Teacher mixes methylated spirits and water
12.	Teacher explanation	Explains that water and methylated spirits have different boiling points and so when heated, methylated spirits will evaporate first and the

		water will be left behind.
13.	Practical demonstration 6	<ul style="list-style-type: none"> <li>• Teacher mixes flour and water and instant coffee and water</li> <li>• Elicits that the bottom part of the flour and water mixture is whiter than the top half – tells class this is residue (incorrect)</li> <li>• Teacher filters flour and water</li> </ul>
14.	Teacher explanation	<ul style="list-style-type: none"> <li>• Explains terms ‘filtrate’ and ‘residue’; some incorrect information re molecules and colloids</li> <li>• Another example of residue is when make tea (not elaborated)</li> </ul>
15.	Teacher explanation: summing up	<ul style="list-style-type: none"> <li>• Mixtures (that have not been made through chemical reaction) can be separated</li> <li>• Have separated mixtures though hand sorting, filtration and evaporation.</li> </ul>
<b>Lesson: A3</b>		
<b>Topic: Decomposition of plants and animals; food web; photosynthesis</b>		
<b>Time: 0h55</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition (following textbook content)	<ul style="list-style-type: none"> <li>• Meaning of inhabitants and mutual relationship</li> <li>• Role of bacteria and maggots in decomposing dead animals</li> <li>• Plants turn brown when they die and form humus which fertilizes the soil</li> <li>• Primary and secondary consumers</li> <li>• Carnivores, omnivores and herbivores</li> <li>• Photosynthesis</li> <li>• Air, soil and water are essential for living organisms</li> <li>• Need to protect the environment</li> </ul>
<b>Lesson: A4</b>		
<b>Topic: Force and calculating work</b>		
<b>Time: 1h30</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher explanation	Scientific meaning of word ‘force’: force must produce an action (incorrect); force is a push or a

		pull (correct)
2.	Teacher demonstration and explanation	Teacher pushes pencil box across desk; pushes and pulls a learner – force has been applied
3.	Teacher demonstration and explanation	Teacher pushes duster across desk and gets learner to push it sideways – effect of force: changes direction
4.	Teacher demonstration and explanation	Teacher gets learner to break a piece of chalk – force changes shape of chalk
5.	Group practical activity	Hands out prestick to each group: learners must make 3 different shapes – change shape – deforming prestick by means of force  Force produces motion – work has been done
6.	Teacher demonstration and explanation	<ul style="list-style-type: none"> <li>• Gets group of learners to push against a wall and joins them</li> <li>• Shows that have not done any work because wall has not moved</li> <li>• Tells story about boy who lifted up cart while father changed wheel – had not done work because cart had not moved</li> </ul>
7.	Teacher demonstration and explanation	Teacher pushes pencil box across desk to demonstrate ‘displacement’ – ‘the change of position through a distance’
8.	Group practical activity	<ul style="list-style-type: none"> <li>• Teacher explains re spring balance and ‘newtons’</li> <li>• Learners come up in groups to read off measurement of mass of pencil case on spring balance</li> <li>• Groups report back (some 1,3N and some 1,4N)and teacher declares 1,4 N correct</li> </ul>
9.	Group practical activity	<ul style="list-style-type: none"> <li>• Measuring accurately: teacher rules line in book and takes round ruler to each group for them to measure line and write down answer</li> <li>• Feedback: groups report 9mm, 10mm, 2 mm</li> <li>• Teacher declares 10 mm correct; asks class how many centimetres are equal to 10 millimetres – unable to answer</li> <li>• Teacher covers up part of ruler to show 10mm on one side and 1 cm on the opposite side – repeats question; learners still unable to answer so teacher tells them.</li> <li>• Teacher tells learners that it is important to</li> </ul>

		line up their eye when measuring to avoid error of parallax and take account of the meniscus (when water is boiling – incorrect) – terms not explained
10.	Teacher demonstration and explanation	<ul style="list-style-type: none"> <li>• Teacher drops duster to demonstrate gravity</li> <li>• Pulls against learner to show that when objects do not move, forces are balanced</li> </ul>
11.	Teacher explanation	Provides formula (force x distance) and does one example
12.	Teacher explanation (accompanied by role play by teacher)	<p>Forces in everyday life:</p> <ul style="list-style-type: none"> <li>• frictional force and slipping on a wet slope</li> <li>• athletes use starting blocks – frictional force (races learner across classroom)</li> <li>• yachts move because of wind blowing</li> <li>• parachute – frictional force – like an umbrella</li> <li>• walking sideways in wind to reduce surface area</li> <li>• force comes from food which gives you energy</li> <li>• car tyres get hot because of friction</li> <li>• sharpen a knife or axe using frictional force</li> </ul>

**Lesson: A5**

**Topic: Force – calculating work and power**

**Time: 0h57**

<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher demonstration	<ul style="list-style-type: none"> <li>• reviews how to calculate work</li> <li>• writes up problem on chalkboard and elicits answers from class</li> </ul>
2.	Teacher explanation	<ul style="list-style-type: none"> <li>• power equals rate of work i.e. amount of work done over a period of time – provides formula ‘power = work ÷ time’</li> <li>• example: athletes are timed – teacher races girl across classroom</li> <li>• example: digging plot of ground – smaller plot takes less time to dig over than big plot; more diggers (boys) takes less time to dig over same size plot</li> </ul>

3.	Teacher demonstration	<ul style="list-style-type: none"> <li>• Solving example with whole class: <ul style="list-style-type: none"> <li>○ Writes up problem on chalkboard</li> <li>○ Elicits answers from learners</li> <li>○ Different results so gets class to vote in correct answer</li> </ul> </li> </ul>
4.	Teacher explanation	Teacher role plays a man loading sand onto a truck – works fast and so very powerful
5.	Group work	Teacher writes problem on chalkboard – calculate work
6.	Group feedback	Teacher elicits answers to work – writes down and ticks correct answer – no explanation
7.	Group work	Teacher writes up second part problem – calculate power
8.	Group feedback	Teacher elicits answers and writes on chalkboard – ticks correct answer – no explanation
9.	Teacher exposition	Learners must work in groups, not try to ‘do it alone ... otherwise you will feel your heads blown up to the sky...’

### Lesson summaries Teacher B

<b>Lesson: B1</b>		
<b>Topic: Properties of mixtures</b>		
<b>Time: 0h48</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Whole class question & answer	Review: <ul style="list-style-type: none"> <li>• a mixture is two things mixed together</li> <li>• the properties of the two things that are mixed remain the same</li> </ul>
2.	Group practical activity  Teacher engages with groups – asks probing questions	Learners copy down table to fill in results of experiment  Identify properties of sulphur powder and iron filings <ul style="list-style-type: none"> <li>• Learners observe and test properties sulphur powder and iron filings and fill in table: re colour and magnetism</li> </ul>

3.	Groups report  Teacher elicits properties and writes up on chalkboard	<ul style="list-style-type: none"> <li>properties of sulphur powder and iron filings: colour and magnetism</li> <li>Sulphur powder <ul style="list-style-type: none"> <li>colour yellow</li> <li>non-magnetic</li> </ul> </li> <li>Iron filings <ul style="list-style-type: none"> <li>colour silver grey</li> <li>magnetic</li> </ul> </li> </ul>
4.	Group practical activity  Teacher engages with groups – asks probing questions	Properties of mixture of sulphur powder and iron filings  Learners observe and test for properties of colour and magnetism of mixture of sulphur and iron filings
5.	Groups report  Teacher elicits properties and writes up on chalkboard	Properties of mixture of iron filings and sulphur  Generalisation: properties of substances in mixtures do not change
6.	Group discussion  Teacher engages with groups – asks probing questions	Definition of a mixture?
7.	Groups report  Teacher elicits definition and writes up on chalkboard	Mixture – where properties of two substances remain the same  Elicits other examples of mixtures and fact that properties do not change.
8.	Whole class question & answer	Why is it necessary to cover magnet with paper when testing iron filings?  So that iron filings can be easily removed
9.	Conclusion:	Will make a compound from sulphur powder and iron filings the following day
<b>Lesson: B2</b>		
<b>Topic: Compounds</b>		
<b>Time: 1h14</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Whole class question &	Which is heavier: kilogram of feathers or kilogram of

	answer  Learners to work it out - will get answer next day	stones?
2.	Whole class question & answer	Review: key concepts re mixtures from previous lesson
3.	Teacher explanation – elicits answers	<p>Meaning of ‘properties’</p> <ul style="list-style-type: none"> <li>• Elicits meaning of ‘properties’ in relation to properties of sulphur and iron filings</li> <li>• Learners look up meaning in textbook glossary</li> <li>• analogy of family features used to identify family members e.g. shape of chin – feature used to identify</li> </ul>
4.	Practical demonstration: learners observe while teacher conducts experiment	<p>Making a compound</p> <ul style="list-style-type: none"> <li>• writes up name of compound: iron sulphide: appearance; magnetic or not</li> <li>• Elicits names and purpose of apparatus <ul style="list-style-type: none"> <li>○ spirit lamp</li> <li>○ deflagrating spoon</li> </ul> </li> <li>• Heats mixture of iron filings and sulphur while learners observe</li> </ul>
5.	Learners report observations	<ul style="list-style-type: none"> <li>• the mixture ‘burns’ with a blue flame</li> <li>• there is a smell</li> </ul>
6.	Teacher explanation – elicits answers	<ul style="list-style-type: none"> <li>• When you heat sulphur powder and iron filings they <u>react</u></li> <li>• The colour of the new substance is brown – different from sulphur (yellow) and iron filings (silver grey)</li> <li>• A new substance is formed: iron sulphide</li> <li>• Iron sulphide is a compound</li> <li>• The properties of iron sulphide are different to the properties of iron filings and sulphur – the reactants</li> <li>• Hydrogen reacts with oxygen to form water</li> <li>• Hydrogen and oxygen are gases; water is a liquid</li> <li>• There is a pattern: the properties of the reactants are completely different to the properties of the compound that is formed</li> <li>• Two elements have reacted to form a compound</li> <li>• The definition of a compound: a substance that is formed when two elements have reacted – with different properties from the reactants</li> </ul>
7.	Individual task	Tabulate 3 differences between mixtures and compounds

8.	Whole class activity	Look up meaning of word 'reaction' in textbook glossaries and dictionaries
<b>Lesson: B3</b>		
<b>Topic: Separating mixtures - soil and water</b>		
<b>Time: 1h14</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Whole class question & answer	Review: <ul style="list-style-type: none"> <li>Elicits that used property of magnetism to separate iron filings and sulphur</li> <li>Emphasizes: to separate mixtures, look at difference in properties</li> </ul>
2.	Group practical activity – teacher asks probing questions	separating mixture soil and water <ul style="list-style-type: none"> <li>Elicits names and purpose of apparatus</li> <li>Must observe carefully because will have to draw apparatus afterwards</li> <li>One learner from each group folds filter paper and inserts in funnel; one learner demonstrates and explains to class</li> <li>Groups each filtered water and write up observations according to guiding questions on chalkboard: <ul style="list-style-type: none"> <li>What do you see on the test tube?</li> <li>What remains on the funnel?</li> </ul> </li> </ul>
3.	Whole class question & answer	Why is the water not running out at the same rate from the different test tubes? <p>Learners offer possible answers:</p> <ul style="list-style-type: none"> <li>filter paper not the same (some groups had been given filter paper, others newsprint – check)</li> <li>the mixtures were not the same – some was thicker than others</li> </ul>
4.	Groups report back – teacher elicits	In test tube there is clean water (filtrate) On the filter paper there is soil (residue)
5.	Teacher explanation – elicits answers	What is the reason that the soil remains on the filter paper and water passes through?  The holes in the filter paper are small; the particles of soil are bigger than the holes in the filter paper.

6.	Teaches terms:	Filtrate Residue Filtration
7.	Group discussion	Uses of filtration in home
8.	Groups report	Making tea Making African beer Making amarhewu
9.	Class discussion	Learner offer apparently nonsensical example – adding sand to muddy water to clean it; with help of other learner it transpires that learner means add cement to muddy water so that sand particles sink to bottom. Teacher provides scientific term: sedimentation – and explains it is not an example of filtration.
10.	Individual classwork	Draw and label filtration apparatus
<b>Lesson: B4</b>		
<b>Topic: Separating mixtures – salt and water</b>		
<b>Time: 1h18</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Whole class question & answer	Review: soil and water mixture was separated using the process of filtration
2.	Teacher explanation	Will separate a salt solution  A mixture of water and anything is called a solution (not correct)  Uses surname as analogy for ‘solution’  Sugar plus water forms a sugar solution
3.	Teacher demonstration – elicits key points	<ul style="list-style-type: none"> <li>• Teacher mixes salt and water; salt dissolves in water to form salt solution; learner tastes solution to show salt has not ‘disappeared’</li> <li>• Teacher elicits that can get salt back by heating solution; water will evaporate – change from liquid to gas phase</li> <li>• Elicits names of apparatus <ul style="list-style-type: none"> <li>○ tripod stand</li> <li>○ wire gauze</li> <li>○ evaporating basin</li> </ul> </li> </ul>

		<ul style="list-style-type: none"> <li>○ spirit lamp</li> <li>○ sodium chloride</li> <li>• will only collect salt, not water</li> <li>• Teacher heats solution in evaporating dish over spirit lamp</li> </ul>
4.	Teacher question and answer	<p>Elicits key observations</p> <ul style="list-style-type: none"> <li>• see water vapour – process of evaporation</li> <li>• salt remains on dish</li> <li>• recovered salt through process of evaporation</li> <li>• when separate mixtures, look at properties</li> </ul>
5.	Teacher question and answer	<p>Other methods without using flame?</p> <ul style="list-style-type: none"> <li>• heat from sun</li> </ul> <p>In nature?</p> <ul style="list-style-type: none"> <li>• evaporation in dams</li> <li>• evaporation and condensation =&gt; water cycle</li> </ul>
6.	<p>Individual classwork</p> <p>Writing frame on chalkboard</p> <p>Oral rehearsal</p> <p>Teacher monitors and intervenes to support writing</p>	Write up experiment
<b>Lesson: B5</b>		
<b>Topic: Separating mixtures using distillation and separating funnel; summary of separation methods</b>		
<b>Time: 1h29</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question and answer	<p>Review:</p> <p>separation method based on difference in properties of components</p>
2.	Teacher explanation – uses chalkboard to illustrate process; elicits key points	Use process of distillation to separate mixture of liquids with different boiling points e.g. alcohol and water

3.	Teacher explanation—uses chalkboard to illustrate process; elicits key points	Use separating funnel to separate mixture oil and water
4.	Teacher question and answer	Summary of separation of mixtures Mindmap of different methods
5.	Individual classwork from textbook; teacher monitors and probes	Methods of separating different kinds of mixtures When deciding on method of separation, need to consider the properties of the substances that are mixed.

## Lesson summaries Teacher C

<b>Lesson: C1</b>		
<b>Topic: Phases of matter and phase changes</b>		
<b>Time: 1h01</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question & answer	Writes up topic on chalkboard: Phases of matter and phase changes  Review: elicits 3 phases matter & examples  <ul style="list-style-type: none"> <li>• Solid</li> <li>• Liquid</li> <li>• Gas</li> </ul>
2.	Teacher exposition – writes up points on chalkboard	Properties  <ul style="list-style-type: none"> <li>• solids - have fixed shape &amp; volume</li> <li>• gases - fill whole container – no fixed shape</li> <li>• liquids – change shape easily but volume stays same</li> </ul>
3.	Teacher demonstration	Liquids take shape on container  Pours water into different containers and shows them to groups
4.	Teacher exposition	Teacher hands out photocopied activity from textbook  Example of phase change: jelly powder and hot water are mixed and cooled to make solid jelly  Goes through this with learners
5.	Teacher exposition	How energy of substance changes from one phase to another  Illustrated on chalkboard
6.	Teacher exposition	Useful phase changes  <ul style="list-style-type: none"> <li>• Glue setting <ul style="list-style-type: none"> <li>○ liquid to solid</li> </ul> </li> <li>• water cycle <ul style="list-style-type: none"> <li>○ evaporation – liquid to gas</li> <li>○ condensation - gas to liquid</li> </ul> </li> </ul>

7.	Teacher exposition	Unwanted phase changes <ul style="list-style-type: none"> <li>• global warming – burning fossil fuels – too much CO<sub>2</sub> – global warming – ice melt in north and south poles in Antarctica – sea get hot – fish die</li> <li>• Evaporation from cells of plants</li> <li>• Water from car radiator freezes</li> </ul>
<b>Lesson: C2</b>		
<b>Topic: Mixtures involving 3 phases of matter</b>		
<b>Time: 0h43</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition – elicits some facts from learners	<ul style="list-style-type: none"> <li>• Review: 3 states of matter</li> <li>• Mixture: substances mixed with another without chemical reaction</li> <li>• Can be elements (one atom) or compounds (2 or more elements)</li> <li>• Types of mixtures</li> <li>• gas &amp; gas</li> <li>• solid &amp; solid</li> <li>• solid &amp; liquid</li> </ul>
2.	Group practical activity	<p>Solid &amp; liquid mixtures</p> <p>Learners add salt to one test tube of water, sugar to another and sand to the third and shake them</p>
3.	Groups report – teacher elicits answers	<ul style="list-style-type: none"> <li>• Sugar dissolves in water – one phase <ul style="list-style-type: none"> <li>○ Solution; solute; solvent</li> </ul> </li> <li>• Salt dissolves in water – one phase</li> <li>• Sand does not dissolve in water <ul style="list-style-type: none"> <li>○ suspension</li> </ul> </li> </ul>
4.	Group practical activity	<p>Liquid &amp; liquid mixtures</p> <p>Learners add vinegar, paraffin &amp; milk to test tubes of water</p>
5.	Groups report – teacher elicits answers	<ul style="list-style-type: none"> <li>• Vinegar &amp; water – one phase – dissolve</li> <li>• Paraffin &amp; water – 2 phases (not corrected) – does not dissolve</li> </ul>
6.	Teacher exposition – elicits some examples	<ul style="list-style-type: none"> <li>• Miscible liquids dissolve e.g. <ul style="list-style-type: none"> <li>○ cooldrink &amp; water</li> <li>○ milk &amp; water</li> </ul> </li> <li>• Immiscible liquids do not dissolve <ul style="list-style-type: none"> <li>○ oil &amp; water</li> </ul> </li> </ul>

		<ul style="list-style-type: none"> <li>○ benzene &amp; water</li> <li>• Suspensions e.g. <ul style="list-style-type: none"> <li>○ blood does not dissolve in water – white blood cells float on top (incorrect)</li> <li>○ milk</li> <li>○ smoke</li> </ul> </li> <li>• Emulsifier – makes oil &amp; water dissolve <ul style="list-style-type: none"> <li>○ emulsion <ul style="list-style-type: none"> <li>▪ e.g. mayonnaise – vinegar &amp; oil</li> </ul> </li> </ul> </li> </ul>
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**Lesson: C3**

**Topic: Choosing a water scheme**

**Time: 2h00**

Episode	Organisation	Content
1.	Teacher question & answer	Announces topic  Asks for examples of development in own community
2.	Teacher exposition	Reads and explains case study of 'Ekulandeni village' from textbook' – 3 different water schemes proposed
3.	Groups discussion	Discuss points for and against each scheme – decide which is best for village
4.	Groups report on comparison on schemes – teacher prompts	Learners do not answer questions – read out inappropriate chunks of text
5.	Group discussion	Choose best scheme for village
6.	Groups report – prompting from teacher	Points unclear

**Lesson: C4**

**Topic: Classifying materials**

**Time: 1h04**

Episode	Organisation	Content
1.	Teacher exposition	Natural & artificial materials (incorrect examples given – confuses 'artificial/man- made material with man-made article)
2.	Teacher explanation	How to classify materials according to properties – based on chart copied from textbook

3.	Group practical activity	Teacher hands out different materials (aluminum foil, ceramic tile, glass, plastic bag,)  Groups to test and classify them according to chart  State common use
4.	Groups report back - teacher prompts and fills in table on chalkboard	‘Tests’ as per chart do not all work with materials provided or means of testing not provided e.g. metal conducts electricity.  Many incorrect conclusions
5.	Teacher exposition	Other properties:  Strength - ability to withstand pressure e.g. disposable nappies  Elasticity  Flammability  Flexibility  Alloys - mixture of metals
6.	Learners copy ‘important points’ from chalkboard	

**Lesson: C5**

**Topic : Synthetic materials**

**Time: 0h46**

<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition - elicits examples	Review:  Artificial and natural materials  Plastics example of synthetic materials - made by humans  Elicits examples of plastic in home  Uses of plastics <ul style="list-style-type: none"> <li>• Medical e.g. artificial hip bone - titanium and plastic - because of properties</li> <li>• Entertainment e.g. CDs, radios, TVs, computers, toys</li> <li>• Packaging e.g. fast food</li> </ul>

		<ul style="list-style-type: none"> <li>• Clothing – polyester</li> </ul> <p>Types of plastic</p> <ul style="list-style-type: none"> <li>• thermoplastics – flexible – burn easily</li> <li>• thermosetting – hard – heat resistant</li> </ul>
2.	Teacher question & answer	<p>Why are plastics the symbol of pollution?</p> <ul style="list-style-type: none"> <li>• People throw plastic bags away</li> </ul> <p>How can people become less dependent on plastic bags?</p> <ul style="list-style-type: none"> <li>• People must buy plastic bags</li> </ul>
3.	Teacher instructions – writes up recycling project	<p>PROJECT</p> <p>A recycling project</p> <p>Have 4 bins side by side. Use one to collect <u>plastics</u>, one for <u>glass</u>, one for <u>metals</u> and one for paper. When each bin is full, you can sell the material at your nearest recycling depot. On your visit find out how the material is recycled and write a full report about your visit.</p> <p>(seems unlikely that this will be possible given remote rural location of school)</p>

## Lesson summaries Teacher D

<b>Lesson: D1</b>		
<b>Topic: Food web</b>		
<b>Time: 0h51</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition – question and answer – writes up answers on chalkboard	<p>Elicits what learners ate for supper previous night.</p> <p>Human beings eat chicken</p> <p>Chicken eat maize</p> <p>This is a food chain</p> <p>Another example is cows eat grass and humans eat cows</p> <p>Plants are the first link in the food chain – they are producers</p> <p>Animals that only eat plants are called herbivores – primary consumers</p>
2.	Group activity – hands out one sheet per group – photocopy of activity from textbook; teacher monitors and asks probing questions	<p>Learners link animals and plants in food chains with arrows</p> <p>Teacher does one example – grass goes to impala and impala goes to lion</p>
3.	Groups report back – teacher elicits	<p>Teacher sticks up words on card on chalkboard to match diagram in textbook – makes linking arrows as learners report on food chains</p> <p>When food chains are linked together they form a food web.</p>
4.	Teacher writes notes on chalkboard and learners copy them in notebooks	<p>NS</p> <p><b>FOOD CHAINS</b></p> <ul style="list-style-type: none"> <li>• A food chain is a way of showing how living organisms depend on one another for food.</li> <li>• The first link of the food chain are the <u>Green Plants</u>.</li> <li>• The green plants are the food producers.</li> </ul>

		<ul style="list-style-type: none"> <li>• The second link of the food chain are the <u>Herbivores</u>.</li> <li>• Herbivores are animals that live on green plants only.</li> <li>• All the animals are consumers since they cannot manufacture their own food.</li> <li>• When two or more food chains are linked together they are known as a <u>food web</u>.</li> </ul> <p>(leaves out carnivores)</p>
5.	Teacher calls on groups to report on food chains again	Groups report as before
6.	Teacher exposition	<p>Sums up key points:</p> <p>First link is green plants</p> <p>Next is herbivores and then animals that eat both animals and plants. (leaves out carnivores)</p>
<b>Lesson: D2</b>		
<b>Topic: Producers and consumers</b>		
<b>Time: 0h51</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question & answer	<p>Review of previous lesson:</p> <ul style="list-style-type: none"> <li>• a food chain is the way living organisms depend on one another</li> <li>• a food web is the link between the food chain</li> <li>• green plants are the first link in the food chain</li> <li>• herbivores are the second link in the food chain</li> <li>• animals are consumers</li> <li>• plants are producers</li> </ul>
2.	Teacher writes notes on chalkboard and learners copy them in notebooks	<p>INFORMATION ABOUT PRODUCERS AND CONSUMERS</p> <ul style="list-style-type: none"> <li>• Plants are producers</li> <li>• Plants can use water, carbon dioxide and the sun's energy to produce food.</li> <li>• Plants store energy in food.</li> <li>• Plants are called producers.</li> </ul>

		<ul style="list-style-type: none"> <li>• Animals are consumers.</li> <li>• Animals use energy from food.</li> <li>• Animals cannot make their own food and therefore they need to eat plants or other animals.</li> <li>• The word <u>consume</u> means to <u>use</u> or to <u>eat</u>.</li> <li>• Animals which eat only plants are called <u>herbivores</u>.</li> <li>• Herbivores are also called <u>primary consumers</u>. They eat producers.</li> <li>• Animals which eat only meat are called <u>carnivores</u>.</li> <li>• Carnivores are called <u>secondary consumers</u> because they eat primary consumers.</li> <li>• Animals which eat plants and animals are called omnivores.</li> <li>• Humans are omnivores.</li> </ul>
3.	Teacher instructs learners to read notes and one scribe per group to copy table from chalkboard.	
4.	Group activity	Learners discuss and fill in information in table about producers and consumers using information in notes.
5.	Teacher question and answer - elicits answers from learners	<p>Primary consumers are herbivores</p> <p>Secondary consumers are carnivores</p> <p>Consumers that are both primary and secondary - omnivores</p>
<b>Lesson: D3</b>		
<b>Topic: Photosynthesis and respiration</b>		
<b>Time: 1h03</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition	Production is the change of input into outputs

		Elicits ingredients and process of making tea Plants use process of photosynthesis to make food
2.	Teacher exposition using chart – copy of picture from textbook of pumpkin plant – to illustrate photosynthesis	Sticks labels on picture while describing process of photosynthesis: <ul style="list-style-type: none"> <li>• Sun</li> <li>• Water</li> <li>• Food</li> <li>• Pumpkin leaves</li> <li>• Carbon dioxide</li> <li>• oxygen</li> </ul>
3.	Teacher exposition – writes up key points on chalkboard;	Photosynthesis is the producing of food by the green plants with the help of the sun, water, carbon dioxide and chlorophyll.  Photosynthesis can be written as an equation:  Chlorophyll + CO <sub>2</sub> + H <sub>2</sub> O + energy from the sun = food and O <sub>2</sub>
4.	Group discussion – write down answers individually.	Plants are producers of food. <p>a. In what way do plants produce their own food (show by means of a table)</p> <p>b. Show by means of an equation how photosynthesis processes take place.</p> <p>c. Define photosynthesis.</p>
5.	Teacher collects class work.	
<b>Lesson: D4</b>		
<b>Topic: Respiration</b>		
<b>Time: 0h28</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition	Review: equation for photosynthesis – reminds class that many forgot to include chlorophyll (incorrect)  Respiration is the method we use to get energy from food  The equation for respiration is the other way round from

		<p>photosynthesis</p> <p>Food + O<sub>2</sub> = H<sub>2</sub>O + CO<sub>2</sub> + sun's energy + chlorophyll</p> <p>We give plants carbon dioxide and plants give us oxygen</p>
2.	Teacher writes notes on chalkboard which learners copy into their notebooks	<p>PHOTOSYNTHESIS</p> <ul style="list-style-type: none"> <li>• Photosynthesis is the method used by the green plants to produce their own food with the help of the energy from the sun; chlorophyll; water (H<sub>2</sub>O) and carbon dioxide.</li> <li>• Photosynthesis also produces oxygen.</li> <li>• Equation for photosynthesis: Energy + CO<sub>2</sub> + H<sub>2</sub>O + chlorophyll = food and oxygen</li> <li>• All living things use a method called <u>RESPIRATION</u> to get energy from their own food.</li> <li>• Respiration is the process whereby living things get energy from food.</li> <li>• As the plants release oxygen during photosynthesis process, living things get that oxygen for breathing.</li> <li>• As living things release carbon dioxide plants get that carbon dioxide for photosynthesis.</li> <li>• Equation for respiration: food and oxygen = energy + CO<sub>2</sub> + H<sub>2</sub>O + chlorophyll</li> <li>• All living things depend on non-living things such as water, sun's energy, carbon dioxide for respiration.</li> </ul>
<b>Lesson: D5</b>		
<b>Topic: Decomposers</b>		
<b>Time: 0h46</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question & answer	<p>Review:</p> <p>'Inputs' in process of photosynthesis</p> <ul style="list-style-type: none"> <li>• sun energy</li> <li>• chlorophyll</li> <li>• water</li> </ul>

		<ul style="list-style-type: none"> <li>• carbon dioxide</li> </ul>
2.	Teacher exposition – writes key points on chalkboard	<p>Plants that have no chlorophyll feed themselves on dead plants and animals because they cannot make their own food.</p> <p>2 types of plants with no chlorophyll</p> <ol style="list-style-type: none"> <li>1. fungus</li> <li>2. bacteria</li> </ol> <p>They are important because</p> <ul style="list-style-type: none"> <li>• They are decomposers</li> <li>• They undergo recycle process</li> <li>• They keep the soil fertile</li> </ul> <p>[note: bacteria and fungi are not plants – although the textbook refers to fungi as plants (p. 26 SfA). Fungi are a separate kingdom ]</p>
3.	Learners copy notes from chalkboard	
4.	Teacher rubs off notes and writes up task – learners complete individually	<ol style="list-style-type: none"> <li>1. What is the name of the green pigment that helps the green plants during photosynthesis?</li> <li>2. Name two plants that cannot make their own food.</li> <li>3. Name two things on which plants named in <u>2</u> live on.</li> </ol>

## Lesson summaries Teacher E

<b>Lesson: E1</b>		
<b>Topic: Saving water</b>		
<b>Time: 0h51</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher instructions for groups to present posters: 2 minutes to present; 1 minute for 'audience to ask question from group; 1 minute for presenters to ask questions to audience	
2.	Group 1 presents – teacher intervenes to correct procedure and to direct questioning by audience and group; class votes on mark for group;	Introduce themselves Stop wasting water – stop taps dripping No questions
3.	Teacher calls for comments; then class claps	Did not raise voices Shy Not sure of what presenting
4.	Group 2 presents – same procedure	Water is made of hydrogen and oxygen Every living thing needs water Our bodies are made up of a third of water (not on topic saving water)
5.	Questions from presenters to class	(not on topic of saving water) Q: Where do you get water from? R: dams R: taps R: oceans

		<p>R: rain</p> <p>Q: How many glasses of water can you drink in a day?</p> <p>R: 8</p> <p>Q: What does water do to our bodies?</p> <p>R: wash</p> <p>R: drink energy</p> <p>R: gives of unwanted substances (teacher)</p>
5.	Teacher calls for marks; class votes on mark; no comments from class	
6.	Group 3 presents – same procedure	<p>Stop wasting water</p> <p>Must not leave tap open</p>
7.	Teacher calls for questions from class – none; calls for questions from presenters	<p>Q: what does poster heading say</p> <p>R: stop wasting water</p> <p>Q: In other names what does water stand for?</p> <p>R: H<sub>2</sub>O</p> <p>Q: If there is no waster what can happen to us?</p> <p>R: we die.</p>
8.	Learner corrects group	H <sub>2</sub> O is not another name for water, it is what water is made of
9.	Teacher calls for marks – same – no voting	
10.	Teacher calls for comments	<p>(procedural matters)</p> <p>Only one member of group talked</p> <p>They did not introduce themselves</p>
11.	Group 4 presents – same procedure	<p>Learners introduce themselves</p> <p>Water is important. Do not waste water</p>
12.	Questions from presenters to class	Question unclear – class laughs
13.	Teacher calls for marks;	

	class votes and claps	
14.	Teacher calls for comments	<p>Presentation not focused on water</p> <p>They were laughing</p> <p>Only one person presented</p> <p>They were not speaking loudly</p>
15.	Group 5 presents - same procedure	<p>Learners introduce themselves</p> <p>Water is colourless</p> <p>It is composed of hydrogen and oxygen</p> <p>This is a tap and water is running</p>
16.	Teacher calls for question to group - none; calls for questions from presenters - none; calls for comments	<p>Only one person talking</p> <p>Not talking about saving water</p>
17.	Teacher calls for marks; class votes (no clapping)	
18.	Group 6 presents - same procedure	<p>Learners introduce themselves</p> <p>We must not let children play with water</p> <p>We must make sure environment is clean round water - dams and lakes</p>
19.	Teacher calls for questions from class	Learner queries that poster was produced by group - teacher rules it irrelevant
20.	Teacher calls for questions from group	<p>Q: Where do we get water?</p> <p>Responses: dams, oceans, lakes</p> <p>Q: Can we save water?</p> <p>R: stopping children (indistinct)</p>
21.	Teacher calls for comments	<p>They were laughing.</p> <p>They were shy.</p> <p>(learner's name) was nervous.</p>

22.	Teacher calls for marks; class votes and claps	
23.	Group 7 presents - same procedure	Learners introduce themselves  We stop people from dirtying water
24.	Teacher calls for questions from class	Asks question re poster (unclear)  Learner reads out: do not waste water.
25.	Teacher calls for question from group to class	Mostly indistinct (class laughing rowdily)  Where do waster come from (not answered)
26.	Teacher calls for comments	They were not sure of what they were presenting.  X was speaking to the audience – he was speaking Xhosa.
27.	Teacher calls for marks – same marks proposed – no voting; class claps.	
28.	Teacher instructions: remaining groups to present in next period	
<b>Lesson: E2</b>		
<b>Topic: Saving water/air pollution</b>		
<b>Time: 0h43</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Group 8 presents poster on saving water– same procedure	Learners introduce themselves  We cannot live without water  We find clean water in the sea, river.
2.	Presenter asks learners in class	Q. Where do we find water?  R. Ocean  Q. What is the colour of water?  R. Water is colourless
3.	Teacher invites questions from class to	indistinct

	presenters	
4.	Teacher calls for comments	They did not prepare
5.	Teacher calls for marks; class votes and claps	
6.	Teacher announces new topic: pollution. Teacher exposition – elicits some information	<p>Pollution is the contamination of the environment</p> <p>There are 4 types of pollution</p> <ul style="list-style-type: none"> <li>• Air pollution</li> <li>• Land pollution</li> <li>• Water pollution</li> <li>• Noise pollution</li> </ul>
7.	Teacher elicits causes of air pollution from class – writes up as mind map	<p>Causes</p> <ul style="list-style-type: none"> <li>• Smoking</li> <li>• Car exhaust</li> <li>• Dust</li> <li>• Fire smoke</li> <li>• Factory chimneys</li> <li>• Trains</li> </ul>
8.	Teacher elicits problems caused by air pollution – writes up as mind map	<p>Problems</p> <ul style="list-style-type: none"> <li>• diseases</li> </ul>
9.	Group discussion	Mind map problems caused by air pollution
10.	Reporting from whole class – teacher elicits and adds to mind map	<p>Problems</p> <ul style="list-style-type: none"> <li>• TB</li> <li>• cancer</li> <li>• asthma</li> <li>• accidents</li> <li>• choking</li> <li>• death</li> </ul>
11.	Teacher instructions - homework	Solutions to problems
<b>Lesson: E3</b>		
<b>Topic: Air pollution/land pollution</b>		
<b>Time: 0h42</b>		

Episode	Organisation	Content
1.	Groups present solutions to air pollution; teacher writes up on chalkboard	SOLUTION <ul style="list-style-type: none"> <li>- stop smoking</li> <li>- stop making fires</li> <li>- use hoovers instead of brooms</li> <li>- stop cooking on fire, buy electric stove [electricity power stations burn coal =&gt; air pollution]</li> <li>- service cars</li> <li>- stop dumping old food</li> </ul>
2.	Teacher exposition	Recycling contributes to the 'People's contract' (ANC election slogan)
3.	Teacher exposition – elicits some points	Land pollution is the contamination of land  Causes: papers, plastics, old food, empty tins/cans, glasses  Pollutant is anything that pollutes the environment
4.	Learners discuss in pairs	examples of pollutants
5.	Learners report – teacher elicits answers and writes up	cardboards, old desks, ornaments, old clothes, bottle tops, hairs [from when hair is cut], old shoes, old cars, empty bottles, dead animals
6.	Group activity	Problems caused by pollutants
7.	Group 1 reports – teacher writes up on chalkboard	Papers block toilets
8.	Group 2 reports	Broken glass causes injuries  Old food smells bad
9.	Group 3 reports	Germs  Smell from dead animals  Hurt from broken glass
<b>Lesson: E4</b>		
<b>Topic: Land pollution</b>		

**Time: 0h42**

<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Group 4 reports; class claps	Germ from old food Smell from dead animals Hurt from broken bottles
2.	Group 5 reports; class claps	Hurt from broken bottles Animals swallow plastic Old food kills animals
3.	Group 6 reports; class claps	(Repetition of previous points ) sick from smell of old food
4.	Group 7 reports; class claps	Old food causes flies Plastic and papers pollute our homes Urinating anywhere
5.	Group 8 reports; class claps	Children get sick from playing with old food Dead animals stink Paper blocks toilets Broken glass makes injuries
6.	Group 9 reports; class claps	Smoking cigarettes causes asthma (ruled irrelevant by teacher) Glass causes injuries Papers block drains Get diseases from old food
7.	Group 10 reports; class claps	(repetition of points)
8.	Group 11 reports; class claps	(repetition of points)
9.	Teacher exposition	When we come from the toilet must wash hands - prevent diseases like cholera.
10.	Teacher instructs groups to report on	

	solutions to land pollution	
11.	Group 1 reports; class claps	Put old food in bins Dig holes for dead animals Stop putting magazines in toilets Stop broken bottles
12.	Teacher exposition	Recycle bottles – sell for profit to fight poverty and unemployment
13.	Group 2 reports; class claps	(repetition previous points) put old food in a banana cycle (elicited by teacher) people must urinate in toilet
14.	Group 3 reports; class claps	Give left over food to people who need it Government must build toilets for people living in shacks. Must not let animals play outside our yards because they can be hit by a car.
15.	Group 4 reports; class claps	(repetition)
16.	Group 5 reports; class claps	(repetition)
17.	Group 6 reports; class claps	(repetition)
18.	Group 7 reports; class claps	(repetition) stop children playing with dirty things
19.	Group 8 reports; class claps	(repetition)
20.	Teacher instructions: short class test next lesson	
<b>Lesson: E5</b>		
<b>Topic: Land pollution</b>		
<b>Time: 0h52</b>		

Episode	Organisation	Content
1.	Teacher instructions: groups to present posters on how to prevent land pollution (repetition of content from previous lesson)	
2.	Group 1 presents poster	Learners introduce themselves. Flowers need healthy soil to grow Farmers need healthy soil to grow food so we must stop land pollution Broken bottles can hurt us. Use dust bins to throw paper.
3.	Teacher instructs class to ask group questions	Q: how do papers make the soil unhealthy? They are just polluting it.
4.	Teacher calls for marks; learners vote; and then clap	
5.	Group 2 presents poster	Learners introduce themselves. Land pollution can make us sick. Fire is dangerous – people must not make fire for no reason.
6.	Teacher calls on class to ask questions from group	Q. Does fire cause land pollution? Only air pollution. R: Lots of ash
7.	Teacher explanation	Grass and animals will be burnt; dead animals contribute to land pollution; soil erosion will take place.
8.	Teacher calls on group to ask questions to class	Q. (indistinct) Responses: papers; plastics; dead animals, broken bottles. Q. What is land pollution R. Pollution that make land dirty; pollutants
9.	Teacher calls for comments	Their poster is so small. Some learners are not talking

		They do not feel free to talk loud. They didn't say stop land pollution.
10.	Teacher calls for marks; class claps	
11.	Group 3 presents	Learners introduce themselves. Stop land pollution. Let's treat our planet like a flower. Use a dustbin for litter.
12.	Teacher calls for questions from class to presenters	Q: What about the flower. R: We must keep our planet alive and growing. Q: (indistinct) R: this world tells you to put garbage inside a dustbin not around the world. Q: (indistinct) R: it says 'If you notice this notice you will notice that this notice is worth noticing.'
13.	Teacher calls for questions from group to class	Q: give me 4 types of pollution Responses: papers; water pollution; noise pollution; Q: What is pollution? (learners break down in giggles when nominated to answer)
14.	Teacher calls for comments	They were laughing. She was speaking Xhosa. (class getting rowdy with loud laughter)
15.	Teacher calls for marks; class votes; class claps	
16.	Group 4 presents	Learners introduce themselves. (repetition of previous points)
17.	Teacher calls for question from class to group	Learners ask for clarification about pictures poster.

18.	Teacher calls for questions from group to class; there are none; class for comments from class	Poster was too small. Only two in group talked. They were laughing.
19.	Teacher calls for marks; class votes and claps.	

## Lesson summaries Teacher F

<b>Lesson: F1</b>		
<b>Topic: Electric circuits</b>		
<b>Time: 0h47</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition – some facts elicited	<ul style="list-style-type: none"> <li>• Volts are amount of energy in battery</li> <li>• 1,5,V &amp; 12 V batteries</li> <li>• positive and negative terminals/signs</li> <li>• copper used for electric circuits because good conductor of electricity</li> <li>• plastic bad conductor – insulator</li> <li>• circuit – path travelled by electricity – positively and negatively charged particles</li> <li>• positively charged particles – protons</li> <li>• negatively charged particles – electrons</li> <li>• electric current – when protons and electrons are moving</li> <li>• plastic bad conductor so used to cover electric wires</li> <li>• homes are supplied with 260 V</li> </ul>
2.	Individual classwork – teacher writes exercise on chalkboard	<p>Classwork</p> <p>a) How do we measure the energy that is contained in a battery.</p> <p>b) i) Give a sign that for positive ii) give a sign for negative</p> <p>c) Why do we use copper for electric circuits</p> <p>d) When the protons and electrons start moving from the battery through the wire we get an electric ....</p>
3.	Report back – Teacher elicits correct answers and learners correct work	<p>a) volt</p> <p>b) - +</p> <p>c) good conductor</p> <p>d) current</p>
<b>Lesson: F2</b>		
<b>Topic: Static electricity</b>		
<b>Time: 0h35</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>

1.	Teacher exposition	<ul style="list-style-type: none"> <li>• Static electricity different to electricity have in homes – static electricity does not move through wires</li> <li>• All objects are neutral – have same number of positively charged particles (protons) and negatively charged particles (electrons)</li> </ul>
2.	Class activity	Tells learners to tear up paper into small pieces; then rub plastic ruler against hair; then pick up pieces of paper with ruler
3.	Teacher exposition	<p>Explains that when rubs ruler, some electrons are rubbed off – ruler is no longer neutral – charged positively</p> <p>Paper is neutral</p> <p>(rest of explanation re attraction very confused; learners get very restive)</p>
4.	Teacher writes up homework	Compare static electricity with the electricity that we use/have at our homes.
5.	Learners ask some questions	<p>L: (indistinct)</p> <p>T: little sparks when take off clothes because they become electrically charged – static electricity</p> <p>L: why do you feel a shock when switch off TV and touch screen (paraphrase)</p> <p>T: There is still a bit of current left in the TV after you switch it off. (incorrect)</p>

**Lesson: F3**

**Topic: Electricity – open and closed circuits**

**Time: 0h57**

Episode	Organisation	Content
1.	Teacher exposition	<ul style="list-style-type: none"> <li>• Batteries are connected with positive pole of one connected to the negative pole of the next battery – unlike poles attract each other and like poles repel each other – therefore electricity will not flow if connect batteries connected positive pole to positive pole or negative pole to negative pole (incorrect – confuses magnetism and electricity)</li> <li>• Explains the difference between open and closed circuits</li> <li>• Draws in a piece of plastic in the circuit – elicits that plastic will block the flow of electricity in the circuit as the plastic is a bad conductor of electricity</li> </ul>

		<ul style="list-style-type: none"> <li>• Draws in a (metal) spoon in the circuit – elicits that the metal will conduct electricity in the circuit as metals are good conductors of electricity</li> </ul>
2.	Teacher exposition	different symbols for battery; switch; bulb; electric wire
3.	Learners individual classwork; teacher rubs of symbols from chalkboard and writes up classwork	<p>a) Use the symbols to represent the following:</p> <ol style="list-style-type: none"> <li>1. battery</li> <li>2. switch</li> <li>3. bulb</li> </ol> <p>b) Why do we connect the battery from negative to positive</p> <p>c) Name any metal other than the copper that can conduct electricity</p> <p>d) Name any insulator other than the plastic</p> <p>[drawing of circuit – see photos]</p> <p>e) distinguish between closed and open circuit</p>
4.	Learners do classwork while teacher monitors and assists	
5.	Report back – teacher elicits correct answers and learners correct work	
<b>Lesson: F4</b>		
<b>Topic: Electricity – uses; resistors</b>		
<b>Time: 0h49</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question & answer	Examples of uses of electricity in home: iron; kettle; heater; stove; television; radio; lights
2.	Teacher exposition – some elicitation	<p>Good and bad conductors</p> <p>Identifies heating appliances from list</p> <p>Heating appliances have resistors made form nichrome</p>

		Resistor in heating appliance converts electrical energy to heat energy  (incorrect: non-heating appliances have no resistors)
3.	Group activity	Classify household appliances into those with resistors and those without resistors (incorrect – all have resistors – teacher equates resistor with heating element)
<b>Lesson: F5</b>		
<b>Topic: Electricity – series and parallel circuits</b>		
<b>Time: 0h43</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition – some elicitation	<ul style="list-style-type: none"> <li>• Review: Heating appliances have resistors made of nichrome</li> <li>• Draws circuit board on chalkboard and reviews how electrical current moves through circuit (does not recognize bulb as resistor; a circuit without insulator or resistor is a short circuit - incorrect)</li> <li>• Elicits that when add battery to circuit the bulb will glow brighter because the current will increase</li> <li>• A fuse is added to a circuit to reduce the current so that appliances will not be damaged (radio, television, hair dryer have no resistors – incorrect)</li> <li>• 2 ways to connect a circuit: series and parallel</li> <li>• In parallel circuit the flow of electrical energy is split</li> <li>• Teacher draws series circuit on chalkboard and asks which bulb will glow brighter in the circuit – learners respond that the first one will – teacher confirms response – (incorrect)</li> <li>• Teacher draws parallel connection and elicits that the current splits and the bulbs light equally</li> </ul>
	Teacher question and answer	Parallel connection used in home and school

## Lesson summaries Teacher G

<b>Lesson: G1</b>		
<b>Topic: Compounds</b>		
<b>Time: 1h12</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher announces	Will make new substances from simpler substances
2.	Group practical activity 1	Identify properties of sulphur and iron filings
3.	Groups report – teacher elicits answers	Properties of iron filings and sulphur powder – colour and magnetism
4.	Group practical activity 2	Learners add dilute hydrochloric acid to iron filings in test tube and observe
5.	Groups report – teacher elicits answers	Gas bubbles are released
6.	Group practical activity 2 (continued)	Test gas – light match above test tube when gas is given off
7.	Groups report – teacher elicits answers	Pop sound is heard  Gas is therefore hydrogen  Tests for other gases: oxygen - a glowing ember will come alight; for carbon dioxide – clear lime water gets milky
8.	Teacher explanation	Hydrogen reacted with oxygen making pop sound – small amount of water vapour formed  (defers explanation of reaction between hydrochloric acid and iron filings)
9.	Group practical activity 3	Mix sulphur and iron filings
10.	Groups report – teacher elicits answers	Colour of mixture is light grey and yellow
11.	Group practical activity 3 (continued)	Add dilute hydrochloric acid to sulphur and iron filings mixture in test tube; observe
12.	Groups report – teacher elicits answers	Gas bubbles are observed (explanation deferred)

13.	Group practical activity 4	Learners heat mixture sulphur and iron filings in deflagrating spoons
14.	Groups report – teacher elicits answers	Observed blue flame; grey substance formed
15.	Teacher explanation	A new substance, iron sulphide was formed
16.	Group practical activity 5	Learners add hydrochloric acid to the iron sulphide and observe
17.	Groups report – teacher elicits answers	Smelly gas is given off
18.	Teacher explanation	Gas is hydrogen sulphide (defers explanation re rest of reaction)
19.	Teacher explanation –	<p>Sums up experiments and products</p> <ul style="list-style-type: none"> <li>• Iron filings + hydrochloric acid -&gt; iron chloride + hydrogen</li> <li>• Mixture of sulphur powder and iron filings – hydrochloric acid only reacted with iron filings, not sulphur to form iron chloride</li> <li>• Iron sulphide + hydrochloric acid -&gt; hydrogen sulphide + iron chloride</li> <li>• sulphur plus iron =&gt; iron sulphide</li> </ul> <p>Tells terms: reactants, product</p>
20.	Individual classwork	<p>1. What is the difference in smell between hydrogen and hydrogen sulphide?</p> <p>2. What is observed when a burning match is held at the mouth of a test tube containing hydrogen?</p> <p>3. Write down the equation for the reaction taking place when</p> <p>a) dilute hydrochloric acid is added to iron filings</p> <p>b) dilute hydrochloric acid is added to iron sulphide</p>
<b>Lesson: G2</b>		
<b>Topic: Separating mixtures</b>		
<b>Time: 0h51</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question &	Review:

	answer	<p>An element is a substance that cannot be broken down into simpler substances</p> <p>Compounds are substances that can be broken down into simpler substances</p> <p>Examples of elements: zinc, iron, copper, carbon, platinum, sulphur, mercury</p> <p>Examples of compounds: water, carbon dioxide, mercury oxide, iron sulphide</p>
2.	Group discussion	Why are sulphur and iron filings not a compound?
3.	Groups report – teacher elicits answers	Sulphur is still an element and iron filings are still an element
4.	Teacher exposition	<ul style="list-style-type: none"> <li>• A mixture is formed when two substances mix but do not mix chemically – there is no chemical reaction</li> <li>• When we heated iron filings and sulphur we got a new substance called iron sulphide, with different properties</li> <li>• Iron filings and sulphur are constituents of the mixture</li> <li>• A pure substance consists of only one constituent</li> <li>• A mixture is an impure substance because it consists of two constituents</li> <li>• We can separate mixtures</li> </ul>
5.	Group practical activity	<p>Mix salt and sand; add water</p> <p>It is an impure substance</p>
6.	Group discussion	How to separate sand and water
7.	Groups report – teacher elicits answers	Filtration method
8.	Practical demonstration by learner	One learner filters mixture and rest class observe
9.	Groups report – teacher elicits answers	Clear water comes through funnel
10.	Explanation	<p>Filtration method</p> <p>Clean water is filtrate</p> <p>Remains on filter paper are residue</p>

11.	Group discussion	Uses of filtration at home
12.	Groups report – teacher elicits answers	Filter dirty water Separate tea leaves when water is dirty (confused – not corrected)
13.	Teacher explanation	Can separate salt from water by evaporation
14.	Practical demonstration by learner	Separates rulers from pens by hand
15.	Teacher explanation	Hand sorting – another example is separating samp from beans
16.	Group practical activity	Separate iron filings from sulphur using a magnet
17.	Groups report – teacher elicits answers	Iron filings stick to magnet; sulphur does not
18.	Teacher explanation	Method is called magnetism
19.	Teacher explanation using chalkboard drawing	Separation of salt and water using Liebig’s condenser - distillation
20.	Teacher explanation using chalkboard drawing	Fractional distillation alcohol and water – different boiling points
21.	Teacher explanation using chalkboard	Separating paraffin and water using separating funnel
22.	Teacher instructions re homework task	Find out about method of separation at Machubeni Dam (not feasible – far from school; no further reference to this in rest of lessons)

**Lesson: G3**

**Topic: Mutual dependency of plants, animals and environment**

**Time: 0h56**

Episode	Organisation	Content
1.	Teacher explanation	Mutual dependency means that plants gain something from animals and animals gain something from plants and the environment
2.	Group discussion	Role of plants in the community

	Key points written on newsprint  no engagement by teacher	
3.	Groups report – teacher confirms – no evaluation	Plants (repetition by groups) <ul style="list-style-type: none"> <li>• Beautify community</li> <li>• Give us wood</li> <li>• Make our furniture</li> <li>• Give us oxygen and use carbon dioxide</li> <li>• Give us fruit, vegetables</li> <li>• Make home beautiful</li> <li>• Give medicine</li> <li>• Make books</li> <li>• Stop soil erosion</li> <li>• Keep environment clean</li> </ul>
4.	Teacher exposition	Sums up ideas from groups  Explains meaning of ‘habitat’ – plants provide habitat for animals  Adds ideas  Plants used for thatch
5.	Group discussion  Key points written on newsprint  no engagement by teacher	Role of animals in community
6.	Groups report – teacher confirms – no evaluation	Animals give us (repetition by groups) <ul style="list-style-type: none"> <li>• Clothes e.g. shoes</li> <li>• Milk and cheese</li> <li>• Dresses, jackets, belts from leather</li> <li>• Blankets and jerseys from wool</li> <li>• Plough with animals</li> <li>• Make flute from animal horn</li> <li>• Cups and saucers from bones of animals</li> <li>• Meat</li> <li>• Eggs from hens</li> <li>• Pull carts</li> <li>• Horses’ tail for hair (extensions)</li> <li>• Dogs protect us</li> <li>• Traditional clothes</li> </ul>

		<ul style="list-style-type: none"> <li>Fertilise soil with dung</li> </ul>
7.	Teacher exposition	<ul style="list-style-type: none"> <li>Animal dung is rich in nitrogen – makes soil fertile</li> <li>Birds and bees help pollinate flowers</li> <li>Animals eat other animals – get a food chain and a food web</li> </ul>
8.	Learners write up food chains on chalkboard	<p>Grass=&gt; sheep =&gt; jackal</p> <p>Wheat =&gt; mouse =&gt; snake =&gt; secretary bird</p>
9.	Teacher exposition	<ul style="list-style-type: none"> <li>Grass and wheat produce food for animals; Plants and animals need air, water &amp; air.</li> <li>This is mutual dependency</li> </ul>
<b>Lesson: G4</b>		
<b>Topic: Electrolysis</b>		
<b>Time: 0h50</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher exposition	<p>Lesson topic: chemical effects of electric current</p> <p>Electricity can go through some solutions such as copper 2 chloride</p>
2.	Practical demonstration – learners assist and class gathers round to observe	<p>Mixes a (saturated)solution of copper 2 chloride in beaker</p> <p>Tests battery with globe to check it is working</p> <p>Attaches carbon rods to battery in a circuit</p> <p>Puts carbon rods in copper 2 chloride solution</p>
3.	Teacher explanation on chalkboard while waiting for chemical reaction	<p>Terms: electrodes, positive and negative poles; positive and negative electrodes; solution electrolyte</p>
4.	Practical demonstration – learners observe and write down observations	
5.	Groups report	<p>Small bubbles round positive electrode</p> <p>Negative electrode colour changes to light pink</p>

6.	Teacher explanation – elicits some information	Solution decomposes into two elements: chlorine gas and copper  Can smell chlorine gas
7.	Practical demonstration	Teacher attaches key to negative electrode
8.	Teacher explanation	Writes up word equation for chemical reaction
9.	Learners observe experiment and discuss in groups	
10.	Groups report	Key changes colour to light brown  Bubbles form
11.	Teacher explanation	Process is called electroplating and is used in industry  Process is called electrolysis

**Lesson: G5**

**Topic: Acid rain and global warming**

**Time: 0h54**

<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question & answer	<ul style="list-style-type: none"> <li>Animals breathe in oxygen and breathe out carbon dioxide and other gases</li> <li>Plants take up carbon dioxide during photosynthesis</li> </ul>
2.	Teacher exposition	<ul style="list-style-type: none"> <li>Animals and plants balance the gases in the atmosphere</li> <li>During combustion, oxygen is used and carbon dioxide is produced</li> <li>Gases are produced with burning of fossil fuels</li> <li>Coal is burned and produces sulphur dioxide</li> <li>Exhaust fumes produce carbon monoxide and nitrogen dioxide</li> <li>These gases combine with water vapour to form carbonic acid sulphuric acid</li> <li>This forms acid rain which is very dangerous because it destroys buildings and plants</li> </ul>
3.	Group discussion –  Points noted on newsprint	How to prevent acid rain

	no engagement by teacher	
4.	Groups report – teacher confirms – no evaluation	<ul style="list-style-type: none"> <li>• Use bicycles not cars</li> <li>• Reduce factories</li> <li>• Plant more plants, not destroy them</li> <li>• Use solar systems (energy)</li> <li>• Stop veld fires</li> <li>• Government must produce car batteries with computers (?)</li> <li>• Government must put electricity everywhere (?)</li> <li>• Use compost to fertilise soil (?)</li> </ul> <p>(all accepted uncritically by teacher)</p>
5.	Teacher exposition	<p>Global warming</p> <p>Atmosphere helps keep temperatures constant</p> <p>Some heat from the sun is not absorbed by the soil – reflected back and reflected back by the atmosphere</p> <p>These ultra-violet rays are dangerous (incorrect)</p> <p>There is too much carbon dioxide in the atmosphere – it keeps the heat of the sun and so earth is getting warmer and warmer =&gt; global warming</p>
6.	Group discussion – Points noted on newsprint no engagement by teacher	How to prevent global warming – keep carbon dioxide out of atmosphere?
7.	Groups report – teacher confirms – no evaluation	<p>Plant more plants</p> <p>Must not destroy forests</p> <p>Reduce factories that burn coal or oil, or produce plastics</p> <p>Reduce ships and transport</p> <p>Book factories should use recycled paper</p>
8.	Teacher exposition	We must conserve our environment

## Lesson summaries Teacher H

<b>Lesson: H1</b>		
<b>Topic: Asexual reproduction – bread mould</b>		
<b>Time: 0h36</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question & answer	Review: sexual and asexual reproduction  Mould an example of asexual reproduction  Reviews how make bread mould
2.	Practical demonstration:  Teacher puts up labeled diagram of bread mould  Hands round examples of bread mould to groups	Identify parts of bread mould from sample and diagram <ul style="list-style-type: none"> <li>• cotton wool thing – mycelium</li> <li>• dots – sporangia - seeds</li> <li>• threads – hyphae</li> <li>• finger like structures – rhizoids</li> <li>• Bread – substratum</li> </ul>
3.	Learner individual task; teacher hands out question papers; goes through questions & answers orally; learners write down answers	<ol style="list-style-type: none"> <li>1. Method for making bread mould</li> <li>2. Where are the stolon, rhizoids, mycelium</li> <li>3. Draw and label bread mould</li> </ol>
4.	Teacher instructions	Teacher tells learners to finish exercise for homework and bring flowers for the next lesson
<b>Lesson: H2</b>		
<b>Topic: Sexual reproduction in plants</b>		
<b>Time: 0h38</b>		
<b>Episode</b>	<b>Organisation</b>	<b>Content</b>
1.	Teacher question & answer	Review: sexual and asexual reproduction
2.	Practical demonstration: teacher puts up labeled	Learners identify parts of flower from diagram and their own flowers <ul style="list-style-type: none"> <li>• Corolla</li> </ul>

	diagram of flower.	<ul style="list-style-type: none"> <li>• Stamen</li> <li>• Anther</li> <li>• Filament</li> <li>• Ovary</li> <li>• Stigma</li> <li>• Style</li> <li>• Ovules</li> <li>• Pedicel</li> <li>• calyx</li> </ul> <p>Pollination – self pollination and cross-pollination</p>
3.	Teacher exposition – some elicitation	<p>Agents of pollination</p> <ol style="list-style-type: none"> <li>1. water</li> <li>2. insects</li> <li>3. wind</li> <li>4. animals</li> </ol> <p>Explains how each takes place.</p>

**Lesson: H3**

**Topic: Kinds of fruit**

**Time: 0h29**

Episode	Organisation	Content
1.	Teacher exposition	Review: 2 kinds reproduction; pollination and fertilization; fruit develops – ripened ovary
2.	Practical demonstration  Teacher puts up diagram of half section of fruit	Learners cut their samples of fruit in half  Identify parts of fruit from own samples and diagram  Outer layer; inner fleshy layer; seed
3.	Teacher exposition	Different kinds of fruit and scientific classification (much incorrect and/or misleading)
4.	Teacher writes up notes for learners to copy	Different kinds of fruit  Diagram of parts of fruit

**Lesson: H4**

**Topic: Fruit - test**

**Time: 0h45**

Episode	Organisation	Content
1.	Teacher writes up test on chalkboard; learners write down answers individually	<p><u>Question 1</u></p> <p>Complete the following sentences by filling in the missing words</p> <p>a) A fruit is a ripened ..... (1)</p> <p>b) Fruits that do not split open when ripe are called .... (1)</p> <p>c) Fruits that split open when ripe are called .... (1)</p> <p>d) Fruit that is fleshy, thick and juicy is a .... (1)</p> <p>e) Collection of individual pistils of the flower join together to form a single fruit called an .... (1)</p> <p><u>Question 2</u></p> <p>Label the following diagram of a fruit from 1-4</p> <p>(diagram of cross-section of apple)</p> <p>(4+5) (9)</p>
2.	Teacher marks learners' tests as soon as they have finished	
3.	Teacher feedback – teacher elicits answers	
4.	Teacher instructions	Will be doing seeds the next day
<b>Lesson: H5</b>		
<b>Topic: Germination of seeds</b>		
<b>Time: 0h32</b>		
Episode	Organisation	Content
1.	Teacher exposition	A seed is a ripened ovary
2.	Teacher question	Examples of seeds – learners provide many examples
3.	Teacher exposition –	Germination of bean seed

	elicits some points	Parts of bean seedling: roots, stem, leaves Monocotyledonous e.g. mealie Dycotyledenous e.g. bean
4.	Teacher exposition – sticks up poster & describes germination process of bean seed	describes 6 stages of germination of bean seed
5.	Teacher question & answer	Key points re stages of germination of bean seed
6.	Teacher questions and answer	Suitable conditions for germination of seeds <ul style="list-style-type: none"> <li>• water</li> <li>• soil</li> <li>• fertilizer</li> <li>• warmth/sun</li> </ul>

## Appendix 5: Textbook activity Food web Lesson A1

### Activity 3 Finding food chains

(Teachers: This is an information skills activity)

Assessment

NS1 AC1,7  
NS2 AC1  
LLC AC1-9  
LLC6 AC 1-6  
HSS6 AC1-6

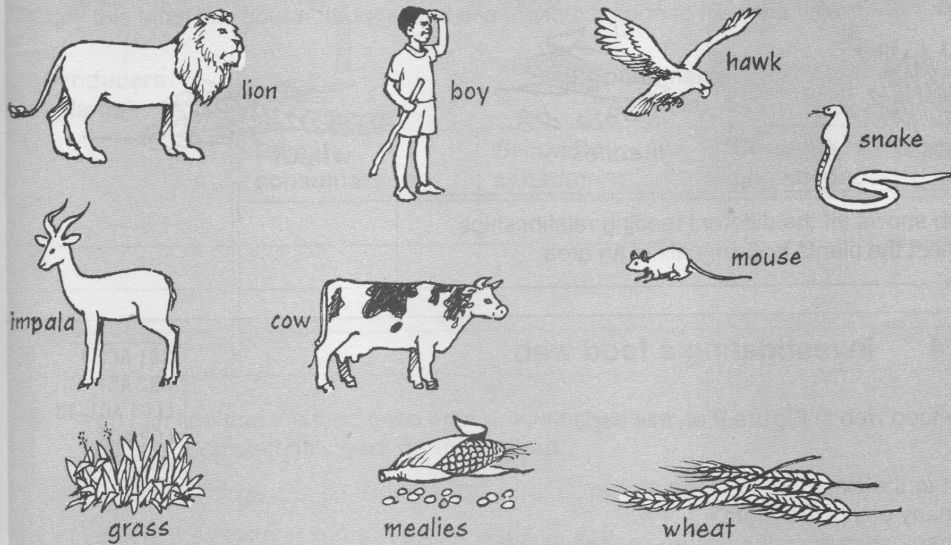
Work in your small group. Look at the organisms\* in **Figure 8**.

- 1 Your group should find at least four food chains. Here is an example:

grass → cow → boy.

Put a heading in your notebook – **Food chains** – and write out your food chains like this example.

**Figure 8** How many food chains can you find here?



- 2 Other groups will find different food chains. How many food chains can the class find in **Figure 8**?

## Appendix 6: Summary of practical activities

Teacher A	
Lesson A2	<p>Topic: Separating mixtures</p> <p><u>Practical activity 1</u>: learners separate beans and copper pieces manually – not linked to generalising principle (coded PA1)</p> <p><u>Practical activity 2</u>: teacher demonstrates to each group how to separate iron filings and sulphur powder – incorrect digression re obtaining iron filings from sharpening a hoe; no link to generalizing principle (coded PA1)</p> <p><u>Practical activity 3</u>: learners try to separate water and salt in salt solution with filter paper - digression; teacher tells them can be separated through boiling the solution – could have been demonstrated; no link to generalizing principle (coded PA1)</p> <p><u>Practical activity 4</u>: learners dissolve sugar in water – not separated (PA1)</p> <p><u>Practical activity 5</u>: teacher demonstrates mixture water and methylated spirits – explains separation through boiling – different boiling points – not linked to generalizing principle (coded PA1)</p> <p><u>Practical activity 6</u>: teacher demonstrates water and flour mixture – separation with filter paper- some incorrect information - not linked to generalizing principle (coded PA1)</p>
Lesson A4	<p>Topic: Force</p> <p><u>Practical activity 1</u>: teacher demonstrates ‘force’ by pushing a learner and a pencil box – links to generalizing principle not clear (coded PA1)</p> <p><u>Practical activity 2</u>: demonstration – teacher pushed duster across desk in one direction; learner pushes in another direction – force changes direction – links to generalizing principle not clear (coded PA1)</p> <p><u>Practical activity 3</u>: demonstration – learn breaks piece of chalk in half – to show that force changes shape of objects - – links to generalizing principle not clear (coded PA1)</p> <p><u>Practical activity 4</u>: learners shape prestick into different shapes – links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 5</u>: gets 5 learners to push against the wall – to show that unless there is movement, no work has been done – links to generalizing principle not clear (coded PA1)</p> <p><u>Practical activity 6</u>: teacher pushed pencil box across desk to demonstrate ‘displacement’ - – links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 7</u>: groups come up in turn to read off measurement of force</p>

	<p>exerted by pencil case on spring balance – links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 8</u>: teacher draws a line in an exercise book and gets groups to measure it with a ruler – each group in turn - first shows learners ruler and asks for name of unit – millimetres; then groups have to measure line in turn – digression not related to main topic (coded PA-0 – digression).</p> <p><u>Practical activity 9</u>: teacher demonstrates force of gravity by dropping pencil box and table – links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 10</u>: teacher demonstrates forces in balance by pulling against learner - links to generalizing principle not clear (coded PA-1)</p>
<b>Teacher B</b>	
Lesson B1	<p>Topic: Mixtures and compounds: defining mixtures</p> <p><u>Practical activity 1</u>: learners identify and tabulate properties of iron filings and sulphur powder – links to generalising principle made explicit (coded PA-2)</p> <p><u>Practical activity 2</u>: learners identify and tabulate properties of mixture of iron filings and sulphur powder - links to generalising principle made explicit (coded PA-2)</p>
Lesson B2	<p>Topic: Mixtures and compounds: defining compounds</p> <p><u>Practical activity 1</u>: teacher demonstrates heating sulphur and iron filings to make compound, iron sulphide - links to generalising principle made explicit (coded PA-2)</p>
Lesson B3	<p>Topic: Separating mixtures</p> <p><u>Practical activity 1</u>: Learners separate mixture soil and water through filtration - links to generalising principle made explicit (coded PA-2)</p>
Lesson B4	<p>Topic: Separating mixtures</p> <p><u>Practical activity 1</u>: Learners separate solution salt and water; write up experiment - links to generalising principle made explicit (coded PA-2)</p>
<b>Teacher C</b>	
Lesson C1	<p>Topic: matter - phase changes</p> <p><u>Practical activity 1</u>: demonstration – learner poured 2 litres water into two different shaped containers – water changed shape but volume remained same – links to generalising principle not clear (coded PA-1)</p>
Lesson C2	<p>Topic: types of mixtures</p> <p><u>Practical activity 1</u>: learners mix solids (salt, sugar, sand) with liquid (water) -</p>

	<p>links to generalising principle not clear (coded PA-1)</p> <p><u>Practical activity 2</u>: learners mix liquids (vinegar, paraffin, milk) with liquids (water) – some incorrect information in explanation (coded PA-1)</p>
Lesson C4	<p>Topic: materials – types</p> <p><u>Practical activity 1</u>: learner classify different types materials according to properties (tin foil, ceramic tile, fabric, glass, plastic) – some incorrect information (coded PA-1)</p>
<b>Teacher F</b>	
Lesson F2	<p>Topic: static electricity</p> <p><u>Practical activity 1</u>: learners rubbed plastic rulers on their hair and attracted small pieces of paper to illustrate static electricity – incorrect and confusing information in explanation (coded PA-1)</p>
<b>Teacher G</b>	
Lesson G1	<p>Topic: compounds</p> <p><u>Practical activity 1</u>: learners identify properties iron filings and sulphur - links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 2</u>: learners add dilute hydrochloric acid to iron filings; identify gas given off: hydrogen - links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 3</u>: learners mix sulphur powder and iron filings; add dilute hydrochloric acid; note bubbles – no further discussion - links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 4</u>: learners heat mixture of iron filings and sulphur; note change in colour – no further discussion - links to generalizing principle not clear (coded PA1)</p> <p><u>Practical activity 5</u>: learners add dilute hydrochloric acid to substance formed in activity 4 – iron sulphide – bad smelling gas – hydrogen sulphide - links to generalizing principle not clear (coded PA-1)</p>
Lesson G2	<p>Topic: separating mixtures</p> <p><u>Practical activity 1</u>: learners mix salt, sand and water; filter mixture to remove sand - links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 2</u>: one learner demonstrates sorting a pile of rulers, pens and pencils by hand - links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 3</u>: learners separate mixture of sulphur powder and iron filings using magnet - links to generalizing principle not clear (coded PA-1)</p>

Lesson G4	<p>Topic: electrolysis</p> <p><u>Practical activity 1</u>: teacher demonstrates electrolysis of copper 2 chloride =&gt; copper and chlorine – uses carbon rods attached to a battery and suspended in solution of copper 2 chloride - links to generalizing principle not clear (coded PA-1)</p> <p><u>Practical activity 2</u>: teacher demonstration – connects key to negative electrode of cells – learners observe that copper collects on key - links to generalizing principle not clear (coded PA-1)</p>
<b>Teacher H</b>	
Lesson H1	<p>Topic: plant reproduction – asexual</p> <p><u>Practical activity 1</u>: learners observed pieces of mouldy bread and identified and named the parts - links to generalizing principle not clear (coded PA-1)</p>
Lesson H2	<p>Topic: Plant reproduction – sexual</p> <p><u>Practical activity 1</u>: learners observed and identified and named parts of flowers – links to generalised terms for particular flower examples done (coded PA-2)</p>
Lesson H3	<p>Topic: Plant reproduction – fruits</p> <p><u>Practical activity 1</u>: learners cut open fruit and identified and named the parts – theory incorrect (coded PA-1)</p>

## Appendix 7: Lesson A1 excerpt - full transcript

Separating iron filings and sulphur powder: Lesson A1, episodes 3-5 (full transcript)

(T= Teacher; L=Learner; Ls=Learners; SL= Same learner *isiXhosa transcription in italics*; translation in square brackets; writing on chalkboard indented, bold)

T: Now...can you see this (holding up bottle) can you see this words? Can you see? How do you pronounce it? Sulphur *ne* [okay]?

Ls: Yes.

T: Can you see all of you? (moving around class with container) Can you see this one? Just open it and look at it. (Handing over container to learners in group) Open and look at it. Don't smell it please. Can you see it...can you see it? Okay how is it's colour? How is the colour? How is the colour? How is the colour? (learner drops something) Sorry. (passes bottle to another group) How is the colour? How is the colour? Don't smell it. We do not smell the chemicals but we test them .. we test them. We don't taste them. You test them. Okay? If we want to know if that is a chemical we must test them. Don't smell it. But some have got (indistinct) smell.

T: Okay how is the colour of this. I just want to know the colour of it.. men. I know...I know there a saying that...men.. men are colour blind. I don't know how far true that is but I know black .. black and white I know. What is the colour? Brown? Yellow, *ne* (okay)?

Ls: Yes.

T: That is sulphur. Then here is (holding up another container) sulphur ...this is also a sulphur although it is not labelled. This is sulphur, this is a powder. This is a sulphur powder. *Ne* [okay]?

Ls: Yes.

T: Sulphur. Then now I am going to give you this, on that piece of paper, and there...take my beans back. Take my beans back (referring to previous activity separating beans and pieces of copper). I want you to make a mixture...I want you to make a mixture of the sulphur and the iron. Sulphur and the iron. But not the iron in it's solid state...in fact...an iron in a ground...grinded form. (walking around class, showing learner contents of container) That is .. what do you call it? These are iron, *ne* [okay]?

Ls: Yes.

T: I want you to mix ... (walking around class with container) (showing group) These are iron filings.. iron filings, *ne* [okay]?

Ls:Yes.

T: (showing another group) Please don't come close to them. These are iron filings, *ne* [okay]?

Ls: Yes.

T: Okay. In fact you are going to see when I give you these...

T: Now I want you to mix these (handing out materials to groups). I want you to mix the? Make the mixture with the copper...I'm sorry, with the sulphur not copper...with the sulphur, *ne* [okay]? I want you to make a mixture of this. Mix them. Mix them. Mix them on that piece of paper. Mix them on that piece of paper. Mix those iron filings. Mix them. Yes. Mix them. You can use the back of your lead pencil or a ruler. You can use your ruler or lead pencil ..yes, like that group is doing. Mix them completely. (busy at desk) Tell me if you have finished. Okay have you finished? Okay. That group also. Okay, now...we said we have mixed the? The iron (writing on board) iron filings.

T: Iron filings and sulphur. Iron filings and? Su? Sulphur.

Iron filings and sulphur

T: Have you mixed them?

T: Okay, now, now I want you to tell me the answer to this question (indistinct) tell me can you be able to see that this is an iron filing *okanye* [or else] these are iron filings in the same mixture? And these are copper...I'm sorry...um sulphur powder? So how is the colour now of your mixture is it still that much yellow or that much brown?

Ls: (indistinct mumbling)

T: Little bit darker, *ne* [okay]?

Ls: Yes.

T: Okay now, how do you think ... I want you to tell me now...tell me .. what can you use to separate that mixture? What you use to separate that mixture? There is a strainer which you use to strain your tea or your coffee in the morning, *ne* [okay]?

Ls: Yes.

T: Your tea in the morning. Can we use that or there is what is used...there's a big dish which has got holes on its bottom. It is used by our mothers when they have made Xhosa beer, *ne* [okay]?

Ls: Yes

T: When they do this (demonstrates mixing motion) they pour in the that Xhosa beer with together .. the sorghum you see. They pour it in here. They do this. They do this (gesturing circular rubbing action). And then underneath we get the...beer...the Xhosa beer without what? Without the sorghum...that is ...that is *sifumana* [we find]... they call it in Xhosa *umqombothi* ... *umqombothi* [beer .. beer]. That is Xhosa beer. That is what they call it. Then there is that *isitya* [strainer] *phaya* [there], can you use it ?

Ls: (mumbling)

T: You can't use that? Can you use that strainer? For straining the tea or for sieving our tea?

Ls: No.

T: No. What can you do? Can you use your hand? And say I am taking away now the what? (demonstrating separating movements) The iron filing and then I am taking away now the sulphur? No. Which thing that we can use? I want you to tell me. Which thing that we can use. Heh? Which thing that we can use? Tell me. Anything. If there is anything here on the table that you can use to separate them, just tell me. Here are the things (opening container and showing class) this is filter paper. This is filter paper. This is filter paper. If you can use filter paper tell me and say you can use filter paper. This is the bar magnet, *ne* [okay]?

Ls: Yes.

T: This is a bar magnet. (looking on desk) I had one small one. Okay, this is bar magnet. This is spirit .. this is water...this is a glass...tell me if you can use the glass or whatever. Which one can we use? Which one? Okay, let us try one of these. (picking up object from desk) Let us try one of these. Let me take this off, this off tissue paper. What is this? (holding up object) Bar magnet?

Ls: (indistinct)

T: This is not bar magnet. Because I hear she say bar magnet. It's not a bar magnet. It's a horse shoe magnet, *ne* [okay]? Horse shoe. Do you know the shoe of a horse? *iimpupu ze hashe* [foot of a horse]?

Ls: Yes

T: *Uyazibona ukuba zinjani* [can you see how they look like]? They are not separated like those of a cow, *ne* [okay]?

Ls: Yes.

T: It's one thing...one thing like this. Okay?

Ls: Yes.

T: Okay. This is the magnet, *ne* [okay]? Okay. Er, what happens when you bring the magnet to a straight pin? What happens? Or what happens to when you bring the magnet to something that is a metal like this nail clipper? What will happen? Can you guess? What happened? What happened? When you bring this magnet to that (touches metal table leg with magnet) what is going to happen to that (indistinct)? Heh?

L: (indistinct)

T: Huh?

SL: *Izakophuka* [it can be broken].

T: She says it can be broken. It can be broken. Okay, let's say you hold the electricity cable. You hold the electricity cable when (indistinct). What will happen to you? Heh?

L: (indistinct)

T: You will become what? Choked, *ne*? You are going to be choked. Then it means that if you are being choked you stick to that you don't move away any more. You see?

Ls: Yes.

T: Because you have been attracted by the? Electricity cable. Then let us see what will happen to this. Is it for the first time that you ever saw this happening? *Uyaqala ukuyibona lento isenzeka?* [is it the first time you see this happen?]

Ls: No.

T: But why didn't you tell me? Huh?

Ls: (indistinct)

T: Magnet? Don't you know the magnet? *Hayi bo?* [No, really!] Have you ever never seen the magnet? In grade seven! (whistles disbelievingly).

T: Okay, let us see...let us go with our...Okay, I want you to bring the .. take it, bring it ...I want you to bring it to that...Can we just .. just remain where we are ...I am just going to go around with it. (to first group) Can you bring that next to that...(helps learner hold magnet) No just put it underneath the paper...underneath the paper...put it under the paper...under the paper...Is there anything that is happening? (learners in group look) No look carefully. Look, look carefully. (indistinct to learners in group) Look. Come let us put it like this (takes over and demonstrates to group). (speaking to learners in group) What is happening? Tell me, tell me, what is happening?

Ls in group: (indistinct)

T: What is it? What are they, they are moving? What are they? What are they? Yes, yes. There are things that look like hairs...baby hairs, *ne* [okay]?

Ls: (from group) Yes

T: Things that look like little hairs.

T: (moving on to next group) Okay, let us bring this below...just below the paper, *ne* [okay]? ...(helping next group with magnet) Look at the things. Look at it.

L: (points to paper and says something indistinct)

T: What is it that is moving? What is it? What is that? Iron, *ne* [okay]? (puts down paper) Is that the iron...are you sure? ...

T: (moving to next group) Let us see...let us see...let us see. What happens here? Let us see. (lifts up paper and holds magnet underneath). Look carefully please. Put the .. but not yet .. put the magnet. Okay, there it is .. (learners cluster round paper) There it is .. they look like hairs, *ne* [okay]? What are they? What are they?. What is it that is moving like hair? I want you to tell me what is that? I want you to tell me what is that?

T: (moving to next group, speaking to class) Because you have mixed two elements there ... or two substance there...you have mixed two constituents there... (teacher helping group) (indistinct)

Ls in group: (laughing)

T: Okay I want each group now to tell me what was moving in your mixture. When I put the ...magnet under the paper in the position of the mixture. What was just moving? If you say that there is something looks like ... looks like ....like your hairs...or small hairs. What was it? What was it? What was moving there? Yes? (pointing to learner) (indistinct – name of learner). What was it? *Yekezwa* [what was it]?

L: (indistinct)

T: What was it?

SL: Hairs.

T: Did you mix hairs there?

SL: No.

T: But what did you mix? What did you mix? Yes? (pointing to another learner)

L: *Udibanise lento titshala kunye netyiwa* [you mixed this with salt teacher].

T: No, no, no. Okay. Let me take you back. We have mixed two things. We have mixed two things there. What .. what did we mix? Okay. What did we mix? (pointing to chalkboard) We mixed the iron filings, *ne* [okay]? And the? Sulphur. Those are the only two things that we have mixed together, okay?

Ls: Yes.

T: But now there was something in that mixture which was moving when I bring in the? The what? The magnet. Then those iron filings they came.. they come from...if you take .. do you know the file .. the feel .. that used to grind...say *umama uyahlakula* [the mother is hoeing her fields]. She is hoeing to her field *ne* [okay]? (demonstrates) And that say, “Hey, it hit hard on the stones and then the hoe (pronounced ‘who’) becomes....you see .....becomes hurt I would say so, becomes hurt and unable to ... becomes not sharp now. Then he will say bring me the what you call it, *ufeel* [file] so that *uthini ndilole* [it happens I sharpen it]. To sharpen my hoe... and then while she is sharpening the hoe there are pieces of metal, that’s what we call the iron...filings. Those pieces of metal are called iron filings.

T: I want to know now what was moving? What was moving? ...Hands up. Hands up. If you got that one you come during the break and then you take 50 cents. (learner raises hand) (teacher and learners laughing) What is it? Was it sulphur?

SL: Yes.

T: Are you sure?

SL: Yes.

T: So it means that. Let us see. Let us see. If this can pull the sulphur. (holding up magnet) Let us see if it can pull the sulphur, *ne* [okay]? Here is the sulphur. (walking over to his desk) Here is the sulphur. I want to ...I don't want to say what she is telling us is not what is ...or is what.....(pouring sulphur into a container in front of class) Okay...let me do it to the sulphur straight. Is the sulphur moving?

Ls: No.

T: Okay, let me put it underneath because it won't move. Is it moving? (showing group in front) Not moving. What is it that was moving if the sulphur is not moving? What is it that was moving in our mixture? Hands up. What is it?

Ls: Iron. (laughing) Iron.

T: Oh. Okay. (laughing) Why now...everybody want to say that first. It was this iron, *ne* [okay]?

Ls: Yes.

T: It was those iron filings that were moving....

T: Okay...let us see now there in the mixture let us see what will happen now...let me go to another group now. (moves to group near window) Take it....(handing magnet to student who shies away) take it, you are not going to be hurt. Are you left-handed?

L: (indistinct)

T: Okay, take it, shake it. Okay stir this...stir this....Okay...let us look at it...what is it that is moving you see in here...what is it? What is this?

L: (indistinct)

T: (demonstrating to group) What is this? What is it? This one? Okay, now .. okay I .. I .. I .. I want you to write down what is it that was taken (away) from the mixture. I don't want you to tell me. I don't want you to tell me. Write it down. Take your piece of paper and you write it down. What was taken? What do you...tell us what was taken. Write it down. Just write it down and tell me what was taken away from the mixture. (tearing up paper)

T: Okay. I want each group to write down their observation. Tell me what happened if you wrapped this magnet and then (demonstrating with group in front) you put it close to your mixture. Just stir your mixture. (indistinct) Let us wait. Let us wait. Write it there...what has been taken away from the mixture by this magnet? Tell me. Write it on your paper. Don't tell the other group...write it on this piece of paper...write it. Write it.

T: (moving on to next group) And now I wrap this with this, okay? (speaking to group) Now I want you, I want you to *zamisa* [stir] (pointing to mixture on paper). To stir, to stir, to stir, and

see what is going to move away from this magnet...hold it up *vuthulula* [shake it] Shake it, shake it, shake it, shake it, shake it, shake it. What is falling and what is staying? (indistinct) There is something that is falling away, *ne* [okay]? ...That is moving away but there is something that stuck to the magnet. Okay, that's good. Okay I want you to take this piece of paper and write down what has been moved away there .. what has been moved away there, because if you can just do it like this again? (demonstrating to same group) I want you to see....Can you see there?...Can you see? I want you to tell me. There is it. There is it. (to whole class) Tell me. Write it down. Write it down.

T: (moving on to another group) Write it down. Write it down. (helping group, indistinct) You must put it there so that we can see...(indistinct) do it again...do it again...do it standing (directing boy with magnet)...do it here...don't bring it too close. Okay, okay, put it here...okay what is that? What is that? Now everybody has finished doing it, *ne* [okay]?

T: (moves on to another group) Now everybody has seen it doing it, *ne* [okay]? Okay you are not busy in this group. I want you to tell me (helping group) Okay?

T: (to whole class) And there is something blackish which has been taken away. What do we call that? And I want each group to tell me what is it that has been taken away from the mixture? (points to group) Yes? What is it group? What do we call that?

L: Iron filings

T: Iron filings, *ne* [okay]? They say it's iron filings. What does this group say?

Ls: Iron filings.

T: Iron filings. And that one? Also iron filings?

Ls: Yes.

T: This one?

Ls: Iron filings.

T: Now what did you use to separate the iron filings from the mixture of the? ... sulphur? What did you use? ... What did you use? To take the iron filings away from the mixture? Come, come, come. Listen, listen. When we are separating the beans from the mixture we used our hands, *ne* [okay]?

Ls: Yes.

T: But now I want to know what did you use now to take the iron filings away from the mixture?

L: Magnet.

T: What did we use? What did we use?

SL: A magnet

T: What? Say it aloud so that others they can hear you. What did you use?

Ls: Magnet.

T: You used what?

Ls: A magnet.

T: A magnet, *ne* [okay]?

Ls: Yes.

T: So a magnet was used to separate the mixture of the iron filings and the sulphur...

T: Now let us go to the third one..let us go to the third one.

## Appendix 8: Lesson B3 excerpt - full transcript

Separating iron filings and sulphur powder: Lesson B3, episode 1 (full transcript)

(T= Teacher; L=Learner; Ls=Learners; SL= Same learner *isiXhosa transcription in italics*; translation in square brackets; writing on chalkboard indented, bold)

T: (indistinct) Now, who can tell me how we can separate those two substances? How can we separate or how did we separate iron from sulphur in the mixture of iron and sulphur?

T: *Siyahlule kanjani* [how did we separate it]? *Siye sathini* [what did we do?] *Sisebenzise ntoni* [what did we use]?

T: What did we use to separate the mixture of iron and sulphur? Mixture of iron and sulphur? (nominates learner)?

L: We used a magnet

T: Mhmm, we used?

SL: A magnet

T: *Heke* [Good]!

T: We used a magnet, very good.

T: *Sisebenzise imagnet* [we used a magnet] *ne* [okay]?

Ls: Yees

T: Now, in using that magnet, what did you consider?

T: *Sijonge ntoni ukuze sisebenzise imagnet, yintoni esiyijongileyo kwezinto zimbini* [what did we test out when we used the magnet, what were we testing in these two things]? What did we consider in these two substances, in order for us to use that magnet, to separate the mixture? *Sijonge intoni yazo* [what was it we looked for in them?] ? Mhmm? *Sijonge intoni yazo* [what was it we looked for in them?]?

T: *Thetha* [speak up] (nominates another learner), *phakama* [stand up].

T: Mhmm, what did we consider? *Phendula* [answer].

L: *Uxolo tishara* [sorry teacher], iron filings.

T: We...We considered *i*-iron filings? What happens to the iron filings ehh... and the magnet?

T: (learner is still standing) *Hlala phantsi* [sit down].

T: Iron filings *ne* [and] magnet *kwenzeka ntoni kuzo* [what happened to them]? Mhmm? Iron filings *ne* [and] magnet, *kwenzeka ntoni* [what happens]? ... What happens when we bring the magnet closer to *i-ironfilings? Kuyathini* [what transpires]? (nominates another learner)?

L: *Iya ncamathela tishara* [it is magnetized, teacher].

T: Mhmm? *Ngesilungu* [in English].

SL: Iron filing is magnetic

T: Iron filings are what?

SL: Is magnetic.

T: Is magnetic. Iron filings are *kaloku* [remember], magnetic, *ne* [okay]? Filings are magnetic.

T: *Ithetha uk'ithini xa kuthiwa* [what does it mean when it is said to be] *i-magnetic*?

What does it mean when we say iron filings are magnetic? *Lanto ibisenzeka siyesathini* [that thing that that happened what did we say]? Iron filings are magnetic. Mhmm? *Ithethuk'ithini* [what does it mean]? When we say iron filings are magnetic what do we mean by that? What does the magnet do to the iron filings? *Izenza ntoni* [what does it do to them]?

T: *Anithethi ngoku* [you are not talking now]. *Uthini* [what are you saying] (points to learner)?

L: *Iyazdibanisa* [it combines them].

T: Mhmm?

SL: *Iyazidibanisa* [it combines them].

T: *Iyaz'ithini* [what does it do]?

SL: *Iyazidibanisa* [it combines them].

T: *Iyazidibanisa*[it combines them]? *Andinawthi iyazdibanisa, leliphi elinye igama esinokulisebenzisa* [I would not exactly say combines them, what other term can we use]? *Wena kaloku xa usithi iyazidibanisa, utheth'ba iyazisondelanisa, ne* [when you say it combines them, you mean it brings them closer, okay]? *Izenza ntoni* [what does it do to them]? *Iyazithini* [it does what to them]? What happens?

L: *Iyaztsala* [it pulls them].

T: *Iyaztsala, iyaztsala. Ngesilungu sizak'ithi iyazithini kaloku uk'tsala* [pulls them, pulls them. In English what're we going to say it does, pull]? Mhmm?

T: What can we say in English? *Iyaz'tsala* [it pulls them]?

L: Pull

T: Pull, pull. It pulls them, heh? Another word which we can use? *I*-scientific word *esinokuyisebenzisa*, *besiyisebenz's'izolo* [a scientific word that we can use, we used it yesterday]. *Ithini* [it what]? *Kula* [in that] pulling? *Xa usondeza* [when you bring] when you bring *.i... i...iron* filing *i...i-magnet kwi* [to]iron filings *ziyatsaleka andithi* [they get pulled isn't it]? *Sathi iyazithini* [what did we say it does to them]?

T: Which word did we use *kokwak'tsala* [for pulling]?

T: (nominates learner)?

L: We put up.

T: You put up ... no, we did not use that name. *Asisebenzisanga elogama* [we did not use that word]. *Eloqala ngo A* [it starts with A]. *Eqala ngo A* [it starts with A]. (gesticulates pulling action with hand) Heh? We said *i-iron* filings *ziyathini* [do what]? *Eqala ngo A* [it starts with A]. Are what?

L: Identify.

T: Identify. *Hayi khona* [no ways]. Not identify. Identify.

T: *Kaloku besithe, besithe uthini kanene* [remember we said, we said they, remember]? *Impawu esibona ngazo ngu Abalu* [the distinguishing characteristics is Abalu]? Heh? *Itsho* [speak] (Pointing to a learner).

L: Attract

T: *Heke* [Good]!

T: Attract, attract. *Besithe kanene kwiiron filings imagnet iyazithini ezanto* [for iron filings what did we say does to those things]? Attracts. (writes on chalkboard)

Attracts

T: *Iyayiattracta naliya elagama* [It attracts it, there is the word]. Attracts, heh?

Ls: Yees

T: A *i..i. i-magnet* attracts *intoni* [what]? *I-iron* filings. *Iyazitsala kokwakutsala besithetha ngako* [it attracts them, it is that pulling we were referring to].

T: But *kwisulphur* [in sulphur] does it attract *i..i lantuka* [what you call it] *i-magnet* does it attract *i-sulphur*, heh?

Ls: No.

T:Heh?

Ls: No

T: *Ayiyiattracta* [it does not attract it]. So, *okwakuattracta okwenzekayo kwisulphur* [that attraction that happens to sulphur] I mean *kwilantuka* [to what you call it] *kwi..kwi.. kwiiron* filings [to ..to iron] *sathi yintoni ye* [what property of] iron filings *leya* [is that]? *Yintoni* [what is it?] We use *lamagnetism* [that magnetism] or that attraction to identify, to identify *intoni* [what]? Iron filings, *ne* [okay]?

Ls: Yees

T: Iron is attracted by a magnet, *andithi* [isn't it]? Iron is attracted by a magnet. So *ibeyintoni ye* [what characteristic of] iron *lonto leyo* [is that]? So, *sithe* [we said] iron is what? (Writes on the board) Is attracted or *sisebenzise* [we use]... magnetized by a magnet.

### **Iron is attracted (magnetized) by a magnet**

T: *Isulphur yona* [sulphur itself] is what? Sulphur is attracted, *andithi* [isn't it]?

Ls: No.

T: Is what? Is not, is not attracted. Sulphur is not attracted by a magnet. (writes on chalkboard)

### **Sulphur is not attracted**

T: So *sathi zintoni eziya* [what did we say those are]? *Yintoni ye..ye.. ye..ye-iron leya* [what of..of..of iron is that]? We call it what? It is *intoni* [what] of an iron? Which we use to differentiate between an iron and a sulphur. *Besithe yintoni* [what did we call it]? (points to a learner)

L: *Yi-reactor* [it is a reactor].

T: *Yi-reactor* [It is a reactor]? No, no *asiyoreaction* [it is not a reaction].

T: *Khumbula* [remember] let me remind you we had a table like this, *ne* [okay]?

Ls: Yees

T: We had a table like this. (writes on the board) *Sathi apha* [we said here] we have a ...appearance, appearance. *Apha sathi* [here we said]...*sathi* [we said] magnetic *phaya* [there].

*Sathi le* [we said this] table, what does this table show us about these two things? Iron and sulphur. What does this table show us about these two things? Iron, sulphur. *Isibonisa ntoni la table ngezanto zimbini* [what does that table show us about those two things]? *Zintoni eziya sizifunde pha* [what was it that we read about there]? What were we looking at? To differentiate *kwezazinto zimbini* [between those two things]. *Besijonge ntoni* [what did we look at], mmmm? *Sathi phaya sizakujonga kwicolour*, *ne* [we said there we will look at the colour]?

Ls: Yees

T: *Into esizakuyijonga izakuba yi colour* [the thing we are going to look at is colour]. So, *la colour sathi iyintoni yala iron* [so the colour we said it is what of the iron]?

Ls: Silver grey.

T: *Sathi icolour yeiron isilver grey, ne* [we said the colour of iron is silver grey,okay]?

Ls: Yees

T: *Lo..lo..lo-grey colour eh... siyayisebenzisa* [that ...that grey colour we use] to differentiate between *i-sulphur* and what?

Ls& T: And iron

T: *Okanye* [or] to identify. We use it to identify... *i-sulphur*, I mean *i-iron kwintoni* [iron in what]? *Kwisulphur* [in sulphur]. So *ngagama elinye sathi ezanto... sathi zintoni zeiron* [In one word we called those things the what of iron], mhmm?

L: *Ziproperties* [it is properties].

T: Mhmm?

L: Properties.

T: *Heke* [Good]! Very good.

T: *Zintoni eziya* [what are those things]?

Ls: *Ziproperties* [it is properties]

T: *Ziproperties, niyilibele ngoku ubiproperty besithe yintoni* [have you forgotten now what we said a property was]? Mhmm? *Zintoni eziya* [What are those things]?

Ls: Properties

T: *Ziproperties ze* [it is properties of] iron and what? And sulphur. That's how it goes. So which means... now to separate, to separate those two the mixture of iron and sulphur we use *intoni* [what]? *I-properties ne*?

Ls: Yees.

T: To separate the mixture of iron and sulphur we use a what? The properties of those two...

T: We know that iiron is attracted by *intoni* [what]? By *i-magnet* whereas *i-sulphur* in not what? Is not attracted by *intoni* [what]? By *i-magnet, andithi* [isn't it]?

Ls: Yees.

T: *Heke* [Good]! So because *siyazi* [we know] *i-iron* is attracted and sulphur is not attracted then to separate them *sisebenzisa ntoni* [we use what]?

Ls: *I-magnet*

T: *Sisebenzisa imagnet. Iyavakala* [we use a magnet. Is it clear]?

Ls: Yees

T: So which means *ithethe lonto okok'ba* [that'll mean] to separate *i*-mixtures, to separate *I*-mixtures we should look at the what?... At the properties, *iyavakala* [is it clear]?

Ls: Yees

T: To separate imixtures we should look at the *ntoni* [what]? ... At the properties, *iyavakala kumntu wonke* [is it clear to everyone]?

Ls: Yees.

T: *Heke* [Good]!

T: So *sijonga ntoni* [what do we look at]? *Iproperties zezosubstance sizitheni* [what did we do with the properties of those substances]? *Sizimiksile* [we mixed them], *ne* [okay]?

Ls: Yees

T: We look at the properties of the substances that we have what? We have mixed, *iyavakala* [is it clear]?

Ls: Yees

T: (Teacher cleans the board) *Heke* [good].

T: *Umzekelo ngulowa* [That was the example]

T: Now today we'll do another... we'll try to... to separate another mixture.

T: So that's what we... we *le nto sizakuyenza* [what we are going to do].

T: Continuing from *lamixture yesulphur ne..ne neiron* [that mixture of sulphur and iron], *ne*?

Ls: Yees

T: *Heke* [good]!

T: We try to separate and we'll try to do another experiment which is going to show us how to separate another mixture.

T: So *kufuneka siyibambe* [so we should keep it in mind]. We should keep that ehh... *intoyokokuba* [that] now when you separate *i*-mixtures, *ne* [right]?

T: When you separate imixtures *ujonga ntoni* [what do you look for]? You have to look at what? At the properties, *ne* [right]?

Ls: Yees

T: You have to look at the properties of the two substances that are mixed.

T: *Kufuneka sijonge iproperties zezinto esizitheni* [we should look at the properties of things that are what]? *Esizixubileyo* [the one's we've mixed]. *Esizimiksileyo, iyavakala* [the one's we have mixed, is it clear]?

Ls: Yees

## Appendix 9: Lesson G2 excerpt - full transcript

Separating iron filings and sulphur powder: Lesson G2, episodes 16-18 (full transcript)

(T= Teacher; L=Learner; Ls=Learners; SL=Same learner; *isiXhosa transcription in italics*; translation in square brackets; writing on chalkboard indented, bold)

T: Yesterday you mixed a sulphur and ..?

T&Ls: iron filings

T: Get it out. (pointing to apparatus at the back)

(learners fetch substances from the back of the class)

T: Can you separate sulphur from iron filings?

Ls: Yes.

T: Hmm?

Ls: Yes.

T: Do it. Separate that mixture. Separate the mixture. (walking around the classroom)

T: (to a group) .. small amounts.

(learners get more apparatus and work in their groups)

T: (to group A) Okay, there is (indistinct) a magnet. I am going to give you a magnet. (indistinct) No don't ... okay do it... okay, okay (chuckles) Do it.

T: (to group B) You use this...to separate the mixture. Use this..

T: (to Group C) What are you going to use?

T: (moves round class) (laughs) So you are going to show them. (laughs) (to Group C) You don't want to use the magnet. (to Group B) (indistinct)

T: (comment for the benefit of the researcher?) I am sure it's very interesting...they are...they are laughing (chuckles)...

(learners in group B laughing)

T: It's very interesting *ne* [okay]? (moves from group to group)

T: Group C is not ready. We are waiting for Group C.

T: (helping group A) Hmm. (indistinct)

T: (to Group B) Use this one. They must not come to the ground because it is very difficult to remove iron filings from the ground. (handing them a magnet) ... Do it. So do you see...(laughs) huh? ...So what ...what do you see? .. Huh?

T: (to learner in Group A) Zwanele *uyakuzama* [you will try]. (Zwanele stands up)

L: The iron filings they are too fast the way they come up to the magnet.

T: They come very fast to the ...to the magnet. So it means iron filings are?

T&Ls: Are magnetic.

T: They are magnetic. Is sulphur magnetic?

Ls: No.

T: So sulphur is not magnetic. So that method is called, magnetism. (writing on board)

### **3. Magnetism**

T: It is called...

Ls: Magnetism.

T: Mag - ne- tism. That method is called a magnetism method. Okay. Okay. Thank you... Okaay.. Okay.

T: Okay. We also..we can also separate mixtures by another method. We can separate mixtures by another method called distillation